



RAMANI RANJAN CHOWDHURY
(Mica Specialist)

HANDBOOK OF MICA

Being a comprehensive treatise in six parts, dealing with Natural and Built-up Mica and Mica Products in all aspects, including Geology, Prospecting, Mining, Production, Manufacture, Utilisation and Marketing of Mica.

By

RAMANI RANJAN CHOWDHURY

(Mica Specialist)

Author of "India Mica", etc., etc.

" * * * In a very real sense, our vast electrical development is a monument to mica,—the one indispensable di-electric. The history of the intensive electrification that has been in progress during the last three decades, is the history of the modern mica industry * * *".—

J. V. LEWIS.

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OTHER BOOKS BY THE SAME
AUTHOR

1. India Mica, Vol. I. Price Rs. 5 inland; 7s. 6d. or \$2.00 foreign, exclusive of postage. To be had of the Economic Supply Agency, Post Box 11437, Calcutta, and other important booksellers in Calcutta.
2. Prospects of the Cane Sugar Industry in Bengal with a Foreword by John D. Nikas, General Manager, Messrs. Carew & Company, Darsana, Bengal. Price Rs. 2 net. To be had of the Economic Supply Agency, Post Box 11437, Calcutta, and other important booksellers.
3. Mica Directory and Who's Who in Mica (under preparation).

For opinions see at the end of this book.

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PREFACE

Since the publication of "India Mica", Vol. I, in February 1932, friends from different parts of the globe urged me to expedite publication of Vol. II, in which I proposed to deal with the international aspects of mica. In view of the great slump in world trade, I decided to wait till a more opportune time. Since 1934, when business once more took a hopeful turn, the trade in mica improved and reached an unprecedented level in 1937, and in these favourable circumstances I have revised my plans and decided to write a comprehensive and up-to-date "Handbook of Mica".

Those who are interested in mica, particularly the mica vendors in India, are, in many cases, not in touch with the world's markets for the demand and supply of mica. The Indian dealers are also often not acquainted with the technique and other essentials of the industry. This is particularly true in regard to their study of the consumer's point of view. These factors are believed to be responsible for much of the abuses that have appeared in the mica trade during the last decade, resulting in a loss of confidence amongst important buyers. India now stands to lose in her international trading if she does not re-organise her mica industry on a more satisfactory basis. Previously India had no rivals in the supply of ruby muscovite mica, which had been her monopoly since about 1884. Now, however, she has seriously to reckon with competition from several muscovite-producing countries, such as South and East Africa and South America. Russia, the earliest and once the only supplier of muscovite mica to Western Europe and North America, has been re-organising her extinct mica industry and her output is already sufficient for her greatly enlarged domestic requirements. The time must shortly come when the proportion of Russian sheet mica production will increase and leave an exportable surplus. India has very little time to lose for re-organising her industry, but if this is carried out on an economic basis, she may still retain the advantages in regard to the preparation, classification and processes

of her mica products. In order to hold the premier position as the largest world supplier of sheet mica, it is necessary for the Indian mica industry to increase its efficiency by cutting down productive costs in all branches of the business, such as mining, manufacture and marketing, without impairing the technical side of the management.

The successful exploitation and development of the national resources of a country largely depend upon the availability of the requisite information regarding the extent, economic character and working facilities for the interested public, but India is very poorly equipped in this respect. The United States of America, Canada, etc., have moved far ahead in this direction and the Bureaux of Mines and Commerce of these countries regularly collect useful information and publish the same in cheap official information circulars, memoirs, bulletins, etc. Mica is a subject very seldom treated by general writers, or by scholars or technicians and the literature on it is very fragmentary and scattered. In India, the only sources of information are the Records and Memoirs of the Geological Survey of India. A few officers of this Department, including the distinguished geologist Sir Thomas Holland, have earnestly interested themselves in this mineral and as a result of the experiences of the Great War (1914-18), attention has been more widely directed to the survey and potentiality of this mineral reserve. A detailed official survey of the reserves of mica in Bihar is already in progress, which is expected to be completed in about a year or two. The Indian public, and mica men in particular, have so far cared very little to derive benefit from these publications; the methods followed in the mining of mica and mica manufacture are greatly wasteful and unscientific. Attempt has been made in the present monograph to treat the subject in a systematic manner and bring together, in one comprehensive volume, all that a mica man needs to know from the practical point of view.

In the preparation of this handbook, and in the study of the subject, I have received valuable guidance and assistance from numerous friends, publishers, authors and contributors of periodicals, journals and papers as also from the various publications of the Geological Survey and Mines Departments of the Governments of India, United States, Canada, Union of South Africa,

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etc., to all of whom I acknowledge my indebtedness. I am particularly grateful to the officers of the Geological Survey of India, specially Dr. A. M. Heron (Director), Dr. Cyril S. Fox, Dr. M. S. Krishnan and Dr. J. A. Dunn. I am also grateful for valuable help to Prof. P. N. Ghosh, Head of the Department of Applied Physics, University College of Science, Calcutta. Without this valuable guidance and assistance offered to me, I could not have accomplished my task. Special mention is also to be made of Messrs. Jaroslaw's Erste Glimmerwaren Fabrik in Berlin, Mr. William Brand, Jr., New York, Major W. I. Anderson of the Associated Insulation Products Ltd., London, Mr. F. C. Chrestien and Mr. W. G. G. Richards of Messrs. F. F. Chrestien & Co., Ltd.

I must also record my indebtedness to Mr. R. S. Carter of Thacker, Spink & Co. (1933), Ltd., and Mr. J. F. Parr of Thacker's Press & Directories, Ltd., Calcutta, for the courtesy and attention that I have received from them during the preparation and publication of this handbook.

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RAMANI RANJAN CHOWDHURY.
POST BOX 11437.

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* Contributed by Dr. P. N. Ghosh, Sir Rash Bihari Ghosh Professor of Applied Physics, University College of Science, Calcutta.

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* "NEMA" = The National Electrical Manufacturers Association of America.

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Handbook of Mica

PART I

GEOLOGY, CHARACTERISTICS AND COMPOSITION OF MICAS

Chapter I

GEOLOGICAL ASPECTS OF MICA

MICA, as an important constituent of granites and schists, is one of the essential rock-forming materials. To study the geological aspects and mineralogical behaviour of mica, therefore, it is necessary to have an idea of the geology of the rocks and the manner in which the mica is supposed to crystallise in the pegmatites and schists.

ROCKS OF THE EARTH

Rocks have been grouped by geologists under three principal heads, namely, (i) igneous rocks, (ii) metamorphic rocks, and (iii) sedimentary rocks.

Igneous rocks.—These rocks form from the cooling of molten material. The molten lava, ejected from a volcano, when solidified forms into a volcanic igneous rock. Other igneous rocks have been formed by the consolidation of igneous material or magma deep down in the earth's crust.

Metamorphic rocks.—These rocks have been metamorphosed since their formation by heat or pressure. Igneous and sedimentary rocks are both subject to metamorphism.

Sedimentary rocks.—Most of the sedimentary rocks have originated from the denudation of igneous or metamorphic rocks and are the products of deposition by water or wind.

The rock-forming minerals include silicates, oxides, carbonates, chlorides, phosphates, sulphates and sulphides. The most important are the silicates, oxides and carbonates. The igneous minerals—quartz, feldspar, micas and pyroxenes—are silicates. The silica content of the igneous rocks is estimated to vary between 40 to 80 per cent.

Feldspar usually breaks along the cleavage planes in the crystals with fairly flat surfaces, but quartz has no cleavage plane and it often breaks in an irregular fashion.

THE MOTHER ROCK OF MICA

The commoner micas, muscovite and biotite, occur abundantly in both igneous and metamorphic rocks, especially acid types, which have crystallised slowly from molten magmas or under hydrothermal conditions. Other types of mica are met with in one or other of these classes of rocks and are generally present only in one particular mode of occurrence.

SOURCE OF COMMERCIAL SHEET MICA

Mica is one of the commonest and most widely distributed constituents of schists, granites and allied rocks of metamorphic or igneous origin. It occurs in commercial quantities and marketable sheets only in the coarser forms of pegmatites of a few restricted areas and is presumed to have originated at considerable depths in the earth's crust. It is therefore found in areas of ancient rocks which have undergone long-continued denudation.

COUNTRIES OF COMPARATIVE GEOLOGICAL STABILITY

Regional metamorphism is probably due to the re-adjustment of the earth's crust in course of or subsequent to the formation of the pegmatites. Such adjustment might be of a violent character like that of earthquake shocks, or might be slow warping or folding. Conditions of extreme geological stability, however, seem to be quite essential to preserve the crystals of mica undamaged, inasmuch as even the slightest earth movement during or after the crystallisation might seriously disturb the consolidation or spoil the usefulness of the crystals irredeemably.

OCCURRENCE OF COMMERCIAL MUSCOVITE RESTRICTED THOUGH PEGMATITES NUMEROUS

In spite, therefore, of innumerable occurrences of muscovite pegmatites in many parts of the globe, deposits of economic importance for production of sheets are met with in very few localities and the finest mica is generally restricted to regions of sound geological stability. Thus the mica districts in Peninsular India, Central and South Africa, eastern side of North and South America as well as Eastern Siberia are all well-known areas of geological stability.

The United States muscovite mica mines occur chiefly in the Appalachian regions of Virginia, Carolina, Georgia and Alabama, and the mica-bearing dykes occur chiefly in the rocks of the

Archæan group. The Canadian phlogopite mica in commercially workable deposits lies in Quebec and Ontario, while muscovite occurs at widely scattered points, including British Columbia. Mica, especially phlogopite, occurs in pyroxenites and gneissic pre-Cambrian rocks in Madagascar. It also occurs in certain Siberian regions.

FORMATION OF SECONDARY MICA OR SERICITE, ETC.

As a constituent of granites and schists, mica is present as flakes, too small for general commercial use. When granite decomposes, the quartz and muscovite mica, being highly resistant to weathering influences, remain intact, even after the other constituents have either been decomposed or carried away. During decomposition a secondary white mica is sometimes formed by the alteration of the feldspars, and in extremely fine-grained form it constitutes an essential component of slates and associated rocks.

THE ORIGIN OF THE PEGMATITES AND THE FORMATION OF MICA

This is yet a debatable subject, but at the same time the different views are worth careful consideration and their study will be helpful in understanding the general occurrence of mica. According to some geologists all pegmatites are formed by the intrusions of granitic magma; according to others the pegmatites are vein deposits; while some others consider them to have been formed by combination of both the processes.

According to Charpentier's theory*, pegmatite is fundamentally of plutonic origin. The original fluid mass is supposed to have cooled gradually from above and hardened into granite, which can subsequently be transformed into gneiss. A portion of the mass remains in a fluid condition below the recently cooled rocks. As the water-free minerals crystallise out of this fluid magma first, it contains considerably more water than the part which has already hardened and can therefore remain fluid at a much lower temperature. Compressed from above, it penetrates into the fissures and cracks of the rocks and eventually crystallises, although much slower than the other rock, on account of its high water content. As a result of this slow crystallisation, the molecules have time to form themselves into large crystals. In this way the coarse-grained structure of the pegmatite is clearly accounted for.

Masses of molten rock, deep in the womb of the earth and constantly subjected to extreme heat and pressure, gradually try

* "Der Glimmer" by Hans Zeitler.

to force their passage upwards to the surface of the earth from which sometimes volcanoes and volcanic eruptions originate; such molten masses sometimes crystallise before arriving at the surface. This excessive heat and pressure within the earth's crust results in cracks and fissures in the solid rocks around the molten mass in process of solidification. As a result, these still molten masses find ready entrance into the fissures and fill them to form sills or dykes in the rocks. The granite, gabbro, pegmatites, porphyry, rhyolite or basalt we meet with, are some of the kinds of igneous rocks formed by these molten masses.

The molten mass contains a high percentage of water. The outer portion of the molten mass first cools and then solidifies, while the inner portion still remains comparatively fluid, thus some of the water naturally finds entrance into the part still liquid. Metals like tin or tungsten, etc., may be carried by this water into the fluid part of the mass to cool, rather than in the part first solidified. When the last molten part cools it may contain some water with the metals and will be very different from the remainder of the rock. So it is given a special name, *PEGMATITE*. Such rocks are often found in cracks or veins into which pressure has forced them.

Sir Thomas Holland considered the mica-bearing pegmatites to be the result of the simple consolidation of an injected magma and whilst the pegmatites have affected the surrounding schists, it seems likely that the schists in return have modified the composition. The hot liquid and vapours emanating from the earlier granitic intrusions and the injections of the pegmatitic residue attack the schists. This results in the formation of mica by the action of potash and fluorine on andalusite, sillimanite and cyanite and the consequent development of a mica-bearing character of the schists.

The rock-forming minerals of primary origin in igneous rocks crystallise out from a cooling magma in the same way. These minerals, present in considerable amount in igneous rocks, are known as the essential constituents. Besides quartz, feldspar, micas, pyroxenes, amphiboles and olivine, other minerals, such as tourmaline, magnetite and apatite, also occur in igneous rocks in small or appreciable quantities, and are usually called accessory minerals.

SECONDARY MINERALS IN THE IGNEOUS ROCKS

Surface weathering and other influences cause alteration of some or all of the primary minerals with the creation of alteration products, which are generally called secondary minerals. Feldspars are thus often converted partly or wholly into kaolin, olivine into serpentine, pyroxene and mica into epidote and chlorates, and so on.

MUSCOVITISATION OF THE PEGMATITES

The following exposition has been given of the muscovitisation of the pegmatites by Mr. T. W. Givers of the South African Geological Survey* :—

“Water vapour is the most preponderating gas present in most of the volcanic exhalations including some of the acid rocks, sometimes to the extent of 8 to 10 per cent. Shepherd found water to compose 80 per cent. of the volatile material pumped out of the Hawaiian lavas when heated *in vacuo*. One of the most extensive alterations of complex pegmatites is the hydration of potash-feldspar to form muscovite and sericite, and since muscovitisation is found to have taken place extensively in most of the pegmatitic mineral deposits, it is natural to conclude that the water vapour of a highly heated aqueous fluid represented the most active and abundant solvent. The fact that the muscovitisation is particularly marked around numerous bodies of later quartz shows these aqueous fluids to have been highly siliceous during the initial stage. Further, the constant association of the muscovite mica with secondary albite and lithium-bearing minerals (spodumene, lepidolite and lethiophilite) shows the aqueous magmatic end-stage emanations to have been rich in sodium and to have contained appreciable quantities of lithium. The extensive and predominating influences of muscovitisation, albitisation and lithienisation indicate aqueous solution particularly rich in sodium and lithium; the latter probably present in the form of halides appears to have been the main vehicles of metalliferous mineralisation around it in many if not all the pegmatitic fields, as in Transvaal”.

DIFFERENCE BETWEEN MICA SCHIST AND GNEISS

Mica schist differs from gneisses by the absence of the conspicuous alternation of schistose and granular bands, which are characteristics of gneisses, as also by the paucity of feldspars. Mica schist is a rock, met with in pre-Cambrian areas, composed essentially of mica and quartz with a foliated or schistose structure which is due to the parallel arrangement of mica flakes. Mica schists generally have a greater variety of constituent minerals than the gneisses and are more coarsely crystallised. Mica schists are almost always metamorphosed sedimentary rocks originally composed of clays and slates and similar materials.

The above and other explanations about the theory of rock formation in general and crystallisation of mica in particular are, as already stated, still controversial topics and differences of opinion exist amongst geologists. It is, however, obviously agreed on all hands that the perfect crystallisation of mica in such

* Geol. Survey Memoir No. 31 of the Union of South Africa.

coarsely-grained pegmatites invariably requires conditions of high molecular mobility and comparative geological quiescence so as to facilitate, undisturbed, the growth and preservation of large flawless crystals in an undamaged condition for long periods of geological time. Serious earth movements or careless drilling may irrecoverably damage the commercial prospects of the crystals of mica which nature has so wonderfully prepared.

THE MINERALOGY OF THE MICA PEGMATITES

Looked at from the mineralogist's point of view the pegmatites are considered as coarse-grained "dykes" or structures, characterised by the acid type of igneous intrusions, and consist generally of a fissure filled with rock material solidified from its molten condition. This is called the "pocket" type of deposits, whereas in case of vein deposits or rather the "veins" of mica, the fissure-filling material is deposited from solution. Pegmatites thus occur both by way of "veins" and "pockets". The pegmatites, mineralogically, have the same composition as the granites, differing only in their form and structure and extremely coarse crystallisation. Their irregularity sometimes takes the form of perpendicular dykes, with well-defined walls and considerable linear extent, or more often they form irregular lenses which thicken or thin out in a surprisingly erratic manner. This uncertainty in the behaviour of mica-pegmatite occurrences renders their systematic mining development very much more difficult and risky than most metalliferous deposits. The pegmatites vary greatly in magnitude, from 2 feet to 300 feet or more in width, and are characteristically irregular in length and depth, very often pinching, forking or branching off most unexpectedly.

PEGMATITE, THE SOURCE OF SHEET MICA

Mica, in profitable quantities of commercial sizes, is generally found in those pegmatitic rocks which formed from the end-products of the crystallisation of great intrusive granite magmas. These are largely composed of quartz and feldspar and various accessory minerals, and though they resemble the granites in composition, differ in structure and crystallisation as already stated. In fact, the only rocks carrying mica of economically remunerative quality and quantity are the pegmatites—called also by some the giant or granite pegmatites.

THE ERRATIC OCCURRENCE OF THE PEGMATITIC CONTENTS

The length of the pegmatitic veins varies considerably, from a few inches to several hundreds of feet, and veins of barely 3 to 4 feet thick have sometimes been found to contain mica contents of very considerable volume and commercial value, while larger veins, on the contrary, have been found to contain no

mica worth exploitation. Indeed, there is no definite rule for guidance to determine the richness or otherwise of a particular vein discovered. This makes the development of mica mines a purely speculative affair.

CLASSIFICATION OF MICA DEPOSITS

From the natural characteristics of the mode of occurrence of mica-bearing pegmatites, the deposits of mica have been classified into three types, namely :—

- (i) Vein or fissure type of deposits.
- (ii) Pocket type of deposits.
- (iii) Contact type of deposits.

"STRINGERS" OR "LEADERS" IN MICA DEPOSITS

At points where lenses or pockets of mica pinch out* they are often found to have small stringers or leaders of mica and quartz. It is claimed that sometimes a selvage connects them with other lenses, both downward and along the strike. In following this class of deposits, the work may pass through entirely barren ground for a distance as great as the length of the productive lenses before commercial deposits are again encountered. Rich mica deposits are not infrequently met with near the points where quartz segregates into large masses, sometimes enclosed in the quartz or feldspar itself or in kaolin, altered from feldspar. Lewis further adds the following modes of occurrence of mica in the pegmatites :—

- (i) Evenly disseminated through the rock, like "plums in a pudding".
- (ii) Gathered here and there into irregular clusters or pockets.
- (iii) Forming lenticular aggregates dispersed through the rock.
- (iv) In lenses arranged somewhat in planes with or without connecting stringers of mica.
- (v) In the form of vein-like continuous tabular aggregates along the sides or in the midst of the dykes.

THE VEIN OR FISSURE DEPOSITS

This class of deposits has more persistence and greater regularity in width, ranging generally from several inches to about 25 to 30 feet or even more and they dip into the gneissic rocks at varying angles. The "body" generally has well-defined walls and the vein-contents characteristically include calcite and

* J. V. Lewis: *Geology and Mining of Mica*, Eng. and Min. Journal, Vol. 113 (No. 20), 1922.

granular apatite in case of phlogopite mica deposits, which are mostly of this nature—with as usual a coarse crystalline structure.

Vein deposits are easy to mine and easy to follow below. The miner is more often than not rewarded with yields of large commercial sizes of sheet mica, compared with other types of deposits described below. Of course here, too, as everywhere in mica mining, there is no general rule and uncertainty of definite return prevails; the widest mica vein does not necessarily contain the largest of commercial crystals.

POCKETY DEPOSITS

Lack of persistence an usual feature of pocket deposit.—Groups of crystals usually occur at wide intervals and in varying widths and depths, resembling a chain of lenticular bodies. One pocket is often connected with the other by a fissure of varying widths, generally very small. These narrow fissures frequently misguide the miners rather than offer any sure encouraging indications. Indeed the erratic course, irregular mode and distribution of crystallisation and above all the absence of persistence in occurrence render the mining of this type of deposits extremely speculative and the miners more often than not are subjected to a lot of confusion while exploiting such deposits. As a matter of fact a large quantity of waste rock has to be removed or handled before actually “winning” the mica at a heavy mining cost.

The deposits in Canada frequently occur in fissures entirely in pyroxenite or at the contact between country rock and pyroxenite and are distinguished by characteristic irregularity in their mode of occurrence, both in persistence and direction.

POCKETY DEPOSITS GENERALLY YIELD LARGER BOOKS OF SHEET MICA

Where pyroxenite rocks enclose “pocket-like” deposits these are generally found to have larger crystals than those of the “vein” or “fissure” types of deposits. Although some of the best mines giving large mica sheets have been found to be of pockety nature, a large proportion of the pockety deposits generally prove distorted or physically defective with little commercial value. Pockety deposits are the most common types of occurrences of mica met with in pyroxenic dykes. The mica contents within are frequently disseminated through masses of calcite, through which sometimes apatite crystals are distributed, while the walls of the pockets or pockety “vugs” are lined up with pyroxenite walls.

Most of the world's mica occurrences happen to be either of the "vein" or "pocket" type with characteristic irregularity and uncertainty, revealing no definite direction or decisive indications. In the case of pockety deposits, consisting of irregular disconnected bodies dispersed through the formation, no systematic modern methods can be employed*.

CONTACT DEPOSITS

This kind of deposits is generally encountered along the contact of pyroxenite dykes at or near the contact surfaces or between the gneiss or pyroxene or limestones. These contact deposits are often found in considerable widths. It may also be noted in this connection that in the contact type of deposits comparatively a much smaller proportion of waste rocks has to be handled while extracting the mica than in the other types. Contact types usually contain more calcite in association with mica than either the "vein" or "pocket" deposits.

According to Spence, the importance of contact deposits, which are far less common than the other types as a source of sheet mica, is small.

THE POCKET AND VEIN DEPOSITS

Hugh de Schmidt mentions another somewhat uncommon type of deposits of mica which can be taken as a combination of both the "pocket" and "vein" types. Schmidt calls it a "true fissure deposit". The "pockets", which seem to persist even in the deeper portions of the dykes, are frequently connected by small fissures or channels of various widths, and these narrow fissures usually serve as "indicators" or "leaders" to further deposits of mica.

MICAS OF COMMERCE

Although mica is one of the commonest rock-forming minerals, commercial mica is obtained exclusively from two classes of rocks, *viz.*, the granitic pegmatites in gneisses and in association with pyroxenite dykes, of which :—

(i) Granitic pegmatites yield the muscovite type of mica and

(ii) Pyroxenite dykes produce the phlogopite type of mica.

All the various types of mica can be broadly brought under either of these two chief groups, as described in detail hereafter.

Unlike any other mineral of economic importance, with perhaps the exception of precious stones and rare gems, the value

* Mica by Fritz Cirkel.

of mica depends on the size and perfection of its crystals. The economic occurrence of commercial sheet mica therefore requires specially favourable conditions for commercial exploitation.

MUSCOVITE OR THE GRANITIC MICA OF COMMERCE

Muscovite, occurring in monoclinic crystals in certain kinds of granitic rocks, is rich in alumina and potash and poor in iron and magnesia. This mica is invariably found in pegmatites which are like granites in mineralogical composition, but are characterised by extremely coarse crystallisation. These pegmatites are always irregular in shape or form, measuring from a few inches to hundreds of feet, and occur in rocks of a gneissic character. Branching or forking off and abrupt expansion or contraction in widths are very common features of these pegmatites yielding large crystals at points of coarse crystallisation. The mica contents are irregular in occurrence and proportion, sometimes being found at random throughout the pegmatite and sometimes constituting the contacts of the rocks around. The chance of sudden petering out of the workable mica in a pegmatite offers a formidable obstacle in mica mining. The percentage of marketable size or quality and quantity of the mica crystals in both "veins" or "pocket" deposits as well as the widths, lengths, etc., of the deposits vary in a surprising manner. Even in the course of a few hours' working this may happen thereby upsetting the most careful estimate for working.

Moreover the bulk of the world's deposits of muscovite mica consists of flakes usually too small or worthless for commercial use as sheets. The mere occurrence of mica in igneous rocks and pegmatites therefore does not, as a rule, carry an economic significance. The only country where mica in all forms has some prospective channel of industrial utilisation is the United States where even defective mica to-day may be saleable. Mica in this country is being developed wherever found, provided the regions of occurrence offer economic working facilities and convenient means of transportation.

THE KAOLINISATION OF THE MUSCOVITE MICA

The marked tendency of the granitic group of mica, muscovite in particular, to mineral decomposition accounts for many mica deposits being unattractive, as the mica is usually unfit for marketing or economic utilisation as useful sheets. Of these alterations of muscovite kaolinization of the feldspar is the most prominent. In the United States it is estimated to constitute 50 per cent. of the total rock content of the pegmatites.

The process of kaolinisation of the muscovite mica and feldspar, etc., is promoted by means of warm percolating waters, carrying carbon dioxide in solution, at considerable depths, causing

physical and chemical disintegration of the rock and thereby facilitating easy excavation and extraction of the crystals. Mica in course of such disintegration generally remains unaffected by the process of kaolinisation or kaolinising influences and the mica crystals remain practically intact, while the feldspar and other associates in the surrounding rocks often undergo drastic alteration. Even altered mica is nowadays being successfully reclaimed in the United States in very large quantities by a patented process*.

THE NATURE OF MICA DEPOSITS IN INDIA

In many places in India valuable mica occurs in the granitic pegmatites in which the constituent minerals have crystallised on a large scale. These rocks occur as vein or dyke-like masses and are found associated with mica schists, quartzites and other rocks of the Archæan group; irregular pegmatitic lenticular bodies are found to intrude into the schists, generally along but sometimes across the folia. The chief constituents of these bodies are quartz, feldspar and mica commonly associated with apatite, sometimes garnet, beryl, schorl and certain other minerals.

Special features of the Bihar mica belt.—Outcrops of such lenticular pegmatites traverse both the gneisses and mica schists. There is usually, almost always, a parallelism between the strike of the pegmatites and the foliation planes of the enclosing gneisses or schists. Pegmatites may, however, traverse foliation planes obliquely or even at right angles. Experience of working in the district of Hazaribagh bears out that it is useless, as a rule, to look for mica of workable quantity and quality in those pegmatites which traverse the gneisses or in those schists which are markedly non-micaceous. Dr. Cyril Fox†, who had personal experience of working the Jorasmar mica mines in the Mushnodi Gadi in 1918-19 during the Great War, further states that most of the marketable mica of the Hazaribagh district appears to be won from pegmatites traversing mica schists. Of course all pegmatites which traverse mica schists are not worth exploiting. Each pegmatite varies in the value of its marketable mica content and the latter can only be determined by actual exploration. The tendency, therefore, is to associate the mica, which is worth mining, with areas in which mica schists occur and to prospect pegmatites which traverse these mica schists. This association holds good in many parts of the district. Dr. Fox also observes

* For commercial reclamation of micaceous schists and masses see Chapter IV.

† Dr. Cyril S. Fox: Quinquennial Review of the Mineral Production of India for the Years 1924-28, see Mica (Records, Geol. Surv. Ind., Vol. LXIV).

that enrichment of mica is not uniform throughout the section of a pegmatite, nor are the minerals composing the pegmatites equally disposed. Pockets of isolated crystals of muscovite mica invariably occur in one side or other of the body of the pegmatite. The central mass of the deposit is usually composed of a core of granular, pellucid quartz in which beryl and tourmaline crystals may be totally enclosed. On each side of the quartz core there is usually a margin of feldspar and it is most frequently at the junction of this feldspathic margin and the central quartz core that the largest "books" of mica are found. Marketable mica is also to be found in certain pegmatites near the actual contact with the schists, either on the hanging or foot-wall side. Large crystals of garnet occur in about the same situation, while tourmaline is common in the margin and in the quartz core. Apatite in varying quantities is found in almost every one of the larger pegmatites.

Fig. 1 illustrates a typical pegmatite in Jorasemar containing mica and some of the other associated minerals.

Mica, the most delicate mineral.—Mica, being one of the most delicate minerals in the rock, is the first to show deterioration as a result of earth movements. It is due to the exceptional quiescence which the Indian Peninsula has enjoyed during long geological periods that it contains the finest mica deposits in the world*.

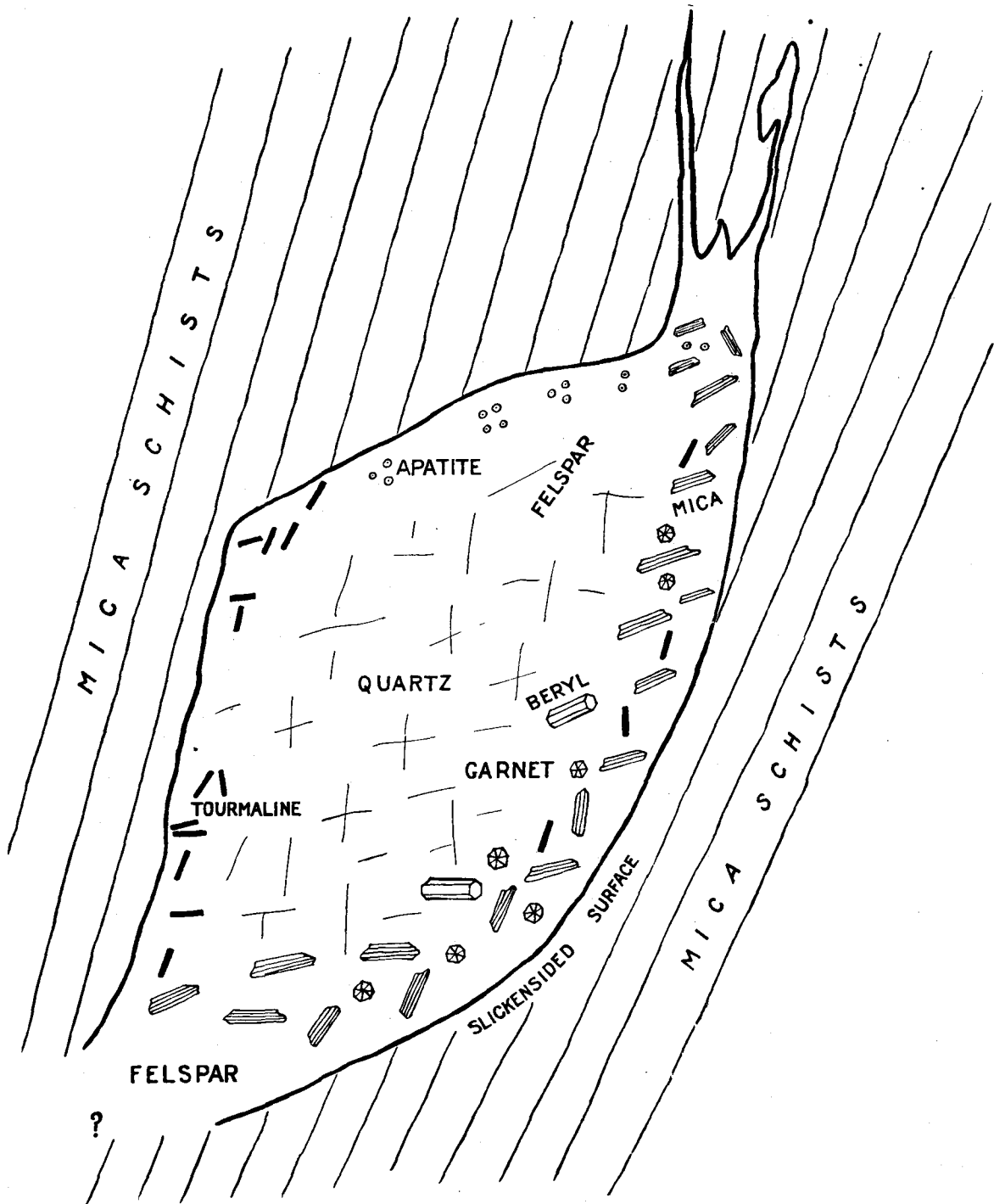
QUALITY OF THE BIHAR MICA

The quality of the Bihar mica varies from silvery soft white, matching the silver amber of Canada, to hard *clear ruby* muscovite (known better as *Bengal ruby mica*), which, on being let fall on a cemented floor or being tapped, would give a metallic sound. Mica, spotted with dots due to the presence of iron oxides, usually between the sheets or laminations, is also frequently encountered; these black spots are generally removable by careful splitting of the sheets and do not constitute mineral stains.

The most common type of deposit in the Bihar area is found by way of veins of quartz and feldspar with a fairly regular strike, cropping out along the top of low ridges, in the Kodarma forest area. The course of the veins is often straight, regular and not infrequently quite persistent, sometimes measuring a few inches and suddenly expanding to even 25 to 30 feet or more or sometimes the course will thin out surprisingly along the strike. The gneisses usually have an east and west strike, with a dip of about 60° to 75° to the north.

The associated minerals in the Bihar mica deposits do not appear to be of much commercial importance and in such high

* Bull. of the Imperial Institute: Suppl. to Board of Trade Journal.



[By permission of the Min. & Geol. Inst. of India.
Fig. 1 representing a typical mica-bearing pegmatite at Jorasemar (after C. S. Fox).

proportions as have been reported in case of the U. S. muscovite deposits. The pegmatite masses, as a rule, follow the plane of foliation of the schist as already stated. Very often, large masses of "books" of mica, weighing more than one ton or several tons, may prove of little commercial value.

The pegmatites in this belt are generally of lenticular form and of lengths up to a maximum of 1,500 feet* with steep dips and fairly thick. Pegmatites also occur in this area in the form of lenses and veins along the bedding planes of the schists generally striking east to west. The pegmatites in India are all either vertical or they dip at high angles and not infrequently with a decided pitch. The "shoots" of mica have also been traced with a decided pitch within the pegmatites†.

The Bihar mica belt coincides with the strip of schists and associated gneiss or granites forming the hills leading from the Hazaribagh plateau to the Gangetic plain. The foliation planes of the schists and gneisses are pierced by the pegmatites which sometimes cut across them. The pegmatites are most productive at points where they traverse the micaceous schists. The Bihar pegmatites are often the source of many accessory minerals such as tourmaline, garnet, apatite, beryl, pitchblende, tantalite and columbite.

Payable mica in India is usually available in abundance in crystalline schists and is often rich in mica-schist country while invariably barren in gneiss country, a fact that, though not satisfactorily explained, is sufficiently established to be taken as a general rule.

Fig. 2, taken by Dr. Cyril Fox of the Geological Survey, shows a view of the mica-schist country at Jorasemar near Kodarma, in the district of Hazaribagh, partially cleared for exploration.

SPECIAL FEATURES OF THE MADRAS MICA BELT

The country rock in this field is an Archæan schistose complex with large pegmatites, yielding big size mica sheets. These masses are very coarse with frequent intergrowth of quartz and feldspar in the granites; tourmaline, garnet, apatite, beryl and biotite mica are common associate minerals. There is a parallelism in trend between the strike of the pegmatites and the foliation planes of the enclosing gneisses, as the schists in Bihar. The foliation planes often have steep dips.

Mr. V. S. Swaminathan describes the characteristics of the Madras mica occurrences as follows‡ :—

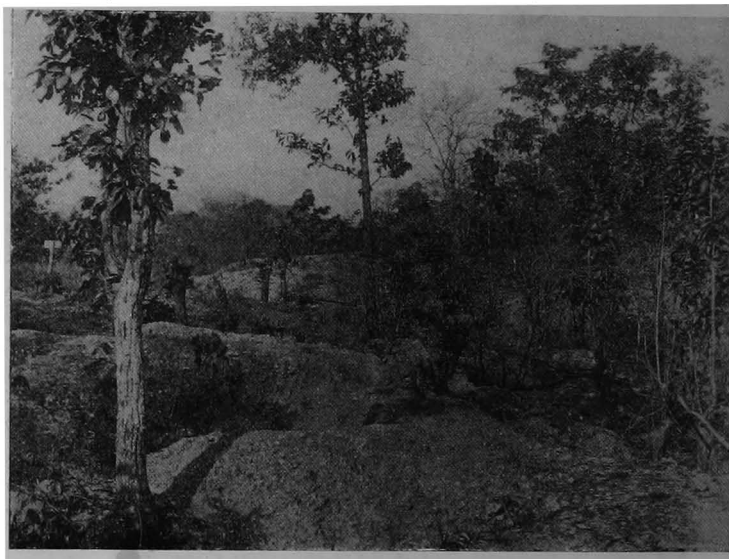
"From sheets fairly uniformly thick over long distances, one finds various gradations to small eye-like lenses of which many

* J. Coggin Brown.

† G. V. Hobson: Bull. 220 (1927) of the Imperial Institute.

‡ Trans. Min. Geol. Inst., India, Vol. XXV, 1930.

may be found projecting from the schist surface over an area of only a few square yards, giving the impression that the pegmatite might have thoroughly impregnated the schists. The constituents



[By permission of the Geological Survey of India.
Fig. 2.—The Hazaribagh mica-schist country, Jorasemar.

of these bodies are quartz, feldspar, apatite as well as microcline, orthoclase and mica, commonly associated with garnet and beryl”.

LARGE MICA CRYSTALS A SPECIALITY OF THIS FIELD

Muscovite crystal measuring 15 feet along the folia and up to 10 feet across the basal plane has been obtained from Inikurti mica mine in the Nellore area. This is probably the largest mica crystal ever obtained. Of course such crystals are exceptional but, comparatively, more numerous large crystals are found in the Nellore mica field than anywhere else in India, including the Bihar mica belt.

THE PHLOGOPITE OR THE PYROXENITE MICA OF COMMERCE

This class of mica occurs in monoclinic crystals with irregular and tapering sides; the phlogopite crystals vary in measurement

from small aggregates up to 4 feet in diameter, though the latter occur very seldom.

Just as the muscovite mica occurs in association with the pegmatitic veins, phlogopite mica is found almost invariably associated with pyroxenite dykes and in association with calcite, apatite and pyroxenes with sometimes hornblende. Thus the mode of occurrence of these two main types of commercial micas is different and the phlogopite type of deposits is generally found in more well-defined veins and in more concentrated form than that of muscovite. Because of this clear distinction, the muscovite and phlogopite micas are sometimes called the "pegmatitic mica" and "pyroxenite mica", respectively. Characteristically the Canadian phlogopite deposits occur in association with a large percentage of calcite. In fact this originally led to the opening up of many of the existing mica mines in Canada for exploitation of calcium phosphate or apatite.

Proportion of mica usually larger in phlogopite occurrence.—The proportion of mica to the total mass content of the "vein" or "pocket" is, almost as a rule, much greater in phlogopite deposits than in the muscovite. Phlogopite occurrences, however, are fewer than those of muscovite in the total number of mica deposits so far known all over the world.

Macroscopic inclusions of calcite, apatite, pyrites, quartz, etc., as films or crystalline layers between the laminations or sometimes in intercrystalline forms or individuals within the mass of the mica crystals, render a great number of the phlogopite deposits commercially defective, such as "cross-grained", "wedgy", etc., which affects the splittability of the mica*.

According to Hess, deposits of sheet phlogopite are formed by pegmatitic solutions interjected into the easily soluble limestones, as observed from the petrographic relationship in all the deposits.

* Hugh de Schmidt.

Chapter II

PHYSICAL CHARACTERISTICS AND CHEMICAL COMPOSITION OF MICAS

All micas consist of compound silicates of aluminium, with varying amounts of potassium, magnesium, iron, chromium and similar bases and are isomorphic. These compounds, however, very seldom contain calcium. They contain about 4 to 6 per cent. of water, which is given off by strong heating between 500°C. and 1,000°C. Vermiculite is an exception and is definitely more hydrated with about 11 to 21 per cent. water.

The mica group of minerals includes a large number of members, all of which are characterised by a perfect cleavage along which mica can be split into thin sheets. Although colour distinctions are not reliable indications from the chemical point of view, there is a group of potash micas generally of a pale colour and another group of magnesium or iron-magnesium micas usually of dark colour. All micas belong to the monoclinic crystal system and possess a pseudo-hexagonal crystalline form commonly occurring in flat six-sided crystals.

All micas, besides being characterised by a perfect cleavage parallel with the basal plane, possess many other useful commercial properties, including a very high degree of flexibility, elasticity, toughness, hardness and transparency of the extremely thin cleavage flakes. The perfect basal cleavage is one of the most important of all the properties characteristic of micas, and is not found equally developed in any other mineral so far known to man.

PERCUSSION AND PRESSURE FIGURES

Reusch first discovered that when a sharp-point punch is placed on a thin plate of mica and struck a sharp blow, with a small hammer, a six-rayed star is formed on the mica plate. This was later confirmed by the investigations carried out by Bauer who, however, recommended the use of a somewhat blunted needle, instead of the blunt instrument used by Reusch*. Pressure with a blunt instrument develops a similar figure but

* T. L. Walker: *American Journal of Science*, Vol. II, 4th series (1896).

having each ray at right angles to one in the first (percussion) figure. These are known as the percussion and pressure figures respectively.

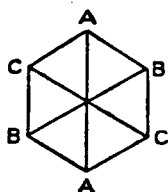


Fig. 3.—Percussion figure.

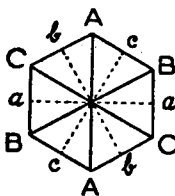


Fig. 4.—Pressure figure.

In fig. 4 the rays *a*, *b*, and *c* are at right angles to the rays A, B and C of the first star in the first figure.

NOMENCLATURE

Mica is called "*abhra*" in India, which is one of the oldest names given to this mineral. It was known to the Aryans in ancient India long before the birth of modern civilisation, but mica appears to have been used in Greece and Rome before the Christian era. In Russia, where white muscovite mica was mined and used from about the fifteenth century or earlier, white mica was called the "*Muscovy glass*", as translated from the latin word "*vitrum muscovitum*". Muscovy was the ancient name of the central part of Russia, the Grand Duchy of Muscovy, where this class of mica was used and traded in, chiefly for glazing and decorative purposes. Muscovy was the first country in Europe to produce marketable muscovite mica. Indian muscovite mica came to be known in Europe soon after, perhaps the sixteenth or seventeenth century.

The term "*mica*" is derived from the latin word "*mico*" meaning to shine. The German word for mica is "*glimmer*" which means "to glitter", originally introduced by Werner, the father of modern mineralogy (1750-1800). Glazing mica is sometimes wrongly called "*isinglass*"*. The Japanese name for it is "*umbo*".

Pliny mentions mica in his "*Historia Naturalis*". The alchemists of medieval times named it variously "*lapis specularis*", "*magnetes ammochrysos*" ("cat's silver" or cat's gold), "*Lady's ice-spar*", St. Mary's glass (*marienglass*), etc. In Arabic "*kaukabul*" is the name for mica, meaning the star of the earth.

* True "*isinglass*" is a soluble combustible material, extracted from the air bladder of certain fish.

DIFFERENT GROUPS AND TYPES OF MICAS

Micas may be classified from the nature of their geological formation, into two principal groups, namely :—

- (i) The granitic group.
- (ii) The pyroxenic group.

The relative theoretical formulæ and chemical composition, so far ascertained from analytical results, are given below.

Group I : Alkaline-granitic micas

- (1) *Muscovite or potash mica* $H_2K.AI_3(SiO_4)_3$.

Formed in granites and pegmatites with quartz and feldspar and frequent accessory minerals such as tourmaline, beryl, topaz, garnet, biotite and lepidolite (mica), magnetite, hematite and goethite in the form of interlaminar inclusions.

Occurrence.—India, United States, Russia, Madagascar, Argentina, Brazil, Tanganyika, Southern Australia, Norway, Guatemala and Canada.

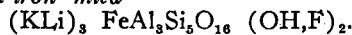
Almost all the mica deposits in India belong to this muscovite or potash group of mica, with the solitary exception, so far known, of a small occurrence of phlogopite in the State of Travancore in South India. Association of muscovite and biotite is quite common.

- (2) *Paragonite or sodium mica* $H_2Na.AI_3(SiO_4)_3$.

Occurrence.—It occurs in crystalline schist and is not known as a pyrogenetic mineral. It forms a schist at Monte Campione, Switzerland, carrying cyanite and staurolite as well as garnet and tourmaline*. This mineral in fact forms the matrix of the well-known blue cyanite and brown staurolite crystals in this locality which is the best known occurrence. It also occurs with tourmaline and corundum at Unionville, Delaware Co., Pa., U. S. A.

In colour it may be yellowish, greyish, greenish, light apple green.

- (3) *Zinwaldite or lithium-iron mica*



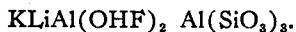
Occurrence.—Cornwall (England), Zinnwald (Germany). It occurs usually in very small flakes and sheets are found very seldom. Its chief occurrence is in the tin-bearing granites at Zinnwald and Altenberg, and also in Cornwall. It is extracted in Zinnwald as a source of lithium.

* Ore and Stone Mining by Foster.

Physical Characteristics & Chemical Composition of Micas 19

Colour.—Grey brown to yellowish or rather grey to smoky brown.

(4) *Lepidolite or lithia mica*



Occurrence.—Germany, Sweden, Czechoslovakia and various parts of the United States.

It occurs in granite and pegmatite and is best known in pegmatites, where it forms violet or lilac-tinted crystals associated with muscovite. It is commonly accompanied by tourmaline, spodumene, amblygonite, topaz and other minerals.

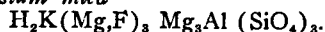
Colour.—White; yellowish, greyish, lilac or rose-red.

Optic axial angle.—50° to 85°. Optic axial plane at right angles to the plane of symmetry.

Association.—Tourmaline, spodumene and amblygonite, sometimes muscovite, are its common associates and it occurs usually in tin-bearing rocks.

Group II : Magnesium-pyroxenic and aqueous-igneous micas.*

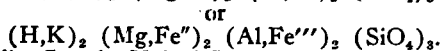
(1) *Phlogopite or magnesium mica*



Occurrence.—Canada, Madagascar, Ceylon, Argentina, Chosen (Korea), Mexico and Central Africa.

Association.—In crystalline limestones or dolomites and serpentine with common accessories of apatite, pyroxene, and sometimes with inclusion of magnetite.

(2) *Biotite or magnesium-iron mica*



Occurrence.—India, Canada, United States, Norway, Sweden, Monte Somma, near Lake Baikal in Siberia, Vesuvius, and Chosen (Korea).

Association.—It is a common constituent of crystalline rocks like gneiss, granite and pegmatites and occurs often in association with muscovite and is found in eruptive rocks of all ages.

Colour.—Usually green or brown to black, sometimes pale yellow, but white is very rare.

* *Pyroxene* : It is the main mineral in the pyroxenic group of deposits and forms its predominant constituent. The colour of pyroxene is pale greenish grey to dark blackish green and it encloses small plates of phlogopite. Pyroxene consists of about 50 per cent. of silica, 45 per cent. of alumina, 2 per cent. of ferrous oxide, 24.50 per cent. of manganese oxide, 15.35 per cent. of magnesium, 1 per cent. of ferric oxide, 0.50 per cent. of potash and 0.25 per cent. of soda, balance representing loss on ignition.—*Spence*.

Optic axial angle.—Optic axial plane parallel to the plane of symmetry, rarely at right angles to it, as in the variety anomite. Pleochroism strong.

- (3) *Lepidomelane or ferric-iron mica.* It is a variety of biotite with a preponderance of ferric-iron contents.

$$\text{H}_2\text{K}_2\text{F}_3'''\text{Fe}_6'''\text{Al}_3(\text{SiO}_4)_6.$$

Occurrence.—Santa Luzia in Brazil. It is known chiefly in feldspathic igneous rocks relatively low in magnesia with notable amounts of iron oxide as in certain granites, syenites and nepheline-syenite where it is often associated with aegirite or soda amphibole. It is found in Langesund fjord, Norway, Letchfield, Me., Ireland and elsewhere.

- (4) *Roscoelite or vanadium mica*

$$\text{H}_8\text{K}(\text{Mg},\text{Fe})(\text{Al},\text{V})_4(\text{SiO}_3)_{12}.$$

Occurrence.—Granite Creek, El Dorado Co., California, United States; also in the Bhandara district, Central Provinces*.

Roscoelite mica generally occurs in minute flakes in the sandstones of the Rifle, New Mine and Placer Ville districts, Colorado. The metallic vanadium content of the run-of-mine averages between 1.5 to 5 per cent.

Colour.—In colour it is dark brown to green and the mica is mined for its vanadium content.

COMMERCIAL AND NON-COMMERCIAL MICAS

There are now eight types of micas recognised by the mineralogists, of which muscovite and phlogopite are the principal commercial mica. Biotite and lepidolite are of minor industrial significance, the latter being utilised as a source of lithia salt or as a component of ornamental stones. Roscoelite or vanadium mica is similarly utilised to recover vanadium, but the roscoelite deposits are not largely available so far as is known. The other types, namely, paragonite or sodium mica, zinnwaldite or iron-lithium mica and fuchsite or chrome micas, etc., have until now been largely minerals of scientific interest with little commercial importance.

FUCHSITE OR CHROME MICA

This is a kind of chromium-bearing mica occurring in Schwarzenstein, Zillarthal in Austria, Ouro Preto in Minas Gerais in Brazil, in the Urals (Russia), Manitoba (Canada),

* Records, Geological Survey of India, Vol. LXV, p. 536.

Physical Characteristics & Chemical Composition of Micas 21

Montgomery Co., Md., and the State of Travancore in Southern India. It has been so named after its original discoverer J. N. v. Fuchs, the French chemist.

It forms compact aggregates of small flakes, having a definite schistose structure and possesses a beautiful emerald green colour. The Manitoba fuchsite is crushed in Winnipeg and used for stucco purposes. This mica seems to have assumed some commercial importance lately.

Fuchsite contains 2 to 4 per cent. of chromic oxide*.

JEFFERISITE

Mr. H. S. Spence writes of jefferisite as having drawn some attention in recent years. Belonging to the Vermiculite Group of hydrated micas, it possesses the peculiar property of swelling up enormously when heated, to form a light spongy mass. It is marketed in the United States under the trade name of "Zonolite" as a heat-insulating, sound-deadening and paint material.

THE MUSCOVITE AND PHLOGOPITE—THE MICAS OF COMMERCE

Of all the different types of micas, muscovite and phlogopite represent the micas of commerce, which are available in abundance and in commercial sizes and qualities.

THE MUSCOVITE OR POTASH TYPE OF MICA

This is also called granitic mica. It is of highest commercial importance and is the finest of all micas in transparency, di-electric strength and perfect cleavage, etc.

The United States, India and Russia are the largest producers of muscovite mica. It has been found in the ancient rocks of several other countries. Most of the production of muscovite mica from these other countries, however, does not satisfactorily conform to normal commercial requirements. This applies to specifications of sheet mica, particularly as compared with the better and cheaper supplies from India. Possibilities of war bring in abnormal conditions and create special interest in mica occurrences where mining remains neglected in times of peace and economic depression.

Muscovite mica is optically negative and has normally an axial angle of about 70° which diminishes to 50° in varieties high in silica. It has a strong double refraction*. At 700°C. muscovite commences to lose water rapidly, but phlogopite remains practically unaffected at temperatures below 1,000°C. Muscovite mica is practically non-magnetic.

*U. S. Bur. Mines, Information Circular No. 6822, p. 6.

Physical properties of muscovite mica.

(i) Hardness on Moh's scale ..	2.0 to 2.5
Shore's test (76 to 106)	
(ii) Specific gravity ..	2.76 to 3.1
(iii) Refractive index (air = 1) ..	1.56 to 1.60/61
(iv) Di-electric strength at 20°C. in	
volts per mil. ..	3,250 to 6,250
(v) Maximum thermal resistance ..	525°C.
(vi) Optic axial angle ..	55° to 75°

The specific gravity of either muscovite or phlogopite, ranging between 2.76 to 3 or 3.1, is higher than that of quartz (2.66) or feldspar (2.5 to 2.7).

According to Schroeder, the specific gravity of mica on the basis of numerous actual experiments is 2.8 and for ascertaining the weight of natural mica sheets this value is applicable to all varieties of mica used for technological purposes.

Muscovite mica is heavier than phlogopite, though the latter is somewhat softer. It has a relatively large amount of potash and silicates of aluminium in its composition and offers a greater resistance to outside chemical influences than any other type of mica, biotite and phlogopite in particular. Muscovite also has a comparatively smaller proportion of iron, which further explains why it is not easily acted upon by external agencies that attack minerals which are richer in iron compounds.

Muscovite mica, as has been explained, is ordinarily almost insensible to atmospheric weathering, but it is found in its natural form to be intergrown with crystals of other minerals. These inclusions vitally alter its constitution and affect its commercial value. A common mineral that contaminates muscovite mica, reducing its commercial worth, is magnetite or magnetic oxide of iron, the presence of which reduces the di-electric property of mica very considerably. Magnetite is brown or black in colour and can be frequently seen.

Colour of ruby muscovite.—Clear muscovite in thin sheets is almost colourless. There are two kinds of this class of mica in India, namely, "ruby" and "green". Ruby muscovite is normally harder and the colour is usually pale brownish red in thin plates (0.5 mm.) and beautiful ruby red in thick plates (10.0 mm.). This type of mica has a highly perfect cleavage rendering it more easily splittable to films 0.001 inch and even thinner, which is a thinness not secured without risks of cracking by any other type of mica.

Lustre.—Vitreous to more or less pearly in altered varieties. Green muscovite varies in colour between green, greenish brown, pale to dark. Green muscovite is softer than the ruby muscovite, owing to its frequently containing a small percentage of moisture between the laminae.

The actual chemical composition of micas usually differs somewhat from the theoretical composition, partly on account of the inclusion of foreign minerals and partly due to replacement by equivalent elements.

From the chemical analysis of micas from India, U. S. A. and elsewhere, as given in the tables of analytical results, it will be seen that the percentages of ferrous and ferric oxides, magnesium oxide, sodium oxide and fluorine are much lower, in some cases lowest in Indian mica, and the percentages of aluminium oxides and potassium oxides, the most essential basic constituents of muscovite, are rather higher. Indian mica has also no titanium oxide, but there are traces of lithium and calcium oxides in particular occurrences.

Though ordinarily chemically stable, muscovite mica is affected by hydrofluoric acid, but it has a strong tendency to resist agencies of physical disintegration or chemical decomposition. However, under prolonged weathering, meteoric water percolates into the pegmatites and enters the edges of the mica crystals.

PHLOGOPITE OR MAGNESIUM MICA (ALSO CALLED PYROXENIC MICA)

Canada had for a long time been the world's only supplier of amber mica (up to the outbreak of the Great War, 1914-18) but since then Madagascar has come in as commercial rival in the supply of phlogopite mica.

Of the world's known deposits of mica, phlogopite occurs in fewer countries than muscovite and, except in Canada and Madagascar, no large deposits of commercially flawless and of sufficiently large-sized sheets of phlogopites have so far been worked.

Phlogopite is practically the only almost iron-free mica of the magnesium group.

Physical properties.

- (i) Hardness on Moh's scale .. 2.5 to 3.0*
(Shore's test 77 to 101)
- (ii) Specific gravity .. 2.74 to 2.95*
- (iii) Refractive index (air = 1) .. 1.58 to 1.61
- (iv) Di-electric strength at 20°C. in
volts per mil. .. 3,700 to 4,200
- (v) Maximum thermal resistance .. 1,000°C.
- (vi) Optic axial angle .. 5° to 18°†

The darker classes of amber mica are notably harder than the light-coloured varieties. Phlogopite particularly of light-coloured

* U. S. Information Circular No. 6822.

† *Vide* Table of British Electric and Allied Industries Research Association.

varieties is more resistant to heat than muscovite and easily stands 800° without appreciable dehydration. The colour of phlogopite mica is brown or greenish brown to fairly colourless and also of greenish shade. According to the different degrees it is variously classified in trade as silver amber, dark amber, light amber, wine amber, and so on. Black phlogopite is harder than the brown, but is poor in di-electric resistance and splittability.

Comparative physical properties.

	Muscovite.	Phlogopite.
Specific gravity	2.76-3.0	2.78-2.85
Hardness	2.8-3.2	2.5-2.7
Maximum temperature where it remains unaffected ..	535°C.	1,000°C.
Specific resistivity, megohms x to 10	7-133	0.45-22
Di-electric strength* at 20°C. in volts per mil.	3,250-6,250	3,700-4,200
Permittivity (S. I. C.)* ..	4.2-5.0	2.9-3.0

Other properties of mica include the following :

Crushing strength : 50 lbs. per mm².

Breakdown strength : about 2,000 to 7,000 volts per mil. according to quality†.

The Canadian amber (phlogopite) is not very suitable for purposes of glazing or where transparency is required and, therefore, as long as the use of mica was restricted to these lines of applications, amber mica was treated as unfit for industrial use. Later, however, with the development of the electrical and heater manufacturing industries, amber mica has been in increasing demand.

Chemical tests

In the closed tube, muscovite gives off water, often with reaction for fluorine; B. B. whitens and fuses on thin edges (F.4.5 to 5.0) to a grey or yellow glass; with fluxes sometimes give reactions for iron, manganese, and chromium (rare). It is not decomposed by acids, except hydrofluoric acid. Green and brown colours are probably due to ferrous iron.

In the closed tube phlogopite gives a little water, some varieties give reaction for fluorine in the open tube, whilst most give little or no reaction for iron with fluxes. B. B. whitens and fuses on thin edges. Completely decomposed by sulphuric acid, leaving the silica in thin scales. The red-brown varieties contain the most fluorine, whilst the greenish varieties contain the least.

* M. I. C., N. Y. Catalogue No. 87

† The Optician. 25th October, 1912.

Colour deepens with increasing iron content, and then approaches biotite in composition.

Optic axial angle

The optic axial plane is parallel to the plane of symmetry in phlogopite mica, whereas it is at right angles to the plane of symmetry in muscovite. The axial angle decreases slightly with increase of temperature in muscovite, but in phlogopite the angle appears to increase with iron content. Pleochroism is strong in dark-coloured varieties of muscovite and it is distinct in phlogopite mica.

BIOTITE OR MAGNESIUM-IRON MICA

Biotite is a black iron mica not infrequently in association with muscovite. Being unsuitable for use in electrical or glazing industries, which call for lustre and transparency as well as splittability, biotite mica has no large commercial use as sheets. It is mostly consumed in the ground form for the manufacture of roofing components. Biotite mica is so named after the French physicist, J. B. Biot, who, in 1816, found that the magnesium micas, both phlogopite and biotite, were optically uni-axial or nearly so and contain a widely varying proportion of iron.

Biotite has generally a brilliant black lustre and is not so easy to split into thin laminæ as muscovite. It has rather a tendency to brittleness.

Biotite and phlogopite micas belong to the same group of magnesium-pyroxenic but the colour of phlogopite is a dark pearl gray, smoky or yellowish to brown red, commercially known as "amber" colour, whereas biotite is almost black and opaque, in thick plates due to its high iron contents. In thin films it is dark brown, yellow or hazy green, also sometimes pale yellow to colourless.

LEPIDOMELANE IS PRACTICALLY A VARIETY OF BIOTITE MICA

It is, however, on mineral grounds grouped with phlogopite. Electrically this is the weakest of all micas.

Specific gravity	..	..	2.6 to 3.2
Optic axial angle	..	..	Nearly 0° to under 5°.
Refractive index	..	..	1.54 to 1.57

Optic axial plane parallel to the plane of symmetry, rarely at right angles to it, as in the variety anomite. Pleochroism strong.

LEPIDOLITE OR LITHIUM MICA

Lepidolite mica is not available ordinarily in large clear sheets, except in the solitary case of a small production of lithium sheet mica in Western Australia, which is used exclusively for the purpose of gramophone diaphragms.

Lepidolite mica is industrially used as a source for recovery of its lithium content, which is employed in the manufacture of opal and special white glass. The lithium content of lepidolite is about 4 to 6 per cent. The lithium and fluorine recovered from lepidolite serve as valuable fluxing agents in the glass manufacturing industry.

Other properties of lepidolite mica

Specific gravity	..	..	2.6 to 3.2
Optic axial angle	..	..	Nearly 0° to 75° to 85°
Refractive index (air = 1)	..	..	1.59 to 1.60

The optic axial plane at right angles to the plane of symmetry.

The mica is hard and has a brilliant appearance; it is rather brittle and not readily splittable into thin laminations.

The following is taken from the U. S. Bureau of Mines Information Circular* :—

“Merely as an opacifier, fluorspar is apparently as effective as lepidolite and being much cheaper it is generally used in opal glasses and enamels, but the presence of lithia is believed to be of value in the manufacture of glasses used for heat resisting purposes.

Some of the qualities which lepidolite is attributed to impart directly or indirectly to glass are the following :—

A lowering of the co-efficient of expansion, thus decreasing the liability to breakage on sudden heating and cooling; the tendency to reduce de-vitrification or the production of “scene” in the melt; the production of a harder surface on the finished glass which will retain its lustre in moist air; lepidolite glass is less brittle and withstands shocks and vibrations; lepidolite increases the index of refraction and hence the brilliancy of the glass; it obviates the corrosion of the glass tanks, when making opal glass, attendant upon the use of cryolite, instead of lepidolite, as an opacifying agent.

Lepidolite mica for use in the manufacture of glass should not contain in its iron content more than 0.05 per cent. of ferric oxide.

Lepidolite sells at about the same price as spodumene except the grades for glass-making which commands a higher figure, due to the more exacting specifications, such as freedom from tourmaline, quartz and other foreign minerals†”.

COMMERCIAL IMPURITIES OF MICA

The common impurities generally found in mica and mostly objected to in the trade consist of iron oxide, silica, garnet, tourmaline, beryl and clay or mud within the mica crystals, along

* U. S. Information Circular No. 6205, p. 31.

† The quotation normally varies between \$20.00 and \$30.00 per ton.

Chemical composition of different types of micas from various sources of occurrence.
(Muscovite, Phlogopite, Biotite and Lepidomelane.)*

		SiO ₂	Al ₂ O ₃	FeO	K ₂ O	Na ₂ O	F	H ₂ O	MnO	LiO	TiO ₂	BaO	P ₂ O ₅	CaO	MgO	Total	Sp. wt.	REMARKS.
MUSCOVITE	MICA	45.2	38.4	..	11.8	..	..	4.6	..	..	..	..	..	..	..	100.0	..	
	Bengal	45.71	36.57	1.19	1.07	9.22	0.79	0.12	4.83	..	..	..	..	0.46	0.71	100.67	2.830	Geol. Surv. of India, Memoir 34.
		45.57	36.72	0.95	1.28	8.81	0.62	0.15	5.05	..	0.19	..	..	0.21	0.38	99.93	2.831	
	Madras	46.28	36.07	0.32	1.58	9.10	0.82	Tr.	3.32	..	..	..	..	1.32	0.84	99.60	..	Inikurti Palamani M., India (1930).
		46.42	36.77	0.21	1.64	8.97	0.72	Tr.	3.24	..	..	..	..	1.28	0.72	99.24	..	
U. S. A.—																		
	N. C.	45.40	33.66	2.36	?	8.33	1.41	0.69	5.46	..	Tr.	1.10	..	..	1.86	100.27	0.29	Alexander Dana's System of Mineralogy.
	Auburn	44.48	35.70	1.05	1.07	9.77	2.41	0.72	5.50	..	..	..	..	0.10	Tr.	100.84	..	
	Connecticut	45.06	30.52	1.14	1.73	10.22	2.13	1.25	6.19	..	..	..	..	..	0.97	99.27	..	
	California	45.63	37.42	Tr.	0.06	9.95	1.43	0.77	4.43	?	0.20	..	..	..	..	99.89	..	
	Brazil	47.60	35.70	4.31	?	6.07	..	4.04	..	..	..	..	..	0.43	0.59	98.74	..	* Incl. MnO. U. S. Geol. Bull., 591.
PYROXENE		50.87	4.57	0.97	1.96	0.50	0.22	..	0.15	..	..	..	..	24.44	15.38	99.05	1.44	Rio de Janeiro, Zeitler's Der Glimmer, Can. Min. Inst., Vol. VII, n. 284.
PHLOGOPITE	Lacey Mine	39.6	17.0	0.5	..	9.9	..	2.24	2.99	..	..	..	..	..	26.5	100.0	..	† Replacing MgO and Al ₂ O ₃ . H. S. Spence, U. S. Geol. Bull., 591.
	(Theoretical), Ontario	39.66	17.07	2.70	2.00	9.97	0.60	2.24	2.99	..	0.56	0.62	..	..	26.49	104.83	..	Analysis of Rocks and Minerals.
U. S. A.—																		
	Edwards, N. Y.	45.05	11.25	..	0.14	8.52	0.45	..	5.37	..	0.07	..	..	..	29.38	100.23	..	
	Ceylon—Ratnapura	42.26	15.64	0.23	1.52	8.68	..	2.19	2.91	..	..	..	..	..	27.23	100.66	2.742	Dana's System of Mineralogy.
BIOTITE—																		
	Bengal	38.10	18.35	..	6.53	8.91	3.44	..	0.40	..	0.35	0.62	..	..	23.57	100.29	..	
	U. S. A.	34.87	30.00	2.42	16.24	7.55	1.67	0.28	4.64	..	3.51	..	..	..	1.98	..	..
	Canada	34.04	15.60	4.27	23.60	8.89	0.88	2.02	1.26	0.99	..	..	..	..	7.46	100.44	0.19	
	Norway	39.05	6.84	24.89	7.47	9.03	2.13	..	2.07	..	Tr.	..	..	0.78	4.05	only	..	
	Russia	40.00	12.67	19.03	..	5.61	..	2.10	..	0.63	..	1.63	..	..	15.70	..	..
LEPIDOMELANE																		
	Baltimore	36.1	10.3	32.1	14.4	6.3	..	0.8	..	..	..	..	..	..	..	100.0	..	
	Letchfield	35.77	16.39	14.55	11.02	7.76	0.57	..	4.48	1.08	..	..	..	..	8.67	100.29	..	Faraday, H. S. Spence, Zeitler, p. 40.
		32.09	18.52	19.49	14.10	8.12	1.55	..	4.62	1.42	..	..	..	..	1.01	100.92	..	Hugh de Schmidt, p. 212.

Chemical composition of different types of micas from different sources of occurrence—contd.
(Lithium, Paragonite and Fuchsite micas.)

	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	MgO	K ₂ O	CaO	Na ₂ O	MnO	Li ₂ O	TiO ₂	BaO	P ₂ O ₅	F	H ₂ O	CuO	PbO	Cr ₂ O ₃	SnO ₂		Remarks	
LITHIUM MICA—																						
Schuttenhofen ..	49.25	25.27	..	0.84	..	13.85	..	0.35	0.85	5.38	..	..	..	5.68	1.76	..	..	..	0.06	103.29	*	
Zinnwaldite (Zinnwald).	46.44	21.84	1.41	10.06	..	10.58	..	0.54	1.89	3.36	..	..	..	7.62	1.76	..	..	..	..	103.74	..	
Paris, N. Y. (Foliated).	50.92	24.99	0.30	0.23	..	11.38	..	2.11	Tr.	4.20	..	..	..	6.29	1.96	..	..	..	..	102.38	Dana.	
Hull, Quebec and Leduc Mine. (Theoretical).	47.89	21.16	2.62	..	0.36	10.73	..	1.34	4.19	5.44	..	..	..	7.41	1.90	..	Tr.	..	..	102.94	Spence.	
PARAGONITE	47.1	40.10	..	..	..	..	..	8.1	..	..	..	..	..	4.7	..	..	..	..	..	100.0	..	
Mt. Campione ..	46.81	40.06	Tr.	..	0.65	Tr.	1.26	6.46	..	..	..	..	..	4.82	..	..	..	..	..	100.0	..	
FUCHSITE—																						
Tyrol ..	47.95	34.45	1.80	3.95	0.71	10.75	0.59	0.37	..	..	..	..	..	0.36	..	..	..	..	3.95	..	100.93	Dana.
Sisarsk (green)	46.17	29.71	2.03	..	2.28	10.40	..	..	..	..	..	..	..	..	5.42	..	..	..	3.31	..	99.52	†
Manitoba, Ont. ..	48.0	30.5	1.5	..	0.80	8.9	..	1.0	..	..	1.7	..	..	..	3.9	..	..	..	3.60	..	99.99	Spence.
Renfrew County	43.72	35.51	2.94	..	1.36	8.88	..	0.39	0.26	..	..	..	..	..	3.68	4.46	..	..	1.26	..	102.46	..
U. S. A. Mount County, Md.	42.21	34.55	1.03	..	3.13	9.16	0.47	0.82	..	..	..	..	..	..	6.77	..	..	..	2.03	..	100.47	..
ROSCOEITE	47.69	14.10	1.67	2.00	7.59	..	..	0.19	Mn ₂ O ₃	Li ₂ O	..	..	..	..	4.96	20.56	..	..	..	..	98.76	..
	41.25	14.34	..	1.96	8.25	0.61	0.72	1.45	..	Tr.	..	..	..	..	0.94	28.85	..	..	..	..	101.53	..
											(Hygrose water.				2.12)							

Spec. gr. * 2.825.
† 2.88

the cleavage planes. Magnetite is also a frequent inclusion often found in the form of black or dark-brown spots. Magnetite inclusions are highly prejudicial as a factor of reducing the di-electric property of mica and this inclusion can be easily tested by means of magnet. That the inclusions are magnetites may be proved by cutting it out and testing them with a magnet. The magnetite inclusions may be converted into hematite or limonite by weathering and show red or brownish-yellow spots. Striking colour patterns are sometimes produced in this way and such micas are sometimes employed in the manufacture of lamp shades and art micas*.

THE PLEOCHROISM IN MICA

Muscovite is practically devoid of pleochroism, while in biotite there is always a great contrast between the colour of rays vibrating across the basal cleavage lines. The absorption of the rays vibrating parallel to the cleavage in biotite is always very great and is sometimes sufficient in the deeply coloured varieties to make the thin section of the mineral appear almost black. Mr. Nilakantan has discussed this in a contribution to the proceedings of the Indian Academy of Sciences, Vol. VIII, No. 1, of July 1938 :—

“The micas constitute a highly interesting class of minerals on account of their characteristic crystallisation, structure and optical properties. Most varieties contain iron to a greater or lesser extent, in the combined state as well as in the form of inclusions and as a result they are generally paramagnetic. Biotite is distinguished by the presence in it of comparatively large amounts of iron and its characteristic optical property is a strong pleochroism in the visible region of light. Light vibrations parallel to the cleavage plane are strongly absorbed, whereas vibrations normal to the plane are more or less freely transmitted. It is also well known that pleochroism is most marked in varieties rich in iron”.

HARDNESS OF MICA

The hardness of mica from different sources and of different types varies from 2 to 2.5 for the softer phlogopite and 3 to 3.5 for the iron-rich varieties like biotite, etc. W. T. Schaller has classified micas on the basis of comparative hardness, as follows, beginning with the softest in order of variation in degrees. Harder types of mica, it may be noted, are less flexible than the softer.

- (i) Canadian amber.
- (ii) White mica (the soft white quality of Indian mica, inferior to the Bengal ruby).
- (iii) Madras soft green.

* U. S. Information Circular No. 6822 (1935) by F. W. Horton.

- (iv) Bengal ruby (muscovite mica produced in Bihar).
- (v) Madras hard green and brown (hard green ruby of Madras ?).
- (vi) West African green, brown and yellow.
- (vii) The United States green.

HARDNESS OF MICA ON THE FACE AND ON THE EDGES

In this connection, it might be observed that the Canadian amber mica is the softest of all the above-mentioned seven types of micas, the United States green being the hardest, but in most of the literature on mica Canadian phlogopite or amber is treated as harder than muscovite, which is far from the real fact. There is a difference between the hardness on the face and that on the edge of a given specimen of mica. The edge hardness of muscovite mica is greater than that of copper, while that of the phlogopite is almost the same as that of copper. For this reason phlogopite mica is found to wear down evenly (*i.e.*, at the same rate) with copper, and thus, in interleaving mica with copper in commutators and similar electrical appliances, phlogopite is better than muscovite, as the even wearing of both mica and copper is of the highest importance in order to avoid sparking and other troubles.

The following characteristics of mica should also be borne in mind :—

Simplest testing of hardness of mica.—The hardness of mica ranges generally between 2·1 to 2·5 in the Moh's scale of hardness, ranging from talc (1) to diamond (10). In other words, mica is harder than rock salt or gypsum, but softer than calcite. Hardness of mica is a factor of considerable importance in the construction and operation of D. C. commutators, since the copper segments are worn down more rapidly by the brushes than are the mica layers by which they are insulated from each other. The mica protrudes after the commutator has been in use for some time. The so-called swelling of the mica, which is actually due to the rapid wearing of the copper, used to be one of the most frequent and annoying causes of disturbances in the operation of such collectors. This defect has, however, been remedied by the use of hard-drawn copper, by using carbon brushes with wire gauze, and by undercutting the mica so as to make its surface 0·20 inch below that of the copper segment. In the United States, plate made of Canadian amber is often used in the construction of commutator segment insulation. In the strict mineralogical sense, it is not really so much softer than the ordinary light-coloured and stained varieties, but being brittle it is pulverised by scraping the edge with the finger nail. This is the simplest and quickest way of ascertaining the hardness of mica. The resistance offered to the finger nail by the edge of a sheet or flake measuring about 0·008 inch in thickness and the degree of

pulverisation thus offered constitute a convenient method of estimating the hardness of mica*.

FINGER MARKS ON MICA

Mica readily shows finger marks on the surface and for this reason it should be carefully handled by the edge like a photo plate. When it becomes necessary to dust the surface of a mica sheet, a fine, well-washed chamois leather should be used.

CHEMICAL INFLUENCE ON MICAS

The micas behave differently towards chemical reagents according to their composition and they appear to be quite differently susceptible to the forces of decomposition encountered in nature. Muscovite and paragonite are not decomposed by acids. Lepidolite and zinnwaldite are attacked but not completely decomposed by common acids. Phlogopite and biotite are completely decomposed by sulphuric acid, leaving the silica in scales. Lepidomelane is easily decomposed by hydrochloric acid, depositing silica in scales. Thus purely alkaline micas are least affected by acids; the magnesium micas are more susceptible while the strongly ferric micas are readily decomposed by hydrochloric acid. Muscovite is frequently an altered product of other minerals and hence is stable under ordinary conditions. It has, however, been found to be hydrated, in some cases losing potassium and taking up magnesium, calcium and sodium and may alter into steatite and serpentine or to some form of vermiculite†.

CHEMICAL STABILITY AND IMPERVIOUSNESS AGAINST MOISTURE AND GASEOUS INFLUENCES

Mechanical effects and damage to mica.—Mica resists effects of shocks, strains and gases and hot or cold oil. It also resists decomposition under physical or chemical influences as explained above. Mechanical action, of course, may damage it in certain cases, such as by penetrating into the folds of laminæ by the edges; oil or water may ruin the prospects of efficiency of mica or even cause its fragmentation into films by disintegration or lowering the cohesive strength. Mica, however, remains unaffected by the actions of gases produced as a by-product of combustion in furnaces, etc. Great care has to be taken to avoid the contact of oil or injurious liquids, including water, with mica *at the edges*, as these materials, though chemically inert with respect to mica, may damage it by mechanical penetration through the narrow interstices of the laminæ, reducing thereby the

* Mica and Mica Products by Richard Schroeder, U.E., p. 6 (N. Y., 1926).

† Rock Minerals by J. P. Iddings, p. 453.

cohesive strength of the leaves, even to the extent of its becoming loose separated laminae.

Thermal resistance of different micas at elevated temperatures.*

	Kind of mica.	700°C.	900°C.	1,100°C.
Phlogopite,	light amber, Canada ..	16	6	15
"	hard, Madagascar ..	19	21	16
"	soft " ..	20	7	6
"	medium hard " ..	22	32	40
"	dark, Canada "Lucky Reserve" mine.	25	13	28
"	Canada "Cliff Mine" ..	69	75	67
"	medium soft, Madagascar	40	22	57
Muscovite,	U. S. A. "Abernathy Mine", N.C.	17	66	51
"	"Climax", S. D. ..	24	55	42
"	"Alexandria Mine", N. H.	27	20	25
"	Clear Indian (Bengal quality ruby).	43	56	54
"	Madras, India ..	72	58	24
"	Good standard Indian ..	24	27	31
"	Brazil, S. S. ..	44	33	54
"	U. S. "Hibbs Quarry", Maine.	37	47	25
"	"Sylvan Lake", S. D. ..	47	57	32
"	Guatemala ..	61	65	74
"	Idaho, U. S. A. ..	62	38	41
Biotite,	South Dakota ..	74	60	73

In the above table, a low figure indicates excellent resistance and a high figure great physical changes; the best micas have lower values.

IMPORTANCE OF CAPILLARITY IN MICA

In spite of the great chemical stability or imperviousness to nature's actions, mica is sensitive to water vapour as it absorbs water very easily at the crystal edges and retains it in the cleavage planes. This capillarity along the cleavage plane is an important factor in the steaming and moulding of micanite, but it is a disadvantage in block mica although the absorption of water is purely mechanical.

HEAT RESISTIVITY OF MICA

Co-efficient of thermal expansion of mica.—Mica is a very poor conductor of heat, its thermal conductivity being about 3.6†. The low co-efficient of thermal expansion, $a = 0.000003$, is responsible for the great resistance of mica to the influence of alternating heat and cold. For this reason, mica can be conveniently used in place of glass for peep-holes, facilitating the process of observation under extreme temperatures in highly heated chambers, such as smelting furnaces and kilns and as heat resistors, as also in special devices such as stoves and windows, etc.

* U. S. Information Circular No. 6822 (1935), p. 53-54.

† H. S. Spence in *Industrial Minerals and Rocks*, 1937, p. 458.

MICA INSULATION FOR BOILER AND STEAM PIPES

The undernoted experiments obtained on the heat insulating property of mica are very important. These experiments, conducted by R. Atkinson, the Chief Engineer of the Canadian Pacific Railway, determined the heat losses of some large steam boilers of equal sizes insulated with different lagging. The experiment was carried on with the water content of 7,000 pounds in each of the boilers experimented upon.

Nature of lagging used.	Drop in temperature in 5 hours.	Temperature at end of 5 hours.
Boiler without lagging ..	84°C.	128°C.
.. with asbestos mixture ..	53°C.	159°C.
.. with magnesium blocks ..	33½°C.	178½°C.
.. with wood and air space between.	33½°C.	178½°C.
.. with asbestos and wood ..	30°C.	181°C.
.. with mica waste ..	20°C.	192°C.

The results of experiments by Prof. Capper are quoted showing that the loss by condensation over a given surface of steam piping was 1.56 lb. of steam in the case of pipes without lagging.

Prof. Capper's experimental results.

Lagging used.	Loss of pressure after 1 hour in lb. per sq. inch.	Loss of heat in calories (heat unit) after an hour.
Boiler not insulated	56	231,000
.. with wood and asbestos paper insulation.	20	73,000
.. magnesium	13	43,900
.. with kieselguhr	24	77,900
.. with mica waste insulation ..	6	21,400

The dielectric constant of micas varies from 4.6 to 8.0. Mica thus proves to be a poor conductor of heat, its specific resistance or specific heat, as already shown, being also 0.2.

Muscovite undergoes calcination at a temperature of 1,100° to 1,250°F. thereby losing its firm crystalline structure and assuming a whitish colour. Amber mica remains almost unaffected under the influence of these temperatures.

MICA IN ELECTRIC INSULATION

In electrical work mica is used for the insulation of terminals from thin bases, in thermocells for the separation of the elements, for support of the wires in holometers, for resistance for insulation between the primary and secondary windings of induction coils and as an insulating medium between the plates of condensers. The function of the insulation is to prevent the electric current from leaving the conductors except at such

points as it is desired to utilise the currents. It may be noted here that excellent insulators are not always excellent di-electrics. For instance, air is the best insulator known, but it is only a fair di-electric.

Thomas Edison, the father of electrical inventions in America, was the first to use mica for the purpose of electric insulation, such as insulating the armatures of dynamos and commutator segments and these applications of mica soon stimulated a demand for mica, exceeding the available supply, calling for fresh sources to be explored all over the world. The major portion of the world's gross tonnage of sheet mica annually consumed is used for the purpose of electric insulation. The very high-working pressures employed nowadays in the generation and distribution of electricity have necessitated new developments in the technique of electric insulation.

MICA, A MUNITION OF VITAL STRATEGIC IMPORTANCE

The generation, transmission and consumption of electricity, particularly the present-day tendency of high voltages in the electric firing of gas and oil engines, in regulating submarines, motors, aircraft, tankers, bombers, wireless, etc., depend on the employment of the thin mica sheet, without which all these operations would be greatly handicapped, if not totally crippled. During the last world war, desperate efforts were made in Germany to find efficient substitutes for mica, but were not successful. Pertinex, a synthetic paper product developed by them, is not an efficient substitute for mica at high voltages, though for service at moderate pressure it is claimed to do well. Some of the essential processes of modern civilisation are dependent on mica. Particularly in times of war, the availability of adequate supplies of mica or lack of it might mean victory or defeat to the belligerent with or without this valuable raw material. Most of the important processes of modern warfare consist of high voltage operations by way of aircraft, submarines, motors, transportation services, firing appliances, communication tanks, sound-producing or sound-deadening devices, etc., owe their maximum efficiency to the employment of mica, natural or built-up. This fact was amply proved by the plight of Germany in the last war, as a result of the British economic blockade, cutting her off from the British sources of supply of mica, including her own colony in East Africa.

Indeed "the interdependence of the electrical and mica industries gives the mineral an economic and military importance not exceeded by any other raw material and makes the matter of adequate supply in war time a subject of vital concern. During the world war, the ensuring of the supply of mica to the various allied countries was one of the important activities of the British

Ministry of Munitions. In a very real sense, *our vast electrical development is a monument to mica* (the italics are mine)—the one indispensable di-electric. The history of the intensive electrification that has been in progress during the last three decades is the history of the modern mica industry. How perfectly this mineral alone, of all known substances, has fulfilled the most exacting requirements of constantly increasing voltages is perhaps fully appreciated only by those who are familiar with the technical difficulties encountered. Because of the experiences incidental to the war (1914-18), many people have now gained a keener appreciation of mica as one of the fundamental materials of our intricate civilisation".*

IMPORTANCE OF MICA FOR ELECTRIC INSULATION

The following are the most essential requirements in the electrical manufacturing industry :—

- (i) Conductors for transmitting the electric current, *viz.*, copper.
- (ii) Carrier of magnetic flux, *viz.*, iron.
- (iii) Structural medium to hold in position the conductors, iron and the shaft.
- (iv) Cooling or heat reducing medium (air/oil).
- (v) Insulation to regulate the flow of electricity along the required pathway.

Of all the above, insulation serves as the determining factor for efficiency and reliability of the work performed, the rest of course constituting principally the structure and engineering expertmanship of the design. The following data will show the superior merits of mica in this respect, compared to other known insulators :—

Comparison of several di-electrics†.

Insulators.	Breakdown voltage per mm. of thickness.
Air	1,670
Dried fibre	13,000
Paraffin	33,900
Milled paraffin	8,100
Turpentine	6,400
Copal varnish	3,000
Vulcanite beston	3,600
Asbestos and paper	4,300
Mica	320,000

* J. Volney Lewis : "Geology and Mining of Mica", Eng. & Min. Journal Press, Vol. 113, No. 20 (1922).

† "Der Glimmer" by Hans Zeitler, p. 28. (Berlin 1913.)

The di-electric constant of an insulating material is the relation of the capacity of two condensers of the same shape and size, one of which has the material in question and the other air as the insulating medium. Di-electric constant of mica ranges between 4.5 to 5.5 (H. Schering). Mr. Zeitler has given the undernoted specific capacity and specific resistances of different types of micas :—

Origin and colour.	Thickness in mm.	Capacity reduced to air = 1.	Specific resistance per c.cm.
Madras, brown spotted ..	2.77	2.5	22.0
" green spotted "A" ..	2.1	4.8	16.0
" " " "B" ..	1.7	5.1	15.6
" " " "C" ..	1.43	3.9	91.0
" red, heavily stained ..	2.4	4.4	55.0
" transparent green "B" ..	1.73	4.4	133.0
" " " "C" ..	1.61	4.5	81.0
" " " "D" ..	1.8	3.9	125.0
Bengal, spotted ..	2.04	4.3	45.0
" red, heavily stained ..	2.5	4.7	20.0
" white ..	1.4	4.2	7.0
" yellow ..	1.4	2.8	80.0
" red, transparent ..	1.9	4.2	118.0
Canadian amber "A" ..	2.1	2.9	3.4
" " "B" ..	5.0	3.0	0.44
" " "C" ..	1.4	2.9	22.0
South African, spotted ..	1.22	5.9	39.0

The disruptive strength of muscovite mica from different sources as found on experiments is shown below. The di-electric strength is usually expressed in volts per mil (0.001 inch) of thickness.

Origin.	Colour.	Thickness in mm.	Disruptive strength in volts per mm.
German East Africa ..	Light brown in thick layers, free from impurities.	0.45	28,000
		0.70	28,500
Bengal ruby ..	Light red in thick layers with a few impurities.	0.48	17,500
Madras green ..	Thick layers green, very soft, fairly numerous red and green spots.	0.35	24,500
Russian muscovite mica	Light yellow with black impurities.	0.48	21,000
Ceylon ..	Thin green, layers thick, layers of dark-reddish yellow.	0.50	20,000

The di-electric strength of ordinary mica of good quality is about 1,000 volts per mil (0.001 inch) of thickness.

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The advantage of mica as an insulating medium for electrical uses includes also its high resistance to puncture (technically expressed as puncture voltage) which remains unaffected by any temperatures that are of practical significance in electrical engineering, no diminution being noticeable until the point of calcination is approached. The following results of tests carried on air and oil have been given by Mr. Schroeder. These results will show that the increasing thickness is accompanied by considerable decrease in the resistance to puncture per 1 mm.

Quality.	Thickness in mm.	In air.		In oil.	
		msd./kv.	kv./mm.	msd./kv.	kv./mm.
Clear ruby	0.055	10.5	191	4.9	89
	0.12	..	..	5.3	44
	0.28	..	..	7.6	27
	0.4	..	..	9.5	24
	1.0	..	..	13.5	13.5
Calcutta, heavily stained	0.11	7,000	64	6,700	60
.. black stained (streaky).	0.11	5,200	47	6,000	54.3
Madras, black stained (roundish blots).	0.10	6,800	68	6,300	63

These measurements were made under uniform conditions with electrodes of 50 mm. The radius of the rounding of the edges was 5 mm. Puncture invariably occurred near the edge as was to be expected.

Di-electric constant and power factor measurements of mica.*

Origin and kind of mica.	Tem- pera- ture.	Frequency.	DI-ELECTRIC CONSTANT.		POWER FACTOR.	
			Aver- age.	Spread.	Aver- age.	Spread.
U. S. clear musco- vite.	25°C.	100-1,000 kilo cycles.	7.20	8.69-6.57	0.02	0.04-0.01
.. muscovite	..	..	7.16	8.69-6.57	0.02	0.04-0.01
India muscovite	..	..	7.32	7.90-7.07	0.02	0.02-0.01
U. S. and Indian spotted musco- vite.	..	..	..	9.64-5.83	..	8.36-0.00
Madagascar phlogopite.	..	..	..	6.07-5.41	..	7.12-0.38
Madagascar muscovite.	..	800 kilo cycles.	7.0	..	0.03 or less.	..
Clear muscovite	20°C.	..	7.1	..	0.024	..
.. phlogopite	..	..	7.0	..	0.68	..

* Leaflet of the American National Bureau of Standards entitled "Some Electrical Properties of Foreign and Domestic Micas". (Research Paper, No. 34.)

A few measurements on stained mica prove it to be unsuited for radio purposes. The power factor of slightly stained mica is shown to be of the order of 0.10 per cent., while heavily stained mica showed a power factor of 8.0 per cent. or higher. For phlogopite it is from 0.04 to 7.0 per cent. In both cases, the power factor was a function of the frequency, increasing with decreasing frequency. There was a similar function of frequency or that there was any close relation between the di-electric constant and the amount of stain present.

In the case of clear micas, both the di-electric constant and power factor were within the range of the measurements and independent of the electric frequency.

The average value of di-electric constant and power factor obtained by experiments has been given in the table on page 37 from which it will appear that the stained muscovite micas and phlogopite show power factors entirely too high to permit their use in applications calling for materials having low power loss. For perfectly clear muscovite mica, one can predict from these data a power factor of 0.02 per cent. with deviation from this of ± 0.01 per cent. on the average. The average di-electric constant of these micas is found to be 7.2 with a deviation from this value of ± 0.3 on the average.

The di-electric strength of mica is less sensitive to the presence of inclusions than is the power factor, which is seriously affected by the slightest trace of air bubbles or metallic oxides. The presence of numerous thin layers of conducting materials in the badly stained micas will tend to seriously distort the electrical field within the crystals. The di-electric strength expressed in volts per mil should vary inversely as the thickness of the specimen of mica.

A comparison of electrical constants shows that mica has a specific induction of 6.6, sulphur 3.97, paraffin wax 2.29, and ebonite 1.92, this explaining the importance of mica in the electrical industries*.

Mr. Allan Monkhouse† puts the di-electric strength in kilovolts per mil at 20°C. between 3.25 to 6.25 for muscovite and 3.7 to 4.2 for phlogopite. Mr. F. W. Horton, mining engineer of the U. S. Bureau of Mines, in an Information Circular, published the results of a series of tests on mica from different sources and put the di-electric constant of muscovite at 6.93 to 8.83 and that of phlogopite at 5.41 to 7.07. Power factors to these two micas of commerce are 0.014 to 8.36 and 0.38 to 7.12 respectively.

* G. V. Hobson: *Mica and Its International Relationships*. Bull. Inst. Min. and Met., No. 270, March 1927, p. 2.

† Monkhouse's "Electrical Insulating Materials" (1926), pp. 174-187.

DI-ELECTRIC TESTING OF MICAS

There are several methods of measuring the di-electric strength of mica followed by different people. The following is one of the methods adopted by the U. S. Bureau of Standards* :—

“Several factors must be considered in specifying the experimental conditions under which the di-electric strength of a material is determined. It is of primary importance that the arrangement of electrodes and the nature of the surrounding medium be such as to subject the specimen under test to a known reproducible, and preferably uniform, electric stress. Some observers have obtained this result by using flat electrodes with well-rounded edges, immersed in a medium having the same di-electric constant as the material under test. In this case a uniform electric stress is produced in the specimen. Other observers have used spherical electrodes or one spherical electrode against a plane electrode. In case the surrounding medium has the same di-electric constant as the medium under test, a non-uniform, but known, electric field is produced. In case the surrounding medium has a di-electric constant different from that of the material under test, a non-uniform field is produced which is not as yet capable of computation. The American Society for Testing Materials and specifications for testing sheet materials call for 2-inch flat electrodes (A. S. T. M. Specification D 149-30 T.) immersed in oil to prevent corona and flash over. Other observers have used mercury electrodes and other devices suitable for use with materials which can be worked or moulded.

“Within the range of ordinary power frequencies it is probable that the effect upon the breakdown voltage of a change in the frequency of the applied alternating voltage is slight. Such an effect exists, however, and it has been shown that the di-electric strength of mica, at frequencies of the order of 200,000 cycles per second, is appreciably lower than at 50 cycles per second. How much of this difference is real and how much is due to the inherent difficulties in measuring such high-frequency voltages is not certain. In the light of the theories of breakdown as caused by the formation of hot spots or hot filaments it is also important to specify the time interval during which the specimen was subjected to the electric field before breakdown occurred, as well as the temperature of the specimen. It is assumed that such self-evident factors as the elimination

* U. S. Dept. of Commerce: National Bureau of Standards: Research Paper No. 347: Journal of Research, Vol. VII of August 1931.

of corona and flash over at the surface of the specimen and the choice of a suitable power supply need not be discussed here.

"It is to be expected that the results in work of this kind will scatter widely. Where large numbers of samples are to be tested the number of observations necessary to obtain consistent results begins to be considerable. As it was the purpose of the present investigation to test a relatively large number of samples, it was necessary in the choice of apparatus to give considerable weight to ease and rapidity of operation. For this reason it was decided to use as electrodes 1-inch metallic spheres immersed in a light mineral oil (transformer oil) to prevent corona and flash over. Such electrodes are easily constructed and are self-aligning in operation. Because of the fact that the sphere tests only a small area of surface, a number of punctures can be made on a single sheet of material, which makes for rapidity in testing. This fact, however, will also tend to produce an increased scattering among the individual observations and to indicate a higher average dielectric strength than would be the case if flat electrodes were used. The fact that the electric field in a sheet of dielectric material placed between two spheres is not readily capable of computation is a disadvantage when comparing the results presented here with the results of other observers, but is of no great importance in the relative comparisons made in this paper.

"In making the tests one of the spherical electrodes was connected to one high-voltage terminal of a step-up transformer giving a maximum of 25,000 volts and rated at 3 kilovolt amperes. The other side of the transformer as well as the other sphere was grounded. This transformer was supplied with 60-cycle alternating voltage of practically sine wave form. The high voltage was measured by means of a step-down transformer of the same ratio and rating as the supply transformer. The high voltage coil of this step-down transformer was placed in parallel with the sphere gap and with the high voltage coil of the step-up transformer, and the resulting secondary voltage was read from a voltmeter across the secondary terminals of the step-down transformer. These voltage readings could be made with an accuracy of about 1 per cent. These voltage readings multiplied by the ratio of transformation of the step-down transformer, which was accurately known, gave the total voltage across the specimen under test. The thickness measurements were made on a dial micrometer on which 0.1 mil (1 mil is 0.001 inch) could be read by estimation".

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The following method is used by an insulating material manufacturing firm* :—

“The test is usually conducted between flat circular electrodes. The voltage is measured by means of a 240 : 1 potential transformer, across the secondaries of which a voltmeter is connected. The voltage is raised at a practically uniform rate of 500 volts per second by means of a motor-driven drop wire which supplies current to the alternator field. The voltmeter reading is taken at the instant of the breakdown. Usually the mica is not called upon to withstand the high voltages to which it is tested. This is specially true of commutators where the voltage between segments is only of the order ranging from 5 to 20 volts, but the plate is tested to be certain that it contains no flaws and it is up to standard, even though it is used on voltages which is a very small percentage of the testing voltage. Mica plate generally stands 300 volts per mil and upward depending upon thickness. As a rule, in the thinner plate, the total breakdown voltage is less but volts per mil is higher. This is true of any di-electric. The thinner samples always break down at higher values of volts per mil than thicker ones, owing to the fact that there is a greater probability of the weak spots lining up in the thicker insulation”.

MICA IN MODERN TRANSPORT ENGINEERING

The invention of the internal combustion engine has revolutionised the system of modern transport engineering and few people perhaps know that it is mica that has made possible the marvellous efficiency attained in transport industries. These engines are put into motion by a magneto which depends for efficient duty on a component of mica.

Mica in fact possesses a unique combination of many useful properties, making it, besides the most valuable insulating medium used in electricity, a significant factor of modern civilisation. Without mica, the most advanced achievements of science and engineering would be seriously crippled if not brought altogether to a standstill, should there be no man-made substitute efficient to take its place. Efforts at finding an effective substitute have till now failed.

* India Mica, Vol. I, p. 34, by R. R. Chowdhury.

PART II

THE PRODUCTION OF MICA

Chapter III

PROSPECTING AND DEVELOPMENT

Prospecting is defined by Mr. M. W. von Bernewitz as follows* :—

“Prospecting, in its widest sense, means the recognition and discovery of the natural resources of a country, which includes animals, minerals or vegetables. It means the opening of the gates of progress, the lighting of darkness and the birth of hope. It stimulates the imagination, it lengthens the vision, dips into the future and forecasts the trend of history. It is a man's work and men are needed for it, of exceptional calibre and attainment. In a narrower sense—prospecting means the search for hidden mineral wealth”.

In prospecting for mica, not only has the general richness of the deposit to be taken into account, but also the quality and dimensions of the sheets and the easy workability of the deposit. Quality is of primary importance and the miner aims at extracting the sheets in maximum dimensions available and that without the least damage to the crystals. Mica prospecting therefore differs from prospecting for ore-bodies in general and is of a more exacting nature, requiring a specialised technical skill and experience.

Advantage of glaciation in prospecting for mica.—In some glaciated regions, as in some parts of United States and Canada, erosion has exposed the pegmatite outcrops where the overburden or sedimentary deposits has been washed off the surface. In such glaciated regions, deposits of mica are often easily discovered, because they sometimes contain glittering flakes of mica scattered about, the presence of which gives probable clues to the occurrence of mica in the locality.

Effect of topography in India.—In the Bihar mica belt, the rather rugged topography is helpful in exposing the pegmatites through surface erosion. In the Madras (Nellore) area the

* Handbook for Prospectors by M. W. von Bernewitz, N.Y., 1935.

topography is less rugged and there is often a cover of soil and detritus, which obscure the outcrops to some extent.

Prospecting in the alluvial plains.—Flat alluvial plains present difficult conditions for prospecting; firstly, rock outcrops are scarce owing to the heavy overburden obscuring the pegmatites below the surface, but agricultural operations and well-sinking have been responsible for the discovery of some deposits; secondly, in course of mining, the handling and removal of heavy overburden and waste materials tell on the economics of mica mining by increasing costs very considerably.

Methods of prospecting.—Pits and trenches are sunk along or across the strike to enable the prospector to form an idea of the commercial prospects of the deposit. Trenching offers the simplest and cheapest course of prospecting where surface outcrops occur. These trenches are carried down from schist to schist across the strike, with shallow pits where necessary. By this course, the prospector can ascertain all the information he needs and also recover sufficient surface mica in the process, which may often cover his costs of prospecting. Cross-cutting tunnels sometimes facilitate the operations and enable the prospector to fix upon the best mode of working, to attack the deposits at suitable points.

On the discovery of promising deposits, the trench and pit-working are continued by open-quarrying methods to considerable length up to 100 feet or more, and if the prospector finds a remunerative yield of mica, the question of development on more efficient lines with mechanical equipment is considered. Economy in working and marketability of the output should be kept constantly in view, without impairing the efficiency of the operations.

Tunnels in prospecting.—In hilly regions, tunnels, instead of shafts, offer greater economic advantage as they save a good deal of pumping and hoisting expense. Overhead stoping with waste-filling support would further economise the costs and give good working results. In case of steep veins, underhand stoping sometimes proves more advantageous. Shafts and cross-cuts would disclose the best method of stoping to be followed.

Characteristics of prospective pegmatites yielding sheet muscovite.—The gneisses in India, according to the geologists, are among the younger members of the Archæan formation. In the Bihar mica tract, with its irregular pegmatite bodies occurring amidst these gneisses, denudation has exposed the rocks and made it easy to plan prospecting and mining with moderate capital funds. Large muscovite mica crystals, yielding commercial sizes and qualities of sheet mica, occur in veins or dykes of extremely coarse-grained granites and pegmatites. These crystals of sheet

mica are generally found parallel and near to the hanging wall or the footwall.

Dr. Coggin Brown in his "Notes on Mica"* states :—

"The regular and restricted sheets and dykes are the ones (pegmatites) most easily mined. Prospectors may note that coarseness of grain is not correlated with the size of the intrusion and that, almost without exception, those pegmatites which carry payable mica show a well-developed central core of quartz, which shades off gradually into softer pegmatite on both walls".

Wide experience of working in the Bihar mica field corroborates this observation. In reporting on the working of the Jorasemar mica mines, Dr. Cyril Fox observed† :—

"Enrichments of mica are not uniform throughout the section of a pegmatite, nor are the minerals composing the pegmatites equally disposed. Pockets of isolated crystals of muscovite mica invariably occur to one side or other of the body of the pegmatite. The central mass of the deposit is usually composed of a core of granular pellucid quartz in which beryl and tourmaline crystals may be totally enclosed. On each side of the quartz core there is usually a margin of feldspar and it is, most frequently, at the junction of this feldspathic margin and central quartz core that the largest 'books' of mica are found. Marketable mica is also to be found, in certain pegmatites near the actual contact with the schists, either on the hanging or the foot-wall side. Large crystals of garnet occur in about the same situation while tourmaline is common in the margin and in the quartz core. Apatite in varying quantities is found in almost every one of the larger pegmatites".

Muscovite mica deposits are generally more persistent than phlogopite and can be followed with comparatively greater ease. Sheet muscovite should invariably be looked for in the granitic pegmatites, which can be easily distinguished where found. Mica, quartz and feldspar are almost invariable associates, of course, in varying proportions, of which mica and quartz are resistant to weathering conditions or underground influences but feldspar is prone to decomposition or alteration to clay, sericite, etc. Amongst the mineral constituents of pegmatites, tourmaline, apatite, beryl, garnet and, more rarely, tantalite and columbite are important so far as Bihar occurrences are concerned. Other minerals occasionally found in association include

* Bull. No. 15 of Indian Industries and Labour, 1923, p. 2.

† Quinquennial Review of Mineral Production for 1924-28 : Records of Geol. Surv. of India, Vol. LXIV, 1924-28, pp. 246-247.

samarските, monazite, pitchblende, etc. Apatite is frequent in the large pegmatites containing muscovite mica in this province.

DIFFERENCE BETWEEN THE MODES OF OCCURRENCE OF MUSCOVITE AND PHLOGOPITE MICAS

Muscovite-bearing pegmatites are decidedly more conspicuous and well-demarcated than the pyroxenite dykes carrying phlogopite mica. But the latter have the special advantage of occurring in rich concentrations and, if heavy overburden is absent, they can be followed up easily. Phlogopite deposits, though less persistent than the muscovite, are somewhat more "inclined". Rich pockets of phlogopite very often peter out in very narrow stringers at points least expected, sometimes to develop into profitable bodies further on. Indeed, the general shallow working and abandonment of pits in Canada are due mainly to handling of heavy overburden or waste rocks and petering out in stringers with characteristic uncertainty about the prospects ahead.

Muscovite mica generally occurs in localised shoots, assuming any position in the dykes, confining itself mostly to one or the other of the contact zones. Phlogopite, on the other hand, occurs in the pyroxenite dykes in more or less vein-like bodies or in irregular pockety masses with a high proportion of calcite in the rocky masses around. The percentage of mica to the total vein matter is also almost always much higher in phlogopite than in muscovite deposits.

Thus there seems to be a fundamental difference in the mode of occurrence of these two principal types of commercial micas and the two never occur in association as in the case of muscovite and biotite micas.

Indicative value of quartz and feldspar in tracing prospective mica deposits.—Opinion differs on this point. Some people are of opinion that excessive quartz synchronises with the inferiority of the mica while others opine that the quality of mica goes hand in hand with the presence of feldspar in predominating proportions. Association of flesh-coloured feldspar is sometimes deemed to indicate the "petering out" of the mica deposits. Occurrence of fine feldspar and milky quartz is also believed to offer encouragement and this is said to have led to big deposits of good mica in certain localities. Experience in well-planned workings in India, particularly in the Bihar fields, has shown that in several cases there is an improvement in the size and flawlessness of the crystals with depth.

Although none of these views can be accepted as a general rule for any wide area, it might hold good for particular localities. Indeed the local environment and nature of crystallisation of the individual pegmatites seem to vary greatly and local experience

constitutes an important factor in prospecting for prospective mica deposits. Lack of education, enlightenment and technical skill amongst the people engaged in mica mining in this country is responsible for lack of realisation of the exact conditions prevailing in different mica mining localities in India.

Mr. R. R. Simpson, the late Chief Inspector of Mines in India, in course of discussions on the subject of mica* stated that mica "books" generally occur in definite veins and usually at a horizon in the vein. The mica miner, as a rule, limits his excavation to such a horizon. Mica is a stable mineral, little affected by weathering agencies. The oxidised zone is shallow and ill-defined. The kaolinisation of the feldspar sometimes extends to a considerable depth, without the mica being affected. This fact, in some mines, facilitates the mining of mica to a considerable degree, as explosives are not required and the yield of marketable mica is increased.

Special features of the Madras mica deposits.—Apart from their occurrence in an area covered to some extent by soil, the Madras deposits are characterised by comparatively lesser persistence but greater lenticularity and irregularity of the outcrops in many instances, than the belt of Bihar. This manner of occurrence makes it very hard for "small ventures" to succeed; it rather strongly suggests the necessity for better organisation, greater capital and employment of scientific methods of mining with efficient mining equipment in this province than elsewhere. Though somewhat inferior in quality to some of the best deposits in Bihar, Madras deposits yield usually a better proportion of larger sizes of crystals, with comparatively greater flawlessness in the bulk of the productions than those of Bihar (with of course rare exceptions). The mica pegmatites in the Nellore district generally cut through the schistose country rock and occur, as in Bihar, with a parallel trend to the direction of the foliation of the schists, with often a steeper dip. The characteristics of the Madras pegmatites have been described by Mr. V. S. Swaminathan as follows† :—

"From sheets fairly uniformly thick over long distances, one finds various gradations to some eye-like lenses of which many may be found projecting from the schist surface over an area of only a few square yards, giving an impression that the pegmatite might have thoroughly impregnated the schists. The chief constituents of these bodies are quartz, feldspar, albite as well as microcline, orthoclase and mica, commonly associated with garnets and beryl".

* Trans. Min. & Geol. Inst. of India, Vol. V, 1910, on the contribution of Mr. A. Krishnaya.

† Trans. Min. & Geol. Inst., India, Vol. XXV, November 1930.

HELPFUL HINTS IN THE PROSPECTING FOR MUSCOVITE MICA DEPOSITS

The following suggestions may be helpful to the prospector of muscovite mica in India :—

(1) Quartz and feldspar are the most usual associates of muscovite mica, of which the feldspar is liable to disintegration or decomposition, while quartz remains unaffected. Quartz veins where found, especially in a schist country, may be tried as an indicator leading to deposits of muscovite nearby. Marketable mica in India almost invariably occurs in association with mica schist and located as a rule in pegmatites traversing the mica schist, and often nearer the actual contact with the schist either on the hanging or the footwall. Pockets of isolated crystals of muscovite also occur in many cases in one side or other of the pegmatitic bodies.

(2) In certain areas in India, larger mica bodies are generally found embedded in feldspar rather than in quartz; as long as the coarsely grained dykes are in evidence, the direction might be followed till the country wall of granite schist warns the prospector to cease further operations in that particular direction. While again the operations disclose deterioration in the degree of coarseness of the pegmatite bodies, the prospector may take it as a hint to consider the stoppage of progress in that direction, and divert attention to other directions. In almost all cases, commercial mica-bearing pegmatites show a well-developed core of quartz, changing gradually into softer pegmatitic bodies on both the walls.

(3) At some depth from the surface, the mica is less flawed and better in quality than at and near the surface. The surface mica is often defective, distorted or stained due to the effects of weather influences and surface conditions.

(4) The presence of accessory minerals, associates or alteration products, characteristic of mica, may offer useful clues for mica deposits. Pegmatites, the home of commercial sheet muscovite, are also the sources of certain other minerals and rare earths including columbite, tantalite, beryl, etc., which are sold at very good prices.

(5) The prospector should constantly bear in mind that two essential factors of utmost importance in determining the economic value of a mica deposit are (i) the transparency and (ii) the physical properties of the sheets, including basal cleavage, hardness, flexibility and elasticity.

(6) The more regular the disposition and structure of the lenses and dykes of pegmatites, the more easy it is to exploit them. The coarseness of grains does not always indicate the size of the intrusion, though occasionally it may bear some relation.

(7) The pegmatites are very irregular in shape and appear to be the products of re-crystallisation of the enclosing rocks. "Enrichments of mica are not uniform throughout the section of a pegmatite, nor are the minerals composing the pegmatites equally disposed"*. One pegmatite differs from another in surroundings, contents and proportion of contents. Local conditions of each individual pegmatite are therefore important factors for consideration in the planning of prospecting or development.

THE SURFACE MINING OR "UPARCHALA" WORKING IN INDIA

The "uparchala" mica is at present a large and important source of mica, which though often defective, stained and not generally as valuable as sheet material from depth, is quite suitable for the purpose of manufacture of splittings, particularly of the cheaper classes. In fact, the largest demand of splittings nowadays, mostly low-grade "loose" or "dust loose" in form, is almost entirely met from this class of mica and "dump reserves", though the latter is nearing exhaustion. In Bihar, there are yet large areas of land, mostly within *zamindari* estates, where surface pegmatitic outcrops are abundant. Petty contractors or "*thikadars*" take contract of working in specified plots and exploit the surface deposits, often by means of mere "picks and shovels". The "uparchala" mica in the Kodarma Government Forest zone has been extensively exploited and exhaustion is apprehended in the very near future.

India has, until now, enjoyed world monopoly in the supply of mica splittings; with cheap reserves of raw materials by way of "uparchala" or surface mica and "dump reserves" and very cheap but traditionally skilful splitting labour in the countryside, she had till now been in a most enviable position and able to defy world competition. Efforts were made in the past, in the United States and Canada, to manufacture fine splittings at competitive prices, but these have been futile. Such a monopolistic situation in India, however, is likely to be seriously imperilled very soon, with the exhaustion of these reserves of raw materials in India, *i.e.*, surface mica and "dump reserves". It is imperatively necessary now to read the signs of times in advance and organise the industry properly as a whole on such an economic, efficient and wholesome basis that, by the time the apprehended exhaustion occurs, India may turn out cheap splittings from "mined mica" at competitive prices and make it impossible for the other mica-producing countries to displace her from her present leading position. Major Athil of Induram Ltd.,

* Dr. Cyril Fox : Records of Geol. Surv. of India, Vol. LXIV, p. 246.

London, has sounded a timely note of warning in the following paragraphs* :—

“ Investigations show that over a wide area ‘uparchala’ yield is falling off in both quality and quantity, that is, the best surface occurrences have been worked out and the others are nearing their end. The precise date of final exhaustion of ‘uparchala’ cannot be predicted, but signs of its exhaustion make it necessary to consider the situation, which will arise when it is eventually reached.

“ If mica splittings are essential there is no question of the world not being able to produce enough of them after the ‘dumps’ and ‘uparchalas’ of India are exhausted. The shortage caused by ‘dump’ and ‘uparchala’ failure will probably be made good by a combination of increased Indian mining and of splitting non-Indian block. The danger is that the failure of these sources, especially of ‘dumps’, will occur before arrangements have been made to replace the deficiency from other sources and that the inevitable rise in price, which would be quite harmless if gradual, will be so abrupt as to cause serious inconvenience. It is guarding against these dangers that combined action may be useful.”

These observations bring out the danger ahead quite well, though the author does not apprehend the crisis of exhaustion of “uparchala” to come so soon as the writer of the above report seems to suggest, but it is sure to come. Beyond the limits of the Kodarma Reserve Forest zone, especially in the *zamindari* lands, there are yet large “uparchala” reserves, but from the trend of increasing demand for cheaper classes of splittings, as evidenced in 1936–37, they would not take a long time to exhaust, but for the difficulty of working in private *zamindari* lands, or lands under group ownership involving fractional interests, commanding no resources of development or mutual comradeship to work in co-operation. The “dumps”, particularly the factory “dumps”, which are the sources of better classes of splittings are almost nearing exhaustion. It is already over six years since Major Athil reported as above and circumstances precipitating the crisis are shaping out ominously from other directions as well. The mica industry, in this state of affairs, needs urgent attention from the State and necessitates a thorough survey of the conditions and prospects of the Indian mica industry in all its phases, including the questions of mining development, manufacturing efficiency, standardisation of products and co-operative marketing as well as mica research and development of mica-products industries in this country.

* A Report on the Mica Situation in India and Elsewhere, London, July 1932, pp. 20 and 24–25.

MICA : A MINERAL OF DEEP-SEATED (IGNEOUS) ORIGIN

As a constituent of igneous rocks mica is crystallised at moderate depths, although the deposits may be exposed at the surface through erosion and denudation. Experience amply proves that comparatively flawless and valuable mica deposits are more often met with at some depth than near the surface. Several well-known mines in the Bihar and Nellore mica fields, particularly in the former, have turned out to be comparatively richer at depth with huge reserves of very fine and large sheet mica than when worked as shallow quarries. Some of the richest mines, worked with high yield at present, are old, worked-out pits re-opened.

This is a usual feature more or less in all mica-bearing areas all the world over and particularly in India. Underground mining, both in Bihar and Madras, has been successful when conducted on a comprehensive, well-laid plan, though very few of the working firms have been able to afford to do it. Reporting on the prospects of the Madras mica field, Dr. P. K. Ghosh of the Geological Survey of India wrote that "most of the workings on scientific methods in this area have been financially successful".

Shallow working and abandonment of mica mines.—The characteristically uncertain and erratic behaviour and the need of large investment in systematic mining of mica have led to the shallow working and frequent abandonment of many pits after surface exploitation. After extracting the mica available within easy reach in the surface outcrops or after mining the nests traced in the neighbourhood by means of "open-cut" and trenching, the miners abandon them as either unremunerative, exhausted or difficult. Infiltration of water in the pits often leads to abandonment. Most of these pits are left in a dangerous condition for the succeeding developer or prospector. In re-opening such pits, the successor has to incur a heavy capital outlay before meeting the next prospective pegmatite; it is, however, not an infrequent occurrence that the successor in such cases gets at a rich deposit, almost at the first effort, within a few feet of the point at which his predecessor left it.

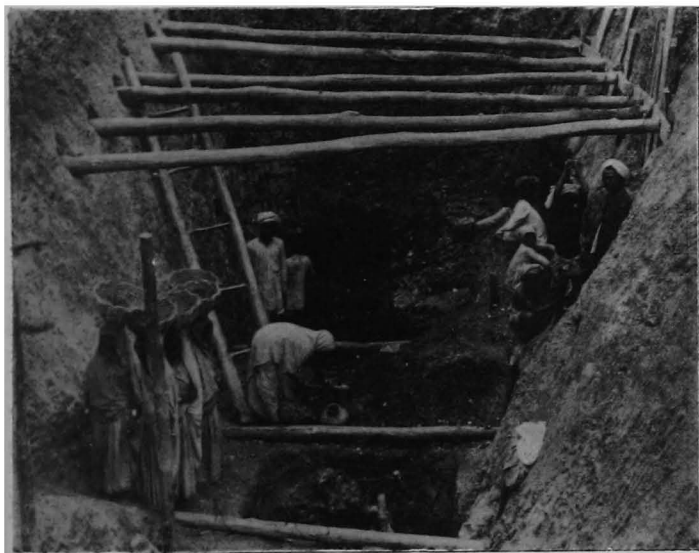
Figures 5, 6 and 7 show the views of old, worked-out mines left in wretched condition and subsequently taken over by the Government, and also the condition of mine entrance and shaft-head of pits after development by Government.

SIZE OF MICA CRYSTALS

Notwithstanding the uncertainty and speculative nature of mica mining, instances are not altogether rare where the miner is favoured with a fortune in the shape of a single crystal of mica, weighing thousands of pounds, covering all his speculative investments. The largest mica crystal ever found in a deposit was obtained from the *Inikurti* mica mine of the Nellore mica

field, which measured 10 feet across the basal plane and 15 feet across the folia*.

This "book"† yielded perfect and flawless mica sheets of 30×24 inches. It is to be regretted that no weight or value of the commercial yield of this "wonder crystal" is on record. The districts of Hazaribagh and Gaya, especially the Government Reserve Forest areas, are said to have produced very big "books" of mica in the past, but there are no authentic records. The Nellore field, however, is reputed to produce comparatively larger mica crystals, yielding more flawless sheets than the Bihar mica field.



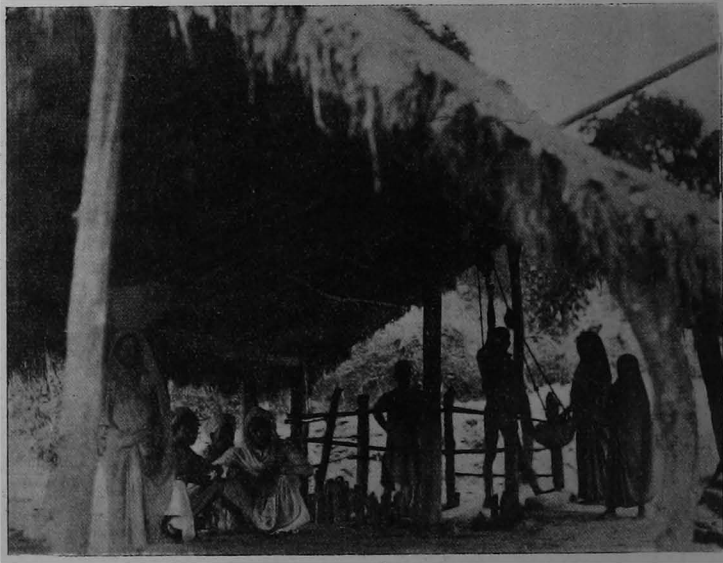
[By permission of the Director, G. S. I.]
Fig. 5.—Uparchalla (open-cut), Jorasemar, Kodarma (after C. S. Fox).

Single crystals of phlogopite mica, weighing over 3,000 pounds and measuring 5 feet across to 9 feet in length, have been obtained from some of the Canadian deposits. One single crystal of the well-known Wallingford mine in Quebec, Canada, yielded \$33,000 worth of trimmed sheets.

* One cubic foot of mica weighs approximately 180 pounds; *vide* Handbook for Prospectors by M. W. von Bernewitz, p. 296.

† The crystal on the basis of Mr. Bernewitz's figure weighs approximately 85 to 90 short tons.

The Spruce Pines Mica Co. of North Carolina in the United States is reported to have obtained a single crystal of mica* weighing 4,232 pounds, from one of their North Carolina mines in 1926. Mr. W. B. Phillips† writes of a mica crystal of about 2,000 pounds, which made two-horse waggon loads to carry. According to Mr. Schaller's report, the General Electric Co. obtained one single mica crystal, measuring 119 inches in width. Mr. Westover of the General Electric Co. made the gift of a section of a phlogopite crystal to the U. S. National Museum, which is somewhat less than an inch thick and measures 47 by 35 inches across the cleavage face.



[By permission of the Director, G. S. I.
Fig. 6.—Top of Shaft, Jorasemar, Kodarma (after C. S. Fox).

One mica crystal obtained in Australia measured 6 by 4 feet and yielded nearly 800 pounds cut mica‡.

These are, of course, exceptional instances of "wonder crystals" in pyroxenite and pegmatitic masses. The normal sizes of big crystals seldom exceed 6 to 12 inches in diameter and the usual sizes of large sheet yielding crystals of 1 foot to 2 feet across the cleavage face. All the same these exceptions prove the rule in mica and when luck intervenes to

* U. S. Mineral Resources: Mica in 1926.

† U. S. Geological Survey: Mica in 1887.

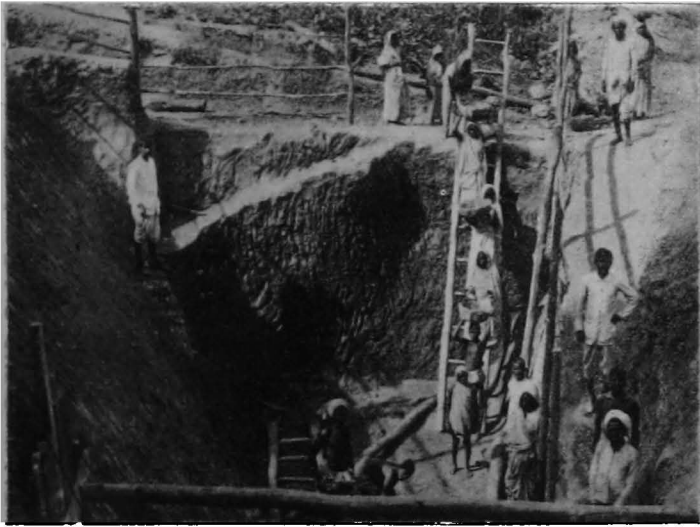
‡ U. S. Mineral Resources: Mica in 1918.

reward the venturesome spirit of the prospector or miner of mica, one large crystal may prove enough to reward him for all his labours. Luck, indeed, plays an important part in mica mining.

DEVELOPMENT IN MICA MINING

Mica mines can be divided into three classes, on the basis of their varying nature, local conditions and commercial possibilities :—

- (a) *First class mines.*—Developed on up-to-date scientific lines with modern mining machinery.



[By permission of the Director, G. S. I.
Fig. 7.—Gutiya (open-cut), Jorasemar, Kodarma (after C. S. Fox).

- (b) *Second class mines.*—Equipped with certain simple types of modern machinery; development not quite systematic either because it is considered unremunerative or because necessary investment on development is beyond the miner's means.
- (c) *Third class or small mines.*—These are no better than shallow worked pits, operated in most cases intermittently on "gophering" or "ground-hogging" method with crude mining implements.

The *third class* mines are worked at minimum expense leaving the waste materials near about the walls or mouths of

the excavations. The mining implements consist generally of picks and shovels. If these small workings reveal good prospects for continuous operations, development may be undertaken to raise the pits to the status of *second class* mines, with mining equipment comprising of jack hammers, air compressors, pumps and boilers : hauling and hoisting appliances are also necessary for economic working of the *second class* mines. Carts and lorries are the usual means of transportation in India; where roads do not exist, construction of roads becomes a difficult problem, which is beyond the capacity of the owners of *second class* mines to solve. Small individual mining enterprises, instead of large corporate bodies on co-operative lines, have proved a serious handicap to economic and efficient mining development in India.

Importance of development.—Proper development of mica mines is a most important economic factor. The efficient and economic exploitation of a mica deposit with maximum available output depends on systematic development. Output of a prospective mica mine cannot be increased to the limit of any accelerated demand at any time the miner may desire even at heavy investment, unless the mine is maintained in good working condition of development. *Development not only calls for sufficient capital and technical skill, but it also involves the factor of time.* The “time element” in development has got a special importance in mica. This fact was amply demonstrated at Jorasemar under the stress of war conditions, when heavy expenditure was not an important question. The mines at Mushnodi Gadi were found in such wretched condition, when taken over by the Government, that it took over a year of expert and efficient management to develop several of the old workings to the stage of economic productive capacity. But by the time the mines were fully developed urgency of demand passed owing to the cessation of war.

In developing a mine, experience in technique is of great importance. Economy at the sacrifice of efficiency has been the curse of the mica mining industry, particularly under untrained management and uneducated owners. Maximum but steady production at lowest working costs may be achieved only by proper development of a mine under efficient technical guidance. There are numerous channels in which to effect economy in mica rather than by retrenching the “brain” of the show or foregoing the services of a competent expert.

NO GENERAL RULE IN MICA

Mica may be said to be the most favourite though somewhat spoilt child of Mother Earth, with a unique combination of many important properties of great industrial and strategic significance, but as like a spoilt child it obeys nobody's

command and follows no specified rules of discipline, *nothing like a general rule can be laid down to prospect or mine it*. Every mica-bearing pegmatite has its own peculiarity in the mode of occurrence or constituent components, behaviour and association.

In order to determine the form of attack or method of exploitation, the miner has first of all to consider the range of persistency of the mica leads; then he has to consider the quality but not so much the quantity of the deposit in view. Rich veins pinch out, fork or branch off at any points or widen up surprisingly at unexpected points; promising deposits, giving steady high daily yield for a long period, show exhaustion sometimes with disconcerting suddenness. The apparently exhausted pegmatite of hopelessly narrow width sometimes takes the miner by surprise with abrupt expansion of the leads bringing a veritable fortune. It might be said, however, to its credit that *"like all other forms of mining mica has its crop of failures, but there is probably no other mineral which lends itself more to reduction of risks in the hands of a trained miner and no other which more quickly brings the usual reward of false economy"*.

"The native system of mining naturally gives quicker return and has the advantage of requiring a small outlay of capital, but the mine worked by the native method has a total life little longer than what would be considered merely the exploratory stage of a mine opened by recognised mining methods and the latter (working a deposit of similar richness) will commence an indefinite period of steady uniform returns when the former has reached its limit."[†]

The most economical system of working, in the light of the foregoing, should be a careful selection of a particular method, out of the recognised scientific systems of mining, modified, if necessary, on the basis of local conditions and environments.

FUTURE OF THE WORKED-OUT MINES

What has already been written explains that the future prospects of a mica mine entirely depends on development. The uncertain distribution of mica makes it very difficult for the ordinary mica miners to judge the chance of future productivity of a mine already exploited up to a considerable depth. The possibilities of a deposit can never be gauged even approximately, and the future is an ever-present problem, especially for small miners who cannot afford to spend for the proper development of the mine. The proper publicity of the speciality of the mica technique would serve to foster a co-operative spirit amongst the mica miners. The people should

* Thomas Holland : Memoir Geol. Surv. of India, Vol. XXXIV.

† *Ibid.*

realise that by their small individual resources the prospects of a mine are often ruined; mica mining inherently calls for sufficient working capital, good organisation and sound management.

As already stated, no general rules can be set up for guidance in regard to the future of a mine; experience has abundantly proved that, in the majority of cases, richer prospects have been found at greater depths. In both Bihar and Madras fields some of the worked-out and abandoned mica mines have yielded large productions to the new enterprising successor who re-opens the pits and works on recognised methods. The following observations of Mr. D. B. Starrett* would be very interesting on the point :—

“The majority of mica mines have been worked only to a depth of less than 100 feet and for a horizontal distance of only 100 to 200 yards along the line of the vein. In some cases, as was true with the famous *Clarissa mine*, they were abandoned with valuable deposits of mica still in sight, owing to the inability of the miners, with their crude methods (having no steam pumps), to contend with water flowing into the mines. In many other cases, where there was no great trouble from waters, mines have been abandoned at depths, where the vein began to be too hard to be worked easily with a pick, for the reason that there were still other softer deposits which could be worked at or near the surface.

“There can be but little doubt that in the case of a considerable number of these mines by the use of the steam pump, the steam drill and other modern mining appliances a number of old mines could be opened up anew and worked at considerable profit. And thus like the *Clarissa*, the *Sinkhole*, the *Hawk*, and the *Cloudland* in the Mitchel County, the *Ray Mine* of Yancey County, the *Burning Town Mine* of the Macon County, which together have yielded considerably more than a million dollars' worth of mica, being worked by crude mining methods, if opened anew under more favourable conditions would undoubtedly yield a supply of mica for many years to come as great or greater than that which they have yielded in the past.”

There are many mines in the Nellore mica field which are far from exhaustion, although production for the province as a whole has come down from a peak of 24,420 cwts. in 1906 to below or about 10,000 cwts. annually nowadays. This decrease in the output of mica, in the view of Mr. R. R.

* U. S. Mineral Resources : Mica in 1912.

Simpson*, the late Chief Inspector of Mines, is due to lack of enterprise. The majority of the known rich mines are far from exhaustion, but successful exploitation requires capital and application of modern mining methods.

Of course all mines may not be equally prospective, but many are. Unless a thorough survey is made, which in mica is extremely difficult, especially in view of the miserable condition in which most of the mines are worked and abandoned, the potentiality of each individual deposits known cannot be even roughly ascertained. I cannot do better than quote here the views of Sir Thomas Holland† :—

“Without calling the process by the abusive term ‘socialism’ and without extending the principle thereby to other industries, in which state interference may do more harm than good, it ought not to be beyond the ingenuity of a government to place mining, for certain purposes, in the category of public utility services with or without the acquisition of mineral rights by the State. The Industrial Commission in India received considerable evidence urging the advisability of State action in this direction but found it impracticable at the time to propose more than acquisition of rights over minerals which were essential for national purposes.”

The mining rules in India are much back-dated and should be thoroughly revised. I may refer here to the opinion of Mr. Oliver Bowles‡ in regard to the royalty on mica in the United States :

“The working of deposits on royalty basis for a set time has also been detrimental to intelligent development work, for the operator is inclined to work out rich pockets and leave the workings in a dangerous and unsatisfactory condition for future development”.

* *Trans. of Min. & Geol. Inst. of India, Vol. V, 1910.*

† *Proposed Review of the Mineral Resources of the Empire by Sir Thomas Holland: Proceedings, Empire Mining and Metallurgical Congress, 1928, Part I, pp. 73.*

‡ *U. S. Bureau of Mines, Information Circular No. 2357, p. 20.*

Chapter IV

THE MINING OF MICA

CRUDE MINING IN INDIA

Introduction of modern mining.—Modern mining by means of inclines and vertical shafts with efficient equipment for haulage and hoisting, including compressors, air drills, etc., has been successfully introduced by the pioneer resourceful firm of F. F. Chrestien & Co., in Bihar, and it has been followed up in several other Indian mines in the districts of Hazaribagh and Gaya in Bihar and Nellore in Madras. Mr. H. J. Sparks* of this firm is reported to have made the first great advance in this respect, having also shown the repetition of the lenticular form of pegmatites at depths.

It was in 1898 that systematic mica mining by means of shafts and cross-cuts was adopted for the first time in India by the Indian Mica Co., at Lalki near Bendi, under the direction of Mr. Mervyn Smith†.

Crude methods.—Mining is carried on in India in open quarries, or with tortuous shafts, zigzag inclines and tunnels or underground passages, etc. This often results in a great deal of damage to the crystals, sometimes to an irredeemable extent, and the mining is limited to near about the surface, the open quarries seldom going lower than 150 to 200 feet. Much of the labour employed is wasted and the working is most uneconomic.

Mining in Bihar.—The mining season here starts by about November and lasts till May, *i.e.*, practically during the months of the winter and early summer only. The area containing the bulk of the mica deposits in this province occurs close to the alluvial tract of the Gangetic valley and as such the labour for the mining has to be drawn generally from the agricultural class who remain busy with agriculture during the months of the monsoon (June or July to October). The suspension of the mining work during these months is due to the accumulation of water in the pits, scarcity of labour and the bad condition of roads for transport. Almost identical conditions prevail in the United States and Canada where the mica tracts lie close to agricultural areas.

Crude blasting.—Explosives were not known before or, even though known, the small miners could not afford to use

* Geol. Surv. of India Records, Vol. LII, 1921.

† Bibliography of Indian Geology by La Touche.

them. To loosen the rocks, the labourers light up large fires in the face of the rocks, pouring down water, which runs down cracks or fissures splitting up the rock; through these narrow cracks, iron wedges are driven, causing detachment of the rocky masses.

Crude method of hoisting.—For removal of rubbish or waste, the miners use primitive mechanical means, namely, a *hand-over-hand* method. Two rows of labourers, usually women, are arrayed in lines from the water level in the pit up to the pithead on the surface. Loaded pitchers or buckets with water and waste rocks are passed up “hand-to-hand” and in this way the topmost hand at the pithead in one row empties the contents of the carrier. The other set on a parallel row similarly passes back the empties down to the water level or the bottom of the pit. Rudely constructed double bamboo ladder or staircase serves as hoisting platforms for the rows of labourers so stationed.

On account of infiltration of water in the pit during the night, all sinking operations are usually delayed every morning by several hours while the draining out of water is in progress. The whole work remains almost completely suspended during the months of the monsoon.

The ancient mica miners.—The “Labenas” and “Mahajins”, two aboriginal tribes, were well known for mica mining in Bihar. The Labenas were very efficient professional prospectors of mica in the district of Hazaribagh. The Mahajins are also credited with excellent skill and traditional efficiency in the prospecting and mining of mica. These people had picks, shovels and spears as their only mining equipments, and their workings seldom exceeded 10 to 15 feet in depth. “Fire-setting” was their method of blasting. They possessed accurate information about the occurrences of valuable mica deposits in the different parts of the district and the high degree of their prospecting efficiency was proved by the discovery of some of the most important mica deposits and shoots towards the middle and close of the last century, following on the leads of the pits worked in the past by them.

The “Yenadis” of Nellore.—Mr. A. Krishnaiya, in his contribution to the Transactions of the Mining and Geological Institute of India (Vol. V, 1910), mentions another aboriginal tribe of Nellore called “Yenadis”, who were usually employed in that area for prospecting of mica deposits, during the pioneer days of mica mining in the district.

THE MODERN MINING METHODS

There are various methods of mining of minerals, metallic and non-metallic, which are adopted by miners, according to

the prevailing circumstances and the suitability of the different lines of mining. They have been classified as follows :—

- | | | | | | |
|--|-------------------------|--|-----|----------------------------------|-------------------------|
| (1) Open-cut with or without stripping. | { | (i) Benches. | and | { | (a) Hand sluicing. |
| | | (ii) Glory-holes | | | (b) Dredging. |
| | | (iii) Placer mining. | | | (c) Hydraulicking. |
| | | (i) Breast stoping (tabular, flat dipping deposits or beds). | | | (a) Continuous horizon. |
| | | (ii) Underhand stoping (veins and large masses). | | | (b) Casual pillars. |
| (2) Underground methods. | { | (iii) Overhand stoping (steep dipping veins or masses). | { | (a) Open stope | |
| | | | | (i) with pillars. | |
| | | | | (ii) with stulls. | |
| | | | | (iii) with square set timbering. | |
| | | | | (b) Filled stope. | |
| | | (i) Horizontal cut-and-fill cut-flat back. | | | |
| | | (ii) Inclined cut and fill (rill). | | | |
| | | (iii) Square set timbering. | | | |
| | | (iv) Rescue or stripping. | | | |
| | | (c) Shrinkage stope. | | | |
| (d) Sub-level stope. | | | | | |
| (iv) Top slicing (wide veins or masses). | (a) Continuous horizon. | | | | |
| (b) Panel slicing. | | | | | |
| (c) Block slicing. | | | | | |
| (d) Inclined slicing. | | | | | |
| (v) Caving (large masses). | { | (a) Sub-level caving. | | | |
| | | (b) Block caving | | | |
| | | (i) under-cut from main level. | | | |
| | | (ii) under-cut from sub-level. | | | |
| | | (iii) with chutes. | | | |
| (iv) with branch rails. | | | | | |
| (3) Combined methods (large masses). | { | (i) Alternate shrinkage stope and pillars; pillars mined by top slicing, sub-level caving or block caving. | | | |
| | | (ii) Square set timbering; pillars mined by slicing. | | | |

Of these, some are exclusively employed for the mining of metallic ore-bodies. Mica, it has already been explained, requires special methods of treatment, which is to be selected from these recognised methods according to suitability. Mica occurs in the rocks in a perfectly crystallised form and has to be recovered in whole crystals undamaged, where the book is found to be of economic value. The least damage to the books in the pegmatitic body may reduce their commercial value very considerably, sometimes even to an irredeemable extent. Of course, as in the United States, there may come a time in India when not only any low-grade mica-bodies will be worked, but even the deposits of micaceous schists will be exploited. The methods of mining which are now being followed in India are exclusively for the mining of sheet-yielding mica "books". The mica miners of the not distant future might have to include some of the other methods in the technique of mica mining, now left out of their consideration.

OPEN-CUT MINING OR OPEN QUARRYING

This is employed in case of mineral deposits, exposed as surface outcrops, but generally covered by heavy overburden. In order to reach the deposit below, this overburden has got to be removed. Open-cut working naturally has a short life and a stage is bound to come with the progress of work when it has to be replaced by *underground mining*. The *open-cut mining* is still the universal method of mining of mica in most of the mica-producing countries.

Small miners, after discovering a mica deposit, usually excavate a pit and extract the deposit found, continuing further exploitation only as long as the extraction of one crystal reveals the trace of another, without much trouble or expense, but as soon as they are confronted with infiltration of water into the pit, further progress is often considered difficult or unremunerative. The mines at this stage are generally abandoned in a miserable condition.

This is the simplest and cheapest method of mining yielding quick return at small investment, but besides being wasteful it often hinders future development of the mine, owing to the heavy heaps of debris accumulated alongside the mouth or walls of the worked-out pits. When small operations disclose good deposits, mechanical equipment is purchased where possible.

Open quarrying is generally justified in mica mining in view of the uncertainty and pockety nature of many deposits. Recovery of mineral deposits in scattered nests and clusters, sometimes separated by yards of useless material entailing heavy expense in shifting the latter by systematic methods of

mining, requires a good deal of investment which people of small means cannot individually afford.

Open trenching.—If the strike of the deposit occurs alongside a ridge, or has a direction normal to the direction of the ridge, the open-cut method supplemented by small tunnels is suitable. The pockety deposits of mica have a natural drainage, water sinking away by itself to lower levels. In deposits other than of a pockety nature, some effective method of drainage requires to be adopted. Sometimes such trenching extends to a pretty good length, even to thousands of feet. The disadvantages of *open quarrying* include, besides wasteful labour, free inflow of water, impracticability of continuing exploitation at greater depths and the difficulty of hoisting and hauling.

UNDERGROUND MINING BY STOPING

Stoping.—This term is applied to breaking the mineral body from the place of occurrence by means of drilling and blasting. The excavation in which the miners work is called a "stope". There are usually three styles of stoping: Breast stoping, Underhand stoping and Overhand stoping.

Breast stoping.—This is followed in case of thin deposits that are either horizontal or that dip at a small angle with the horizontal. Thickness of the deposits in this case would not ordinarily be over 10 to 12 feet; of course, there is no common rule; according to the special conditions the method of stoping is modified to suit beds sometimes as thick as 60 to 70 feet if not more. The whole deposit in entire thickness is gradually exploited at one time, advancing in a horizontal or breast fashion. Bench method is applied in case of thicker bodies. *Continuous horizon* is a term meaning a long working face, which is attacked simultaneously from several points. Breast stoping is sometimes suitably adopted in mica mining.

Underhand stoping.—This implies working from the top downwards. Holes for blasting are drilled downward. It is a common practice to mine underground in *levels*, fixed at intervals of about 100 feet vertically, the distance varying according to the nature and circumstances of the exploitable deposits. In these levels, the recovered mine-run, wastes or provisions are stored temporarily, to be disposed of according to needs and opportunities. Passages are provided horizontally along the vein, on the levels which are called "drifts". Single "drifts" are also called "levels" and the "drifts" driven across the vein from wall are called "cross-cuts". Raises, *i.e.*, vertical or inclined openings, are provided for inter-level connection. Such inter-level opening, when driven upward from a "level", is called a "raise" and when it is driven downward from a level it goes by the name of a "winze".

“Underhand stoping” with waste filling supports is sometimes very suitable in mica mining, particularly where the dip is not very great. The miner requires some “timber-set” as a working platform, to stope the mica from below him and advance longitudinally.

Overhand stoping.—The stopes in this process are advanced upwards, the mica-body being exploited in a horizontal, vertical or inclined fashion, in front of or above the miner. “Overhand stoping” combined with waste filling seems to be the most economic and suitable process for general mica mining in India. Stopping processes are adopted specially for exploiting steep-vein deposits. In “overhand stoping” the miner requires to handle the ore in front, before attacking the next lower one. It is a more economic and expeditious process than the “underhand”. Mr. Archibald Dickson, however, considers the “underhand stoping” to be more suitable, as in his opinion “overhand stoping”, with untrained labour, entails the risk of roof-falling. Since Mr. Dickson expressed this opinion, many years have passed, but accidents with “untrained labour working on overhand stoping” have not been frequent.

Mr. G. V. Hobson* pointed out the suitability of “overhand stoping” rather than “underhand”, for mining of mica in India and, in his opinion, open-cast mining is suitable for Bihar. In this connection the following observations of Mr. Oliver Bowles†, Mineral Technologist of the U. S. Bureau of Mines, would be very useful :—

“Every mine should have a definite plan having in view the operation covering a number of years. No mining industry can prosper when the surface of the deposits is merely scratched and then abandoned in favour of other outcrops which are treated in the same way. Proper planning for the future does not necessarily involve costly equipment. It demands that waste rock be so disposed that it will not interfere with future operations, that proper precautions be taken to avoid caving and that development proceed in a systematic way. A certain amount of timbering may be necessary, but in stoping it may be possible to have supporting pillars that will ensure safety for roof collapse. Provision should be made for disposal of water. Gasoline, electric or steam pump is not costly to maintain or operate. Many properties have been abandoned simply because no means were at hand for disposal of water. In all probability mica of better quality may be secured below the level of ground water than above, and this in itself should encourage deeper mining.

* Geol. Surv. of India Records, Vol. LXV, 1924.

† U. S. Bur. Mines, Rept. Inv. Serial No. 2357, pp. 25-26.

"The high percentage of water encountered in mica mining encourages the development of methods for the most economical disposal of waste. Where pegmatites approach a vertical attitude it seems possible to employ an overhand stoping method such as that followed in the slate mines in *Angers* in France and at *Monson* at Maine. This would involve that sinking of a deep shaft and projecting drifts to right and left on the vein. By overhand stoping the roof would then be brought down, the mica sorted from the rock and the latter left on the floor. Thus the floor would be constantly built up with waste and so would keep pace with the upward progress of stoping from the roof. The chief advantages of such methods are: (1) the great saving in hoisting and transportation occasioned by leaving the waste rock in the pit; (2) reduction in hazard for roof falls, the floor being at all times only a short distance below the roof; and (3) saving in timbering. It may be possible to use the method where the pegmatites dip 40° to 60° ."

UNDERGROUND MICA MINING

When mica mining is done by open quarrying at the surface no working plan is necessary as the operations are confined to the following up of the individual mica-bearing pegmatites.

Mining of vein deposits.—Generally in mining vein-like deposits with well-defined walls shafts are sunk almost invariably on the pegmatite (foot wall outcrops and the mica is then exploited. In case of prospecting deposits, drifts are run along the strike of the pegmatite at vertical intervals of 50 to 100 feet and mica is stoped out, sometimes with pillars left at suitable places as supports to the walls and roofs in the drifts. As the mining advances, the shaft is carried down, with "raises" and "winzes" between the levels (drifts) for hoisting.

Mica mining lower than 300 feet below the surface is not frequent outside India. There are, however, several well-planned muscovite mica mines in the United States, worked under the auspices of the General Electric Co., of Schenectady, N. Y., and Westinghouse Electric & Manufacturing Co., of East Pittsburg, Pa., on ideal lines.

Pocket deposits.—For "pockets" of mica, occurring scattered in chains or otherwise, no regular system can be planned in advance. This class of deposits has to be exploited on methods most suitable for the local conditions and characteristics of the particular deposit. The work requires an expert miner to do the best possible and so avoid extra expenditure, particularly in handling the rocks. An inclined central shaft,

located in the surface outcrop, facilitates hoisting of the output and waste. As the shaft is continued further down, drifts are run in different directions in search of further nests around.

IDEAL MUSCOVITE MICA MINING IN UNITED STATES

Extracts of description of some well-planned mica mines in the United States are given below. India and the United States are the two largest muscovite mica-producing countries and Indian miners can benefit by following the lines of working of mica mines in the United States. The Union of South Africa is also a muscovite mica producer and this country is moving well ahead in mica mining, though of course the potentiality of the Indian deposits is not excelled by any country in the world. It is a pity that mining of mica has not been possible in India on a large comprehensive scale, except a solitary exception in Bihar. The Government have not given this industry the backing it deserves, in spite of the most encouraging prospects of the deposits of mica.

The following is the description of the New York mica mines* in the Black Hills, South Dakota, which is said to be the largest of the Westinghouse mica mines :—

“The output comprises of sheets from 2 to 8 inches in diameter and from 1 inch to 5 inches thick although books up to a yard in diameter have been found. This mica occurs in a dyke 40 feet wide and dipping 50 feet. The mine is developed to a depth of 300 feet by means of a vertical shaft cutting the dyke between 100 and 200 feet levels and cross-cuts to the dyke at 100, 200, and 300 feet levels. Overhand stopes 6 feet wide between are carried upwards on the mica schists, both on the foot and on the hanging wall of the dyke. The ground stands well, requiring only an occasional stull as timbering. Holes about 7 feet deep were drilled and loaded lightly to minimise the injury to mica books when blasting. Mica and waste were sorted underground and the greater amount of waste was used as filling, a small portion only having to be hoisted. Separate chutes were provided in the stopes for the mica and the cars of mica on arrival at the surface were trammed to a trimming and grinding house. The White Star and Crown Mines were each developed by means of 100 feet shafts.”

This mine was equipped with electric light, electric hoist and compressed-air drills. The “run-of-mine” mica is estimated to constitute 66 per cent.* of the vein matter.

* Rept. Inv. Serial 2357.

The Alexandria Mine of the General Electric Co., at Alexandria, New Hampshire, is another well-planned mica mine, containing flat-lying deposits. This mine is worked sometimes on *room and pillar* method.

The Arnott Mica Mine in the Arnott County, Alabama, is a good example of a mine properly planned and developed for continuous operation. The pegmatite dyke dips about 40°. A shaft was sunk to a depth of 15 feet on the out crop. From the bottom of shaft, a 37 feet slope, a level tunnel 80 feet long connected with an open-cut on the side of a stream valley and thus permitted easy disposal of the waste and provided good route. At the foot of the slope, right and left, drifts were projected in the pegmatites. Similar drifts joining a second level were driven about half-way up the slope and a third pair forming an upper level near the top of the slope*.

OPEN-CUT MINING

The following is the description of the open-cut working of the French mine near Alsted, Cheshire County, N. H.† :—

“The working consists of a large open-cut 60 yards long, 30 to 40 yards wide and 20 to 60 feet deep, with smaller openings at the north and a shaft or pit 20 feet deeper than the bottom of the cut or 80 feet from the surface. Two steam drills are used in mining and derrick-pivots and an inclined truck is used to remove waste and mica from the pit.

“The country rock is mica gneiss with highly schistose layers. The gneiss strikes north to N. 30°E. and dips 60° to 80° S.E. The pegmatite occurs in a large mass cutting the gneiss. Two prominent ‘horses’ of schist extending nearly across the pit were left standing above the level of the adjoining floor. The area of the pegmatite is larger below ground than on the surface so that the walls of the cut show pegmatite below with mica schist or gneiss above.”

THE WINNING OF MICA

Drilling for minerals in general differs from that of mica, because of the fact that in drilling for mica the drillman has to see that the crystals of mica are not damaged in the least by drilling. Hand-drilling in general mining has been replaced almost everywhere by machine-drilling, but in mica hand-drilling is still a universal practice.

* Rept. Inv. Serial 2357.

† Bull. 580F. D. and B. Starett : Some Deposits of Mica in U. S. A., pp. 89-90.

Hand-drilling and machine-drilling.—The peculiar location in the rock matrix of the mica crystals, both in single “books” and in clusters, makes a certain position of the drill imperative, so that the fine mica sheets may be recovered intact and undamaged. Such a position of the drill can only be possible by hand- and not machine-drilling. Hand-drilling is therefore generally employed, specially in the regions where large sheet-yielding pegmatites occur. In the United States the percentage of large flawless sheet in the deposits is almost insignificant and the bulk of the mica is mined for grinding purposes. So to mine scrap mica, or some proportion of small sheet mica with care, machine-drilling is not only suitable but very economical. Except for the question of the successful recovery of sheet, power-drilling is far more efficient than hand-drilling. In countries like India and Madagascar, scrap and waste have little industrial use or marketing outlet. If, in the United States, the crystals of mica get damaged irredeemably in course of exploitation as sheets, the productions may go as commercial scrap, but in India the damaged crystals, however large or pure they may be, would become absolutely useless and thrown away into the dump heaps.

Drilling for sheet and scrap mica.—Thus there is difference in the proper economic method to be applied in drilling mica for sheets as well as scrap, especially for large-size flawless sheets, for there were formerly large and constant demand for large-size flawless mica sheets, which were sold at paying prices. Where, therefore, large-size sheet mica occurred, mining was very remunerative, even at additional cost, to recover as large sheets as possible. Quality was a greater consideration than quantity. Nowadays, however, demand consists mostly of small-size mica sheets from No. 4 down. Miners feel more inclined to secure a large output of mica from a pegmatite rather than the whole crystal intact in full available dimensions to yield large-size sheet mica; moreover, mining the latter requires a considerably higher expenditure than the former. In countries producing sheet mica, miners are now seriously considering the advisability of power-drills in place of hand-drills and the employment of power-drills is already growing popular. Largest output at the cheapest cost is now the motto of a mica miner against the best quality at highest economic cost of the former days. In India most of the miners still follow the conservative hand-drilling principles of mining.

Drillmen.—Practised and skilful drillmen can detect the touch of the mica by the drill, by the mere “feel” of it, instantaneously, due to the property of resilience in mica. Mica dust coming out of the sledge of the drill also indicates the touch of mica below the drill. It is always a prudent policy for the miner to employ expert drillmen, for an inexperienced

drillman does more harm than good and damages valuable crystals sometimes quite irredeemably at a tremendous loss to the miner. The probable loss for inefficient drilling in mica can be comprehended from the fact that a single "giant crystal" of mica sometimes fetches many thousands of rupees which, if vitally damaged in drilling, would become a lump of scrap mica of little use and of trifling value. It thus follows that the commercial value of sheet mica obtained by mining depends on the degree of perfection and freedom from flaws, quantity of the output being of secondary importance. The quality being unmarketably bad, quantity claims little consideration.

Method of hand-drilling.—Three-men drilling is the most satisfactory form of hand-drilling. It consists of one man holding the drill in position and two hammer-men striking at the drill with hammers. One-inch drill and 6- to 7-lb. hammers (preferably jack hammers) are employed.

Should the drill touch mica, the drill should be immediately stopped. A hole is then drilled at one side, as the front and back portions of the mica crystals are generally flawed and it does not vitally damage the sound portion of the crystal.

Power-drills.—Power-drills are now in wide use in the United States, where the mined output consists in the bulk, except a few instances of good sheet-producing mines, of scrappy and small-size sheets. These drills are run by portable boilers. Air-drills run from gasoline-driven compressors are the latest improvements. Portable units offer good working facility in the efficient prospecting and mining of small pits. Steam-drills are also coming into use in America.

Mr. Archibald Dickson favours the employment in India of air-drills, in preference to steam-drill, as the latter gives too much heat and vapour from the exhaust rendering it uncomfortable for the miners and drillers. Air compressors, besides their service in drilling, can be suitably employed for the purposes of ventilating and pumping as well; this would prove of good economy in underhand stoping.

Power-drilling with deep-hole blasting has given satisfactory results. Diamond-drilling, it may be noted, is not generally suited to mica mining as it often gives somewhat misleading indications.

Cost of drilling.—Mr. Oliver Bowles* writes that in the Canadian mines with one turner and two strikers about 15 feet of 1-inch hole could be drilled per day at a cost of 30 to 35 cents per foot in 1910. With steam or compressed air 40 to 50 feet were drilled per day at a cost ranging from 17 to 25 cents per foot. Some of the more progressive

* U. S. Bur. Mines Rept. Inv. Serial 2357.

operators now employ hammer drills for which compressed air is supplied by steam, gasoline or electric operated compressors.

Blasting.—Blasting is necessary where the rocks to be handled are hard. The degree of intensity of the blasting is a vital point for consideration. The aim of blasting is just to shatter the rock matrix in which the mica occurs, so as to facilitate the extraction of the mica by mere picking or, in case of valuable crystals, by hammer and chisel. The blasting must not damage the mica crystals. This is an important point particularly in case of large sheet-yielding deposits as in India.

A charge of 40 per cent. dynamite is the normal blasting explosive employed everywhere. Charging the "pop-holes", drilled 10 to 15 inches deep, with half a stick of dynamite is the usual practice. This blows a handful of rock, without any vital damage to the crystals. In America a kind of patent blasting powder is used. Firing is done by fuse and battery, fuse firing being more popular than the firing by battery.

It may also be noted here that the rocks enclosing muscovite deposits, such as in India, the United States, Brazil and the Union of South Africa, are generally softened by the kaolinisation of feldspar at depths even to 100 feet or more. Rocks in these areas can generally be handled by means of picks and shovels.

Lighting.—Formerly, in India, kerosene or similar oil lamps were used for mine-lighting. Apart from being very clumsy in handling, they do not sufficiently light the mines for careful working. The smoke and fumes of the lamp often produce a dangerous atmosphere and cause dizziness to miners in close underground workings.

This has now almost everywhere given place to candle light. Other modern forms of lighting the mines are :

- (a) Reflected daylight.
- (b) Special miner's lamps (*viz.*, safety lamps).
- (c) Gas lamp or gas lighting.
- (d) Electric lighting.

Torches and open lamps are also still used and the former is sometimes employed for special purposes.

Of all the above, electric lighting is undoubtedly the best and most economic for the *first-class mica mines*, working on the latest improved methods. All the required power in that case for the mining operations can be provided from the same source as for lighting.

HOISTING

Windlasses and hand-winches form the commonest means of hoisting, boom derricks being the improved form of hoisting equipment for the purpose of second and third class mines. For shallow workings the swinging-derrick hoist and for workings

at greater depths the drum-winch hoists are suitable. Hoisting by human labour is still used in many small mines.

Cable derricks and aerial ropeways.—These are the latest advanced forms of hoisting and hauling equipments adopted in several large and prospective mica mines in America. In India, although it would be very suitable, it has not been adopted anywhere; only large, well-financed mining companies can afford to go in for them.

Mica deposits in India are generally large sheet yielding and more persistent and they may be expected to give large profitable yields, if worked efficiently with modern methods and machinery on waste-saving economic lines. Small workings in mica in India are doing more incalculable harm than good from the wider national viewpoint.

HAULAGE

Carts and lorries are in use where roads exist or are specially constructed.

Ropeway haulage would be very economic and efficient, especially in hilly tracts not easily accessible from centres of transportation, but it is possible only for large commercial ventures.

POWER FOR TRACTION

Besides human or animal power, gravity, steam, water, compressed air or electricity are the usual kinds of power provided for general mining. Steam or electric power will always be the best for first-class mines.

Where wood fuel is abundantly available, steam power may be used. Improved types of light, portable, gasoline-driven compressors are replacing the other methods in America. In intermittent mining operations, as is usual in many third-class mines and small pits, steam or electric power is out of the question.

In Madras, which is situated far away from the Bengal and Hyderabad coal fields, coal is very costly and fuel becomes a difficult problem. Oil engines may, however, prove satisfactory and economic where electric installation is not practicable.

RECLAMATION OF MICA

Reclamation of mica to-day is an important factor in the domestic production of mica in the United States.

“Recovery of highly valuable mica* by the application of electrolytes as flocculating reagents has revolutionised the prospects of the mica mining industry in the United States. The utilisation of scrap mica has been a benefit to any mine as having afforded additional revenue, sufficient to justify the operation of properties which could not produce sheet mica alone. The market absorbs from 5,000 to

* Eng. and Min. Journ., Vol. 123, No. 23, June 1927.

9,000 tons of ground mica." This has come now to over 20,000 to 25,000 short tons.

It is the latest advancement in the technology of mica and is a most significant achievement from the economic point of view. Besides production of sheet and scrap by the usual processes of mining, very large quantities of mica are nowadays being reclaimed from micaceous rocks, such as mica schists, kaolinised granites, etc. In fact, production of reclaimed mica has of late vastly outstripped that of the sheet or scrap, the latter forming just a fractional proportion now in the total production of domestic mica in the United States.

In 1935 and 1936 the production of mica stood as follows :—

	(In short tons.)	
	1935.	1936.
1. Sheeting material	468	659
2. Waste or scrap	12,185	12,697
3. Reclaimed mica	6,667	8,258

The previous maximum figures are 1,238 tons sheets in 1910 and 9,695 tons scrap in 1925. Reclaimed mica has come to assume a definite importance in the official reports of production of mica from 1935 only. This will show the place reclaimed mica is now occupying in the United States mica industry.

The following description has been given of reclaiming mica in North Carolina by Mr. S. T. Henry in the "Engineering and Mining Journal" (Vol. 127, No. 16, 1929) :—

"Fine mica is being reclaimed by the Harris Clay Co. at Spruce Pine, N. C. The Harris Clay Co. is the only active producer of primary kaolin or china clay in the U. S. and conduct five operations in the Spruce Pine district. After the kaolin-bearing material is stripped, the hydraulic monitors are used to loosen the material which is then washed into flumes. In these it flows by gravity to simple wheel-type bucket sand washers. The deposit contains from 9 to 12 per cent. pure kaolin, the remainder consisting of white sand, particles of feldspar and finely divided mica. Washers remove all the pebbles and much of the sand. The kaolin is very finely divided and is lighter than other materials with which it occurs except mica. The latter is in larger particles than the clay, however, so that it has less buoyancy. In the treatment process, the kaolin also goes almost in complete suspension. These conditions render the first separation quite simple when properly conducted.

"Leaving the sand washers, the stream of water carries practically all of the kaolin, all of the mica and some of the fine sand in the deposit, and the latter is settled in

troughs immediately beyond the washers. The current of the water in the troughs and their length are such that the fine sand is completely precipitated in them while the kaolin continues to the dehydration plant. Fine mica also settles in the troughs after the stream leaves the washers. In the past the mica was washed with refuse sand. This was because no method of recovering at a cost that would show a profit had been developed. The product now obtained competes satisfactorily with fine mica produced by other methods.

“The first step in the separation of mica from the settlings in the troughs beyond the washers is accomplished with screens. The settled wastes containing the mica are hand-shovelled from the troughs into a vat the bottom of which slopes towards the four simple hand-operated wooden gates along one side. From each gate a 4-inch pipe leads to one of the four cylindrical screens. A 1-inch stream of water is used to facilitate the flow of the material in the vat. This set-up of washers, troughs, vats and screens is crude, simple and cheaply constructed. The 4-inch cylindrical screens to which the 4-inch pipes deliver the material from the vat are 4 feet in diameter and 5 feet long. They are set almost horizontal and are motor-driven at 30 r.p.m. The fine mica in the waste material is remarkably uniform as to the maximum size of its particles. About 90 per cent. of it will pass a 20-mesh and be retained on a 60-mesh screen. The proportion of sand carried over with mica is separated from the latter by a Deister overstream concentrating table. The mica delivered from the table is now practically 100 per cent. pure. From the concentrating table the mica is piped in suspension to a dehydrating plant. After simple settling in a wooden vat, the mica in sludge form is shovelled out by hand. An overhead carrier delivers the sludge to adjacent driers. Dried fine mica weighs less than 18 lb. a cubic foot and is very fluffy and has therefore to be handled with special care to avoid loss. Delivery of it to a nearby grading and packing building is accordingly made in an overhead little carrier. In the mica grading house, the dried mica can be elevated satisfactorily in closed chutes by bucket elevators, delivering to overhead bins. From the latter, the material flows by gravity through two sets of Rotex screens, made by the Orville Simplex Co. of Cincinnati, Ohio. These screens effectively separate the material into the two sized grades required by consumers. From the screens the mica flows by gravity to bagging machines. The character of the finished material may be partly judged from the fact that a 100-lb. mill-feed

sack will hold only 75 lb. of it, even when filled with a packing machine. The plant of the Harris Clay Co. in the Spruce Pine district, N. C., produces about 6 tons of fine mica per day at an average price of \$22.50 per ton. All of this is obtained as a by-product from the kaolin mining."

THE KHALAKTAMBI MICA MINE, KODARMA,
INDIA

This is one of the few well-developed mica mines in India and belongs to the Chrestien Mining Co., Ltd., of Domchanch. It is one of the original prospecting pits, worked by the contractors and developed later by the Company into a large steadily productive mine, at a considerable capital expenditure (*see illustration on p. 95*).

The mine has now attained to a vertical depth of about 400 feet* and is being worked at the 13th level with an average length of the strike of 250 feet, the width varying from 3 to 40 feet. From the 1st to the 7th level, the vein was comparatively poor and the strike only short. The mine was first worked by two incline shafts, followed by a vertical shaft, sunk to the 3rd level. At the 7th level, the strike shortened to a few feet only but after further sinking opened up until, on the 9th, the vein widened up to 50 feet in the centre of the lens, the length of the strike exceeding 300 feet.

The vein pinched out almost to total disappearance, after the 10th level. Stopping was resorted to from the roof of this level and, in course of stopping between the 8th and 9th levels, production is reported to have come up to 200 maunds per shift. The average production of rough mica in this mine was about 5 to 50 maunds per shift under development and 20 to 200 maunds per shift from stopes. During the stopping, further study revealed the prospect of a separate occurrence for which a cross-cut was started through the hanging-wall schist and a *stringer* (or *leader*) was in sight, at a distance of about 150 feet and, following this, a sinking was started and the vein was immediately opened up. After breaking through several layers of intrusive schist, a further development disclosed a deposit equally as large as the one then being stoped. This fresh working necessitated the sinking of a new vertical shaft, 350 feet deep.

The mining equipment consisted, besides the usual accessories, of one *Ingersoll-Rand "Carels" Diesel engine*, driving a *horizontal compressor*, supplying air to the *machine-drills* all over the mine, a *Robey Lighting Set* illuminating the surface and underground workings. Pumping and winding are managed with steam power.

* There are a few others at Mashnodi and elsewhere worked at about 500 feet.

Chapter V

THE ECONOMICS OF MICA AND THE PROBLEM OF WASTAGE

Wastage is the most important problem in the mining and manufacture of mica; in all the various stages of its treatment from the pit to the works of eventual industrial employment by the users, there is an enormous amount of wastage by way of cobbing waste, factory trimmings, splitting waste and rejections in finish. It has been explained that mica, to be fit for use in a particular line of application, requires to conform strictly to certain specifications. Possessing a unique combination of many useful properties, it has often to meet several requirements which are often of strictly exacting nature. Sometimes certain degrees of di-electric strength, thermal resistance, transparency, freedom from mineral stains or inclusions, flexibility and elasticity are specified; individual sheets possess varying properties in almost all the above requirements. Thus, in final test for application, a certain but considerable portion has to be rejected. Now, before the mica has come to the user, it has passed through sets of intermediary parties since it was disposed of by the original miner, who himself must have prepared it for marketing after a heavy wastage.

The following may be stated as the important stages where the bulk of the rejection is accounted for :—

- (i) In the cobbing shed in the mine or working pits: the rejections in the mine form the "*mine waste dumps*".
- (ii) In the miner's factory (*i.e.*, the issuing or cobbing shops in the mica factory). The rejections of the factory form the "*factory waste dumps*".
- (iii) In the mica factory of the intermediary dealers and manufacturers, who buy raw mica from the miners. In this case also the rejections form "*factory waste dumps*".

- (iv) In the works of the industrial manufacturers or electrical firms where the mica is actually employed in appliances, etc.

Mine waste (cobbing in the mine).—The *mine-run* or *run-of-mine* mica, as brought from underground to the godown, is issued to cutters, who roughly treat it to make it free from foreign inclusions, adhering dirt and useless portions by hammering, thumb-trimming and rough-dressing by means of sickle or knife. The resultant output is known in the trade as *rough mica*. The usual “mine-run” of America greatly differs from the “rough mica” of the Indian mines, the former being subject in final dressing to greater proportion of rejections than the latter. The rejections in the mines or mining sheds accumulate into *dump heaps*.

Proportion of “R.M.” and “S.D.B.” mica to total rock.—The rough-dressed mica, known in trade as *rough mica*, does not usually amount to more than 5 per cent. of the total *run-of-mine*, brought out into the mine’s godown, the rest representing waste or scrap. One per cent. is taken as the general average of “R.M.”, calculated on the gross quantity of the rock handled in exploitation. The “cut mica”, dressed by sickle, called “S.D.B.” mica, is estimated at an average of 1/5,000 to 1/10,000, *i.e.*, one-fiftieth to one-hundredth per cent. of the gross rock mass handled (pegmatitic contents). The variation depends on the extent of richness or otherwise of the deposits, which greatly differs in different formations and localities. In making safe estimates, the latter percentage is considered a more reliable approach. Occasionally this exceeds beyond the normal calculations in exceptionally prospective deposits.

Mica content of pegmatite and percentage of commercial yield in India.—Mr. R. R. Simpson*, the late Chief Inspector of Mines in India, states that the average mica content of the workable portions of pegmatites vary greatly in India, from 3 to 10 per cent. with an average of 6 per cent. of the total rock excavated.

This was perhaps based on Dr. Cyril Fox’s report on the Jorasemar workings.

Mr. F. Dixon puts the mica content at 1/8 of the vein matter in some of the mine productions in India, one-half of which comes to the surface as *rough mica*.

The following data from Dr. C. S. Fox’s records represent the percentage of the various sizes obtained by sorting a

* Indian Mines Manual, 1929.

month's supply, about 400 maunds of cut ("S.D.B.") mica at Jorasemar :—

Quality. Size.	Clear.	Slightly Stained.	Fair Stained.	Stained.	Waste.
Specials ..	<i>Nil</i>	0.005	0.010	0.005	0.100
No. 1 ..	0.015	0.040	0.020	0.045	0.150
No. 2 ..	0.035	0.090	0.055	0.200	0.150
No. 3 ..	0.080	0.160	1.000	0.260	0.250
No. 4 ..	0.380	0.800	0.480	1.380	0.300
No. 5 ..	1.100	2.000	0.900	6.000	0.650
No. 5½ ..	0.640	1.300	0.020	4.200	0.350
No. 6 ..	1.600	4.700	0.200	65.500	1.050
Rough films ..	Total	4.000		Total waste	3.000
S.D. films ..	Total	4.680			

The above figures may therefore be taken as representing a true practical test, so that for every 100 maunds of cut, unsorted mica only 88 maunds were shipped as block (S.D.B.) and some 8½ maunds were available as films for local sale. This 100 maunds of cut mica represents the cutting of 500 maunds of rough mica. For every two maunds of rough mica brought to the godown nearly one maund is discarded in picking while making up the bundles at the mine; 750 maunds of mined mica, therefore, give 100 maunds of cut, unsorted mica.

A yield of 10 to 15 per cent. of "S.D.B." mica (*i.e.*, *cut mica* of the American trade) at an average of the total "mine-run" issued for dressing is a general estimate*. At Jorasemar this came up to about 20 per cent., as will be evident from the above data. In the course of a working period of about 17 months (from January 1918 to May 1919), 6,363 maunds of rough mica were produced yielding 1,236 maunds of "S.D.B." mica, which works approximately to 20 per cent., or every 50 maunds of rough mica yielded approximately 10 maunds of "S.D.B.". This was a very good working result and speaks well of the mining operations at Jorasemar, specially considering the urgent circumstances of the working and the wretched conditions in which the mines had been worked and left by the previous miners (the "Bhavans" of Mashnodi).

In exceptional deposits worked up efficiently, the figures may come up in India to even 25 per cent. Schaller cited the case

* Widest veins do not necessarily contain the largest blocks and usually not more than 10 to 15 per cent. of that mined can be *cut into plates*, the next being classed as *scrap mica*.—Economic Geology by H. Ries, 1937, p. 364.

of an Indian mica mine and stated that a pegmatite dyke of 40 feet thick, worked with modern methods in 1900 for more than 300 feet, yielded 40 lb. of "mine-run" or 10 lb. of trimmed mica for each ton of pegmatite rocks removed. The "mine-run" did not include waste mica.

THE GOVERNMENT MICA MINING AT JORASEMAR

During the Great War (1914), when a shortage of mica was experienced for munition purposes, the British Government urgently required increased supply of Indian mica. By a Government Notification No. 1752, dated 20th December, 1917, the Governor-General in Council called on all owners and persons in charge of mica mines and deposits of mica situated in Gadi Mashnodi, Tauzi No. 32, Pargana Kharagdiha, district Hazaribagh, to place at his disposal all mica mines and deposits of mica owned by them or under their control within the area, and all buildings, works and plants connected therewith. Mashnodi Gadi is an area of 45 square miles lying 14 miles N.E. of Kodarma and contains the main areas in which marketable mica is won from the mines, namely (1) Dhab, (2) Kobrabut and (3) Jorasemar, the last being the smallest but perhaps the best muscovite mica area.

Ghutiya was the biggest mine, but when Government took it over it was found almost ruined by irresponsible mining.

Mica was found to occur always associated with mica schist and invariably with pegmatites traversing the mica schist.

The mica mining operations at Jorasemar by the Geological Survey of India on behalf of the Ministry of Munitions, London.

(1918-1919.)

The following working report by Dr. Cyril S. Fox has been taken by permission from the Records of the Geological Survey of India, Vol. LXIV (1930). Dr. Cyril S. Fox of the Geological Survey of India was placed in charge of the operations :—

The prevailing rocks at Jorasemar are varieties of mica schist in a narrow strip which terminates about $1\frac{1}{2}$ miles to the east of Jorasemar camp. The mica schist band is about a mile broad from north to south at the camp itself and trends away westward to join the large area of mica schists in the Government Reserve Forest north of Kodarma. At Jorasemar the mica schists appear to lie in a synclinal fold of the gneisses of Bihar. The foliation strike of both gneisses and mica schists is invariably E.-W. The foliation dips are usually very steep (frequently vertical), in some exposures northward and in

others to the south. Local variations in strike and dip are by no means uncommon—anticlinal pitching folds, evidences of puckering and apparent thrust-faulting in miniature being often observed at various places.

The pegmatites of Jorasemar have been found to be exceedingly erratic both in continuity and shape. They have, however, one common feature, and this is that, though keeping a rough parallelism with the foliation planes of the enclosing mica schists, they pitch or plunge down, at a slant to the dip of the foliation plane, in a direction always towards the west, *i.e.*, away from the point where the schists themselves pinch out. None of these pegmatites has a greater thickness than 15 feet, and of those which have been worked to any considerable extent, few continue more than 100 feet without change in strike, dip, thickness or in the richness or quality of their mica-bearing contents.

The area contains many pegmatites, some worthless from a mining point of view, others remarkably prolific in certain portions of the pegmatite. Some of the large pegmatites are clearly associated with lines of faulting and special buckling of the schists, the faulting being shown by slicken-sided surfaces. The faults appear to have been formed before the larger mica crystals had developed, for the crystals, though at times badly buckled and cleaved, could not have survived the intense contortion to which the schists owe their origin without complete destruction from a marketable standpoint.

It was hardly possible to say from day to day how a working was going to turn out in the next three or four days, and this state of uncertainty continued to the day of closing down the mines. Out of at least 100 places, which were either taken over from petty contractors, or reopened from a disused condition, or started from new ventures, only five showed comparative steadiness for any length of time from the day they were put in working order.

As most of the pegmatites were of no great size, in nearly all cases each working place required its own entrance and separate arrangements for hoisting and pumping. In the larger pegmatites, the shape and position of the rich mica-bearing portion were usually found to be so disposed that it was difficult to arrange for more than three or four working places.

The production of large quantities of mica, other things being equal, depends entirely on the number of productive working places. If the development has to be done on numerous small pegmatites, as detailed above, then working costs will be greater than those of the exploitation of an equal number of working faces in a single large pegmatite.

At Jorasemar the production simply depended on finding and opening up more and more working places. As labour

became available the output steadily rose and the maximum output* would have been reached when every possible workable pegmatite had been opened or when the maximum permissible expenditure was being incurred. Practically no machinery was found necessary other than that worked by hand. Buckets and hand-pumps were found sufficient in dealing with the small quantities of water that accumulated in the workings. Shear-legs, a swinging derrick, a capstan, three crab winches and a few single-sheave pulley-blocks comprised the most complicated forms of hoisting apparatus necessary for these simple mines.

In proportion to the development work, somewhat large quantities of explosives were used. Small and frequent charges of 40 per cent. dynamite were utilised in loosening the matrix in which the larger crystals of mica were embedded. These "shots" were so fired as to leave the mica undamaged and yet save the laborious chiselling that would otherwise have been necessary to get out the "books" intact. Candles were exclusively used for lighting. There was also a heavy wear on the drills owing to the practice of prizing up rock loosened by "shots", breakages became so frequent that a portable forge had to be placed near the distant workings and the sirdar warned that crowbars were to be used in place of chisels. Timbering was occasionally necessary in the mines, especially when working in the neighbourhood of slicken-side surfaces. The mouths of many of the shafts were safe if thatched shelters were built over them to prevent rain beating in.

The rough books of mica were split or cleaved into thick plates at the mines and the worthless pieces thrown away. After handpicking, the plates were tied into bundles of about 50 lb. weight each and carried to the godown where they were weighed and stored, the bundles of large mica being kept separate from the small or *ruddi* bundles.

Each morning *rough mica* was issued to the cutters for sickle-trimming. Useless pieces were cut away, flaws removed and rough-dressed plates of block mica obtained. On an average 100 cutters, of varying degrees of efficiency, were able to deal with 50 maunds of Jorasemar mica and produce 10 maunds of sickle-dressed ruby (S.D.B.) mica. The waste is, therefore, nearly 80 per cent. of the cut mica which is considered a very good performance; the average of the district varied from 10 to 14 per cent.

The cost of cutting varies. Good cutters or sickle-dressers get as much as nine to ten annas a day, while women, working

* Dr. Fox succeeded in bringing up the output of the mines from about 1½ tons per month to nearly 7 tons. Records of the Geol. Surv. India, Vol. LI (1919).

less efficiently, earn three to four annas daily. The average cost at a rate of six annas works out to about Rs. 4 per maund of *cut mica* obtained.

The average mica content of the workable portions of pegmatites varies greatly from 3 to 10 per cent. with an average of about 6 per cent. in the total rock excavated; this works out to less than 1 per cent. of *cut or marketable mica* from the rock excavated. It would represent a very low grade ore in a metal ore mining proposition. Unlike the mining of other minerals where every particle of the substance is valuable *it is the quality as well as the size of the product mined which is of importance in mica mining.* The objective is to produce the largest possible quantity of clear sound mica. It should be free from flaws, cracks or other deleterious defects and in as large pieces as possible. Frequently large 'books' of mica are obtained, 1 foot to 2 feet across, out of which it is perhaps impossible to get a single piece of stained No. 6, owing to the heavily stained, flawed and buckled condition of the plates, or due to *jatai* by which is meant an interlocking of cleavage plates so that the laminæ are stuck together and do not easily come off or split into the clean-surfaced thin sheets known as splittings.

From the *sizers*, 8 of whom can easily handle 10 maunds of *cut mica* per day, the sized mica is passed to the *graders*. Twenty *graders* should deal with 10 maunds of *sized mica* in a day. In the process of separating out the various qualities small cracks or flaws or a film or two have frequently to be removed from the mica plates. There is thus a slight loss in waste and the production of some films. Nine maunds of mica worth shipping, out of 10 maunds, was the proportion obtained at Jorasemar with $\frac{1}{2}$ maund S. D. films and $\frac{1}{2}$ maund of waste.

In the majority of cases biotite is also present in association with muscovite-bearing pegmatites. This black mica, however, is not at present utilised; it contains a larger percentage of FeO (16 per cent.) but less H₂O (2 per cent.) than muscovite. The other associate minerals in a mica-bearing pegmatite are massive triangular quartz, coarse aggregates of orthoclase (microcline), feldspar, tourmaline, garnet (common iron), apatite and beryl. In certain cases semarskite (*Sankara mica mine*), pitchblende and monazite have been found (*Abraki Pahar, Gaya*). The degree of coarseness in the texture of the pegmatitic constituents indicates quiescent conditions suitable for slow crystallisation. The pegmatites stand in striking contrast with the mica schists and gneisses in which they occur. These rocks are nothing like so coarse-textured; their minerals are orientated parallel to the foliation planes and there is abundant evidence of buckling, puckering and crushing. The most careful

scrutiny fails to discover any thermal metamorphism at the contact between the pegmatite and the enclosing schists. In some cases the pegmatites are known to form simple lenses in the schists entirely unconnected with any larger mass of pegmatite. Many of the larger pegmatites have been proved to have no connection, other than perhaps the plane of a fault, with any other pegmatites and certainly with no granitic intrusion in the immediate vicinity.

From the above-mentioned facts and data it is evident that in the majority of cases the mica-bearing pegmatites of Jorasemar are not, primarily, of igneous origin. The field evidence points to these lenticular masses of coarse-textured granitoid rock as being the re-crystallised products of the mica schists themselves. The digestion and re-crystallisation, however, has been localised to certain particular parts of the metamorphic schists. Careful investigation at Jorasemar appeared to indicate that such re-crystallisation was best developed in the arches and troughs of folds in certain fault zones where great crushing took place, or at places where, although no appreciable dynamic forces developed, the static pressures must have been very large. In these circumstances one is led to the possibility that many of the pegmatites of the mica schists of Bihar and Madras are a large scale representation of the phenomena, carried to completion, so evident in the "spotted slates, which so often mark the beginning of change in argillaceous sediments since in these we see the process arrested at an early stage".*

COST OF PRODUCTION AT JORASEMAR

The average cost of production in this (Jorasemar) area might be taken to vary according to the richness of the deposits, the proportion of higher grades and qualities and the degree of efficiency in management, between Rs. 16 to Rs. 5 per maund of *rough mica*, obtained from the mine, including all overhead expenses, mining costs, etc. The average may be taken at Rs. 10 to Rs. 15 per maund, or to be more conservative at Rs. 20 per maund, on the *rough mica (beema)* delivered at the godown. Now estimating the "S.D.B." yield of the *rough mica* at 20 per cent., one maund of "S.D.B." mica would cost approximately Rs. 100 to Rs. 105 per maund. It must, of course, be borne in mind that the higher or lower proportions of higher gradings and qualities in the yield of a mine influences the mining cost a good deal. The production of by-product or associate minerals and the marketing of mica waste and scrap including *dump* or dump-recovered splittings, provide additional economic advantages in reducing the

* Harker : "Natural History of Rocks", p. lxxi.

overhead expenses of the mining. The cost of mining *rough mica* may be estimated normally to vary between Rs. 5 to Rs. 10 per maund, the miner being advised to base his calculations on the latter rather than the former limit.

Mr. Hugh S. de Schmidt*, it may be noted, has recorded the mining cost in one phlogopite mine in Canada at approximately \$179 per ton of thumb-trimmed mica in sizes 1 inch to 7 inches and upwards for the year 1904.

WASTAGE AND COMMERCIAL YIELD IN THE UNITED STATES

Mica content in pegmatites and percentage of commercial yield.—10 to 15 per cent.† of the mica mined can be cut to sheets, the rest representing waste or scrap mica. The average of cut sheets ready for trade from "run-of-mine" mica is about 17 per cent. in New Hampshire, 10 per cent. for South Dakota, and about 6 per cent. for Virginia and North Carolina. The average yield‡ for the United States is about 11 per cent., the limits being 2 per cent. and 33 per cent.‡

The eastern mica deposits in the United States are more prolific in the proportion of sheets than the western States. From some of the latter, *viz.*, California and New Mexico, the yield of cut sheet hardly exceeds even 2 to 3 per cent. The average of the United States as calculated on the total production is 7 per cent.

The amount of mica in the dyke varies from 1 to 10 per cent. of the mined output. The cut sheets seldom exceed 10 to 15 per cent., the rest being rejections. In selected cases, however, the proportion of cut sheets may go up even 30 to 40 per cent. of the trimmed sheets amounting occasionally even up to 75 per cent. in exceptionally prospective deposits. Sometimes, on the other hand, no commercial sheets may be found from certain portions of the pegmatite. Such disproportions may take place even within the space of a few feet. Scrap constitutes 75 to 90 per cent. of the mined mica, formerly thrown away and now used in the form of ground mica‡.

The following represents the analysis of productions of a New Hampshire mica mine§, showing the net yield of finished mica sheets and the total scrap mica out of a "mine-run" lot.

* Mica by Hugh S. de Schmidt, Second Edition, 1912, p. 14.

† U. S. Mineral Resources : Mica in 1904.

‡ U. S. Mineral Resources : Mica in 1906.

§ Mineral Industry, 1916, p. 507.

1,000 lb. "mine-run" lot

(going to rifters, each rifter handling 200 lb. per day).

1. This yielded—
 - (a) 400 lb. thumb-trimmed plate, going to cutters.
 - (b) 50 lb. $2\frac{3}{4}$ -inch washer stock, going to washer cutters.
 - (c) 60 lb. $1\frac{3}{4}$ -inch washer stock, going to washer cutters.
 - (d) 370 lb. $\frac{3}{4}$ -inch washer stock, going to washer cutters.
 - (e) 120 lb. waste, going to grinding.

1,000 lb.
2. 400 lb. thumb-trimmed plates yielded—
 - (a) 80 lb. uncleaned stone mica, going to cleaners.
 - (b) 220 lb. waste, going to grinding.
 - (c) 100 lb. electric quality plates, going to cleaners.

400 lb.
3. 50 lb. $2\frac{3}{4}$ -inch washers yielded—
 - (a) 40 lb. uncleaned washers, going to washer sorters.
 - (b) 10 lb. waste, going to grinding.

50 lb.
4. 60 lb. $1\frac{3}{4}$ -inch washers yielded—
 - (a) 45 lb. uncleaned washers, going to washer sorters.
 - (b) 15 lb. waste, going to grinders.

60 lb.
5. 370 lb. $\frac{3}{4}$ -inch washers yielded—
 - (a) 92 lb. uncleaned washers, going to washer sorters.
 - (b) 278 lb. waste, going to grinding.

370 lb.
6. 120 lb. waste yielded—
 - 2 a. 80 lb. uncleaned stone mica yielded—
 - (i) 60 lb. *finished stoves* at \$1.50 per lb.
 - (ii) 20 lb. thin split, which going to tube makers yielded finally 1,500 tubes at \$10.00 per thousand, and 5 lb. waste, going to grinding.
 - 2 c. 100 lb. electric quality plates yielded—
 - (i) 75 lb. *electric finished plates* at 50 cents per lb.
 - (ii) 20 lb. thin splits, going to tube makers yielding finally 1,500 tubes at \$10.00 per 1,000 and 5 lb. waste, going to grinding.
 - (iii) 5 lb. waste going to grinding.
 - 3 a. 40 lb. uncleaned washers yielded—
 - (i) 30 lb. *plate finished washers* at 40 cents per lb.
 - (ii) 10 lb. waste, going to grinding.

- 4 a. 45 lb. uncleaned washers yielded—
 (i) 35 lb. washers at 30 cents per lb.
 (ii) 10 lb. waste, going to grinding.
- 5 a. 92 lb. uncleaned washers yielded—
 (i) 65 lb. washers, going to core department making
 650 cores at 10 cents per lb.
 (ii) 27 lb. waste, going to grinding.

Waste account.

lb.		lb.	
1 (e)	.. 120	2 c (ii)	.. 5
2 (b)	.. 220	2 c (iii)	.. 5
3 (b)	.. 10	3 a (ii)	.. 10
4 (b)	.. 15	4 a (ii)	.. 10
5 (b)	.. 278	5 a (ii)	.. 27
2 a (ii)	.. 5		
			705

All the wastes in the above processes, viz., 1(e), 2(b), 3(b), 4(b), 5(b), 2 a(ii); 2 c(iii), 3 a(ii), 4 a(ii) and 5 a(ii) amount to 705 pounds. Out of this 23 lb. accounted for shrinkage in entire process and the balance 682 lb. made—

		\$
28 lb. ground	200-160 mesh at 2½ cents per lb.	= 0.63
56 " "	160-120 " " 2 " " "	= 1.12
70 " "	120-80 " " 1¾ " " "	= 1.22
105 " "	80-40 " " 1½ " " "	= 1.57
423 " "	40-10 " " 1½ " " "	= 5.34
682	Value of waste product =	9.88

The finished materials fetched in value the following:—

		\$
2 a (i)	60 lb. finished stoves at \$1.50 per lb.	= 90.00
2 a (ii)	1,500 tubes at \$10.00 per thousand	= 15.00
2 c (i)	75 lb. electric finished plates at 50 cents per thousand	= 37.50
2 c (ii)	1,500 tubes at \$10.00 per thousand	= 15.00
3 a (i)	30 lb. plate finished washers at 40 cents per lb.	= 12.00
4 a (i)	35 lb. washers at 30 cents per lb.	= 10.50
5 a (i)	650 cores at 10 cents per lb.	= 65.00
	Value of sheet products =	245.00

Total value fetched by the finished product of the entire lot = \$ 254.88

The waste in this lot thus amounted altogether to over 70 per cent.

The following working results of another lot of "mine-run" mica of a North Carolina mine, given by W. T. Schaller*, contain a rough detailed idea of the net quantity of finished mica sheets :—

Yield of the various sizes :—

	Inches.	Per cent.	Per cent.
Uncut	1½ × 2 ..	3	<i>i.e.</i> 33.3 on total "uncut".
"	2 × 2 ..	2	" 22.2 " " "
"	2 × 3 ..	2	" 22.2 " " "
"	3 × 3 ..	1	" 11.1 " " "
"	larger ..	1	" 11.1 " " "
		9	
Uncut punch mica	..	26	
Waste or scrap	..	65	
		100	

The 26 per cent. of "punches" yielded 8 per cent. of "cut" washers.

These 9 per cent. sheets yielded only 3 per cent. manufactured articles in actual employment—

Condenser plates	.. 1.2	<i>i.e.</i> 40	per cent. of the finished articles.
Used for electric purposes	1.2	" 36.6	" "
Used in oven or as heat resisting medium	.. 0.4	" 13.3	" "
Used as diaphragm mica in phonograph sound box	.. 0.1	" 3.3	" "
Made into splittings	.. 0.2	" 6.6	" "
		3	about 100 " "

* U. S. Year Book Mineral Resources, 1918.

Thus the total wastage on the above lot of "mine-run" mica 100 per cent. amounted to as under :—

	Per cent.
(a) In the cobbing and trimming processes	65
(b) In the final dressing into the various sizes in the mica factory ..	6
(c) In punching wastage out of the 26 per cent. uncut punch	18
	<hr/>
Total wastage	89

Thus of the entire lot of "mine-run" 100 per cent. only 3 per cent. manufactured mica and 8 per cent. cut washers could be obtained, the balance 89 per cent. constituting the total wastage.

COST AND RECOVERY OF MICA

Mr. Horton* has published the following detailed analysis of the working results of two mica mines in Spruce Pine, North Carolina :—

Mine No. 10

Analysis of mining operations

(Mine producing mica and feldspar)

Rock and spar mined and hoisted ..	tons	13,655
Rock mined and back-filled ..	"	800
		<hr/>
Total rock and spar mined ..	"	14,455
		<hr/>
Shots fired		5,113
Holes drilled, total length ..	feet	25,565
Per ton of rock broken ..	"	1.75
Dynamite used (40 per cent.) ..	pounds	9,932
Average charge per hole ..	"	1.94
Rock broken per pound of dynamite ..	tons	1.4
Block mica recovered (not including mine scrap) ..	"	276
Recovered per ton of rock ..	pounds	38

*U. S. Bureau of Mines Inf. Cir. 6822 (1935), pp. 17 to 19; Inf. Cir. 6616 (1932), p. 16.

Analysis of production

(i) : (Clear mica)

Size, inches.	Pounds.	Total value. \$	Value per \$
8 × 10 ..	100		
6 × 8 ..	189		
4 × 6 ..	690		
3 × 5 ..	880		
3 × 4 ..	659		
3 × 3 ..	799		
2 × 3 ..	1,886		
2 × 2 ..	1,120		
1½ × 2 ..	1,068		
Total clear mica	7,391	10,077-31	1-35

(ii) : (Electrical mica)

Size, inches.	Pounds.	Total value. \$	Value per \$
8 × 10 ..	373		
6 × 8 ..	941		
4 × 6 ..	3,577		
3 × 5 ..	3,888		
3 × 4 ..	2,721		
2 × 3 ..	5,602		
2 × 2 ..	14,285		
Total electrical mica	33,681	28,588-30	0-85
Total sheet mica	41,072	38,665-61	0-94
Punch mica	156,238	7,761-85	0-05
Factory scrap mica	354,776	3,547-76	0-01
Total block mica	552,086	49,975-22	0-0905
Value of mine scrap, mica and feldspar	..	6,987-14	..
Total value recovered	..	56,762-32	..

(iii) : (Costs)

	Total	Per ton of rock mined. \$	Per lb. of block mica recovered. \$
Mining labour	24,455-34	1-692	0-0443
Mining supplies incl. fuel	9,455-87	0-654	0-0171
Sheeting costs	5,854-81	0-405	0-0106
Total cost of mining and sheeting	38,766-02	2-751	0-0720

Handbook of Mica

Mine No. 21
Analysis of mining operation
(Producing mica only)

Rock mined and hoisted	.. tons	4,530.00
Holes drilled, total length	.. feet	9,290
Per ton of rock broken	.. "	2.05
Shots fired	.. "	2,066
Dynamite used (40 per cent.)	.. pounds	3,814
Average charge per hole	.. "	1.84
Rock broken per pound of dynamite	tons	1.2
Block mica recovered	.. "	107
Recovered per ton of rock	.. pounds	47

Analysis of production
(i) : (Clear mica)

Size, inches.	Pounds.	Total value. \$	Value per pound. \$
4 × 6 ..	18		
3 × 5 ..	95		
3 × 4 ..	137		
3 × 3 ..	343		
2 × 3 ..	1,702		
2 × 2 ..	1,641		
1½ × 2 ..	8,946		
Total clear mica	12,882	5,391.60	0.42
(ii) : (Electrical mica)			
3 × 5 ..	6		
3 × 4 ..	12		
3 × 3 ..	27		
2 × 3 ..	185		
2 × 2 ..	447		
Total electrical mica	677	251.80	0.365
Total sheet mica	13,559	5,643.40	0.417
Punch mica	106,849	5,344.95	0.05
Scrap mica	93,833	562.92	0.006
Total block mica	214,241	11,551.34	0.539

(iii) : (Costs)

	Total \$	Per ton of rock mined. \$	Per ton of block mined. \$
Mining labour	6,519.07	1.439	0.0304
Mining supplies incl. fuel	1,673.05	0.424	0.0778
Sheeting costs	1,922.90	0.369	0.0090
Total cost of mining	10,115.02	2.232	0.0472

Mr. Horton makes the following pertinent observation on the above analysis :—

“The mining costs given above are high and plainly indicate the need of more efficient mining methods. It must be remembered, however, that there seems to be no way to prove mica values in advance of mining and that the initial investment required for the installation of machinery for low operating cost is not warranted except in unusual instances. Investment in more efficient equipment might be justified if a group of mines were operated which could be worked out one after the other and if each individual pegmatite were mined rapidly. * * * *
The wide difference in production costs, yields and the grades and classifications of mica recovered at these two mines are characteristic of mica mining the world over.”

The cost of mining mica in mine No. 10 has been \$2.346 per ton of rock and \$0.0614 per lb. of mica, which with manufacturing expenses (*i.e.*, sheeting cost) amounted to \$2.751 per ton of rock and \$0.0720 per lb. of mica. This gives feldspar as saleable by-product. In mine No. 21, the costs have been \$1.808 per ton of rock and \$0.0382 per lb. of mica and taking the manufacturing of sheets into account, the cost of mica sheets per lb. has come to \$0.472 per lb. It will be seen that although mine No. 10 produced feldspar as by-product, the cost has been much higher than that of mine No. 21, owing to the fact that mine No. 21 yielded 95 per cent. of clear mica and 5 per cent. of stained against 18 per cent. only of clear and 82 per cent of stained mica in mine No. 10. In mine No. 10, it may be further noted, 24 per cent. of sheet mica was in the 3 by 5 inches and larger dimensions against only 1 per cent. of similar dimensions in mine No. 21. As a result of this, the final cost of prepared sheet mica in mine No. 10 was as high as \$181 per ton against \$108 only per ton for that of mine No. 21.

From this analysis and the general working experience of mica mines everywhere, it is established that the low working cost of a mica mine depends on the following principal factors :—

- (i) The proportion of fine to low-grade mica.
- (ii) The proportion of large to small size productions.
- (iii) The existence of a saleable by-product mineral.
- (iv) Employment of efficient mining methods with all waste-saving appliances.

Now in developing a mica mine on the best working method, a heavy expenditure is not always possible or advisable, in view of the uncertainty of the leads and productivity of

the deposits as well as the difficulty, if not impossibility, of determining the quality and extent of the expected yield. It can only be arranged for in **group management**, with several mines under one working unit.

THE PROPORTION OF MINED SHEETS AND ROCK IN DIFFERENT COUNTRIES

Canada.—Mr. Hugh de Schmidt* states that the “run-of-mine” brought up to the cobbing sheds ranges between 3 to 10 per cent, the average being about 5 per cent. A greater yield than this average indicates an unusual richness of the deposits. Mr. Cirkel† gives the following yield of sheets from the “run-of-mine” of several mines in Canada :—

	A mine in Wake- field.		Lacey mines, Sydenham.	Mine “Battle- Lake”, Tem- pleton (yields large sheets).
	Inches.	Per cent.	Per cent.	Per cent.
Thumb-trimmed cutting	1 × 3	61	50	<i>Nil</i>
“	2 × 3	26	30	36
“	2 × 4	9	10	27
“	3 × 5	3	6	20
“	4 × 6			
	and over	3	4	17

The Lacey mines produced crystals of 5 feet diameter, yielding extraordinary quantity of commercially useful mica sheets of large size; crystals of 2 to 3 inches were of daily occurrence.

Experience shows that under ordinary circumstances at least 1,250 pounds of trimmed mica must be extracted for every 100 tons of rock mined (the depth of the shaft not exceeding 300 feet) in order to pay a profit. The proportion of run-of-mine is of course very much larger, in some cases being 20 times as much; however the run-of-mine should not be more than 8 to 10 times the quantity of trimmed mica. In other words, in the case of quarry work, about 3 tons of “run-of-mine” yielding 750 pounds and in the case of underground working, about 5 tons of run-of-mine yielding 1,250 pounds of thumb-trimmed mica should be extracted for every 100 tons of rock in order to make a mine working under ordinary conditions pay all expenses and leave a profit‡.

Mr. H. S. Spence‡ gives the following percentages of the

* Mica by Hugh S. de Schmidt, Ottawa, 1912.

† Mica by F. Cirkel, Ottawa, 1905, p. 45.

‡ Mica by H. S. Spence, Ottawa, 1929, p. 44.

different sizes yielded by a lot of "run-of-mine" of the Blackburn mine, amounting to approximately 35 per cent., "representing merchantable thumb-trimmed sheet, the remainder being waste." This mine is one of the largest and oldest established producers and the figures may be taken as a fair average for a Canadian phlogopite deposit.

Size, inches.	Percentage of merchantable sheet.	Percentage of total "run-of-mine" mica.
1 × 1	44	15.40
1 × 2	26	9.10
1 × 3	15	5.25
2 × 3	9	3.15
2 × 4	4	1.40
Larger sizes	2	0.70

It might be noted here that the proportion of mica to the vein matter is, as a rule, much higher in phlogopite than in muscovite deposits*. According to Zeitler, 2 to 5 per cent. of the mine-run mica in Canada actually finds way into the trade.

South African Union.—In South Africa 2 to 4 per cent. may be taken as the average merchantable sheet mica, passing eventually into the trade against 1 to 5 per cent. "S.D.B." mica of Bihar in India. Mr. A. L. Hall, in his monograph on "the Mica Deposits in Eastern Transvaal†", has given the following analysis of one short ton of electrical mica from South Africa and Madras, showing the different sizes of sheets obtained :—

Weight in pounds (per 2,000 lb.)

Size in inches.	Madras mine Leysdorp mica mine.		
	lb.	(1908) lb.	(1910) lb.
1 to 1½ × 4 to 7 and up	52	96	729
2 to 2½ × 4 to 7 .. "	52½	278	754
3 to 3½ × 4 to 7 .. "	65	289½	209
4 to 4½ × 4 to 7 .. "	31½	105	99
(incl. 5" and up)	201	769	1,791
Under 2" × 3"	.. 1,681	757	Nil
2" × 3" up to but under 4 inches long	118	474	209
Total	2,000	2,000	2,000

* Oliver Bowles : Rep. Invt. Serial No. 2357, 1922, p. 4.

† Memoir No. 13, Geol. Surv., Union of South Africa.

In the above, out of one short ton mica produced in Leysdorp mine in 1910, 681 lb. represented sheets measuring from 4 to 4½ inches square to 4 to 4½ by 7 inches and up as compared with 191 lb. for the same size in a similar output from Madras.

Mr. Hall also states that, in the Leysdorp mine, it was found from a particular working instance that 100 tons of rock had to be handled to obtain 1 ton of crude mica, out of which 5 to 10 per cent. was dressed as saleable stuff, the balance being treated as scrap. The average for this mine has been estimated at 6 to 7 per cent cut mica obtained and on this basis 1,400 tons of rock practically correspond to one short ton cut saleable mica. In the Premier mica field, the proportion was 1,700 tons of rock against 1 ton of prepared mica, which later improved to 850 tons of rock. The estimate of the Union Mica Mine was about 1,600 tons for a ton of cut mica.

Rhodesia.—Mr. Hobson* states that in the Lomagundi field the recovery of 1½ lb. of trimmed mica per hundredweight of mine mica is considered a good average.

East Africa (Tanganyika Territory).—2 to 4 per cent. is reported to be the average of merchantable mica on "run-of-mine" eventually passing into the trade.

Brazil.—Mr. Hans Zeitler estimates 10 per cent. of the mine-run becoming knife-trimmed sheets, one-half of which is obtained as "cut sheet".

Mr. Hugh S. de Schmidt (p. 53) gives the following cost of the Brazilian mica up to arrival at importing port:—

	\$ per ton.
Cost of mining, trimming and preparing for the market, including transport to Santa Luzia Station of the Leopoldina Railway	243.50
Freight charge to Rio de Janeiro	7.80
State export tax	29.23
Storage, transhipment, etc.	4.87
Freight to European port with insurance wharfage, etc.	24.35
	309.75

PLACE OF SUPERVISION IN A MICA BUSINESS

The mica business, from the peculiar nature of the mineral, requires very intelligent and efficient supervision for both mining and manufacture. The following requirements of the technique

* Mica and Its International Relationships, Bull. Inst. Min. and Met., No. 270, March 1927, p. 26.

of mica should as far as possible be constantly kept in view by all mica men, be he a proprietor, director, manager, miner or a factory worker :—

- (i) Minimum of wastage in the mining and manufacturing processes.
- (ii) Good dressing and grading of mica so as to establish a reliability and confidence in the supplies of the particular mica firm, in the estimation of the buyer, whoever he may be, user, dealer, manufacturer or exporter.
- (iii) Elimination of commercial defects and imperfections with minimum of corner or triangle cuts, specially far towards the centre. The man in charge should be familiar with the general specifications of mica.
- (iv) Systematic account-keeping, including detailed mining accounts, *viz.*, detonators, fuel, candles used, rock handled or raised, shots fired and length of holes drilled, rock broken, mica recovered per ton of rock broken, charge of dynamite per hole, recovery of mica per ton of rock, cost of mica mined per pound or maund, cost of "S.D.B." mica per maund or pound (*i.e.*, taking dressing expenses along with the mining cost), etc.
- (v) Mining maps: map of the working mine, showing its detailed working progress including shafts, levels, tunnels, veins, adits, etc. This kind of map is of vital importance in case of future development or exploration of further prospective deposits of mica in the locality.
- (vi) Working knowledge of the technique of mica including manufacture and marketing.

Few of the mine or factory supervisors at present employed in the Indian mica firms are qualified enough to look efficiently after such a specialised line of work. Most of the failures in mica business can be attributed to one or other of the above causes. The following extract is taken from "Political and Commercial Geology" by Mr. D. A. Hall :—

"No matter how great the merit of the mines in a district may be, unless the mica is carefully prepared, graded as to size and quality and shipments are standardised, it cannot expect to obtain permanent favour among the consumers in this country (America) or in Europe."

India mastered the art of preparing, grading and standardising mica to the fullest satisfaction of the American and European consumers of Indian mica but the reputation has been vitally affected of late, a fact that should be looked into and acted

upon before it is too late. There is already a good deal of prejudice in the foreign market, specially about the preparation of mica in Kodarma and Giridih sides.

MILL FLOW-SHEET FOR RECLAMATION OF MICA*

The following flow-sheet, describing the treatment of mica-bearing pegmatites, appeared in the Eng. and Min. Journal :—

“The ore is trammed from the open pit over a trestle, from which it is dumped on a platform on a level with the trap of the primary crusher in the mill. It is hand-fed to a high-speed centrifugal beater (i) operating at 1,000 r.p.m., and having grate openings of $\frac{3}{4}$ inch. The rock is crushed dry, but a stream of water smites the broken material from below the grates into a large washer, (ii) the kaolin content is here beaten loose from the mica and quartz, being finely disintegrated and held in suspension. The mica and quartz free from kaolin pass into a screw classifier, (iii) the box enclosing the screw has been built up to a height of 3 feet above the bottom at the end where the screw is submerged. This is for the purpose of allowing a thinner slip to be made and the lighter sands to have a chance to settle quickly. The thin slip flowing over the heel of this classifier is collected in the cone (iv) which makes further separation of the sand from the slime. The overflow from the cone goes to a screen having an opening of 100 meshes to the inch. This screen (v) eliminates any flake mica passing over from the cone. The slime from the screen (vi) passes to settling tanks. From these tanks the thickened slime is pumped to filter presses. The cake is both steam- and air-dried on floors, after which operation it is loaded for shipment.

“From the upper end of the screw classifier (3) the coarse mica to silica are sluiced into a revolving screen (6) having $\frac{1}{2}$ -inch openings. The material passing over the screen (plus $\frac{1}{2}$ inch) is carried by a 4-inch screen conveyor to a set of light rolls (8) thence to the revolving screen (9) having $\frac{1}{8}$ -inch openings. The underflow from screen (9) goes to waste.

“The material passing through screen (6) ($\frac{1}{2}$ -inch) is led to a revolving screen (10) having $\frac{1}{8}$ -inch openings. The oversize is delivered by a drag belt to a heavy roll (11) after passing through which it goes to the screen (9), the undersize from the screens (10) waste containing mostly fine sand.

* Eng. and Min. Journal, 1936.

“ Fresh water is applied at each screening operation, so that no particles of sand adhere to the mica when it reaches the rolls. The amount of rock included here with the mica is negligible and is all washed out in the first part of the screen (9). The mica coming off this screen is very smooth. From the screen (9), the mica is conveyed by a 4-inch screw to a cross-belt having drags attached, which apparatus in turn conveys it to a storage bin.

“ From the storage bin, part of the mica may be drawn automatically into a drier, from which it is fed in two Raymond beater mills; the ground mica is hoisted by a bucket elevator and fed to two belting reels, one having a 20-mesh screen and the other 100-mesh screen. The 20 to 100-mesh constitutes one grade of roofing mica, while the 100-mesh mica commands a much higher price and is used for other purposes than as roofing material.”

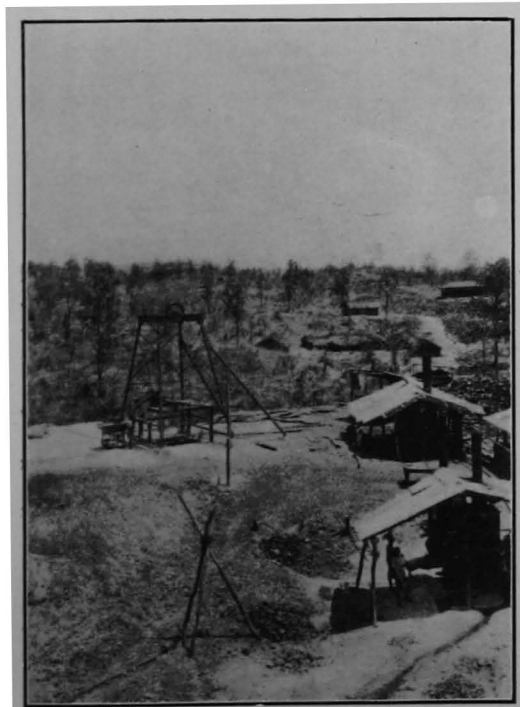


Fig. 8.—The Khalkatambi Mica Mine (Kodarma Reserve Forest).

PART III

OCCURRENCE AND DISTRIBUTION OF MICA

Chapter VI

MICA IN INDIA

Mica has been known in India from time immemorial. It is called "Abhra" in Sanskrit, meaning cloud. The use of mica in early times seems to have been confined to (i) Medicines, (ii) Ornaments and vestures for idols, (iii) Decorations, (iv) Glazing or transparent medium and (v) Painting bases.

Mica in Hindu chemistry and medicine.—Sir P. C. Roy, D.Sc., in his well-known "History of Hindu Chemistry"*, has shown the place which mica occupied in the Hindu system of medicine, quoting fully from the old Sanskrit writings on the subject. "Abhra" (or mica) was treated as one of the eight "rasas", and it was classified into three varieties—(a) *Pinakam*, (b) *Nangamandukam* and (c) *Vajram*—and each of these again is of four different colours—white, red, yellow and black.

In the Hindu Materia Medica, the mineral kingdom is broadly divided into the *rasas* and the *uparasas*, the *ratnas* (gems) and the *lohas* (metals). The term *rasa* is generally reserved for mercury, though it is equally applicable to a mineral or metallic preparation thereof.

According to the Hindu chemists and physicians, such easily splittable mica, which readily takes up (or *swallows*) mercury, can alone be used with the metals and administered as medicines. Mica, which has been *killed*, is prescribed in the treatment of various diseases. The variety which has the lustre of the moon, if taken internally, brings on dyspepsia and urinary disorders. Mica heated seven times and plunged into sour gruel or cow's urine or decoction of the chebulic myrobalan or cow's milk is freed from all impurities. Mica mixed with paddy grain and reduced to powder, tied in a piece

* History of Hindu Chemistry, Vol. II, Calcutta, 1903.

of cloth and suspended on sour gruel and then passed through linen is known as *Dhanyabhram* (literally, combination with paddy). The process of *killing* mica consists in *Dhanyabhram* being rubbed with the juice of *Cassia sophora* and roasted ten times in a closed crucible.

Liquefaction of mica.—Dr. Roy further writes that “thin plates of mica are to be smeared with the three alkalis and borax and strongly heated in a crucible. The mass fuses (*Kakachandes Harimata Tantra*). Refractory silicates are treated similarly at the present day with the *fusion mixture*.”

Hindu writers imagined the crystals of mica to be the remains of lightning flashes from which sparks had emanated and become preserved in the ground. These crystals were regarded as being endowed with extraordinary properties.

Traces of mica mining have been recorded in India since about 2,000 years B.C., but no systematic history of the development of the mining of mica in ancient India is available.

EARLY HISTORY OF THE MODERN MICA INDUSTRY

The modern mica industry may be taken to have dated from about the first quarter of the last century, if not still earlier. The first traceable record is that of Surgeon P. Burton who states that in the year 1826 large transparent laminae were procured a few miles to the east of Hazaribagh station*.

In 1849, Dr. McClelland described the mica mines at Dhanwi Dhoba (Dhunbhar ?) and Quadrumma (Kodarma ?). At Dhanwi the mica is said to occur in strata alternating with coarse gneiss. About 50 to 100 men and boys were engaged in the mines, which were inclines running with the dip, and as many more women and children occupied themselves with sorting and dressing of the plates. From this mine alone, 100,000 maunds were despatched to Calcutta where they were sold at the rate of Rs. 7-8-0 per maund. From other mines, still greater amounts were produced and were sold on the spot at Rs. 4 per maund†.

Captain Sherwill wrote in 1851 that the mines in Debar and Rajani in the district of Gaya produced about 14 tons of mica annually yielding about 23 million plates of nine inches square. He described certain mica mines on the western prolongation of the zone in which the Hazaribagh mines occur‡.

According to the Statistical Account of Bengal (Vol. XIII, p. 171), in 1863, 10,000 maunds of mica were exported at Rs. 3 per maund or a total value of Rs. 30,000, half of which went

* Trans. Med. and Phys. Society of Calcutta, Vol. II, p. 261.

† Report of Geol. Survey, India, 1848-49, p. 20.

‡ Journ. As. Soc. Bengal, Vol. XX, p. 295.

to Calcutta and half to Patna. A consignment of Bengal mica of about 7,500 pounds to England in the year 1863 has been recorded*.

The following gradings and sizes current in the under-noted localities have been mentioned :—

	Average measurements.	
	Dhub (Dhab ?).	Jamtara.
	Inches.	Inches.
(i) Sanjhla ..	5 × 4	4 × 3
(ii) Manjhla ..	7 × 5	5 × 4
(iii) Rasi ..	9 × 6	6 × 5
(iv) Karra ..	12 × 9	8 × 6

The sizes "Urtha" and "Admalla" were available only in the best mines. The largest plates seen measured 19 by 14 inches and 20 by 17 inches, but considerably larger ones were also sometimes obtained.

Indian mica exports have been more or less regular from 1884, which is practically the first year of India's regular entry into the international mica trade.

Towards the close of the last century, with the rapid development of the electrical industry in the United States and Germany, demands for mica as an insulator for electric and heating appliances grew up by leaps and bounds. The demand stimulated increased production of mica in countries then known to possess mica, namely, India, Canada and the United States.

Development of Madras mica industry.—According to Mr. A. Krishniya†, mica was discovered for the first time in certain localities in the Rapur zone of the district of Nellore as early as 1887. From this year, the attention of the Madras Board of Revenue was called to the mineral and the Collector was authorised to auction the mining rights in the specified localities for periods of 2 years‡. Mr. R. W. Thompson, in his article on "the mica mining in Nellore", in the Journal of Society of Arts (June 1898), states that the industry started in 1888. The first shipment of Madras mica, however, commenced from 1895. Shipments of 66,815, 71,030, and 89,330 lb. are recorded to have been made from Madras in the first half and in the second half of 1895 and the first half of 1896§ respectively. Mica mining operations were found (in 1898) in progress in the villages Inikurti, Utukur, Chaganum, Sydapuram and Khandah, all lying S.W. to S.S.W. of the town of Nellore.

* Manual of Indian Geology, Vol. III, by V. Ball, p. 525, 1881.

† Trans. Min. & Geol. Inst. India, Vol. V, 1910.

‡ Sir Thomas Holland : Mica Deposits in India, Records Geol. Surv. India, Vol. XXXII.

§ Mineral Industry, 1895.

Types of Indian productions.—Indian mica predominantly consists of ruby muscovite type, with biotite in frequent association. The only phlogopite deposit in India so far discovered occurs in the Eraniel Taluq of the State of Travancore in Southern India. This Travancore deposit was not commercially worked till 1935, from when small annual productions appear in official records. The phlogopite is soft in quality and amber in colour.

The other large muscovite mica producer is the United States, but 75 to 95 per cent. of its total production of mica consists of scrap. The Indian production, on the contrary, consists almost entirely of sheet, *i.e.*, blocks, splittings and films.

Dumps in India.—There being no consuming market in India for waste or scrap mica, the mine and factory rejections are thrown away and accumulate in *dumps*. In the earlier days of the electrical industry, electrical requirement of mica was mostly confined to large-size natural mica sheets from No. 3 up, while mica from No. 4 down used to be thrown away as waste. Since the invention of the process for making built-up mica or micanite, about the year 1893, a large demand grew up for sizes up to No. 5. Even up to the Great War (1914–18), the call for sizes smaller than No. 5 was small. During and after the World War, however, demands for smaller sizes of mica, *viz.*, No. 4 to No. 6 or even No. 6-small (some call it by No. 7), have vastly increased, and now even outstrip the demand for the larger sizes of mica.

Dump-cut splittings.—As a result of the great progress in the manufacture of built-up mica or micanite and the consequent increased demand for large quantities of small-size mica, miners who had large accumulations of mica wastes and rejections, in their *mines and factory dumps*, recovered a large portion of the *dump scrap* in saleable mica. More recently the demand for cheap, loose, mica splittings has become very keen and the *dumps*, providing the cheapest suitable raw material for manufacture of cheap splittings, have become an additional source of income to those who owned them. The *dumps*, originally accumulated and abandoned sometimes by a chain of predecessors, have immensely benefited the successors in these days.

As a matter of fact the enormous *dump* assets in India, which mostly contained a large percentage of recoverable sheet mica, enabled India to secure a world monopoly in the supply of cheap loose splittings. The raw material obtained from *dumps* is practically costless—at just the expense of *dump cutting*—with no mining charges. Splittings made from the freshly “mined” stuff cannot naturally compete with it.

Exhaustion of the dumps in sight.—These *dumps*, however, are being rapidly exhausted and the problem of manufacturing

cheap loose splittings at a similar minimum cost will soon face the Indian mica miners. Their position as sole suppliers of cheap ruby loose splittings threatens to be seriously imperilled.

"Uparchala" or surface mica deposits.—The other cheap source of mica splittings is the "uparchala" mica which, though often found stained, distorted or rendered otherwise unsound by surface conditions, proves suitable for manufacture of splittings. Many of these available reserves have also been worked out and early exhaustion is apprehended.

Indian mica known as Bengal mica in international trade.—The present Bihar mica field was, till 1912, within the Presidency of Bengal. Mica produced in this belt and shipped from Calcutta, the capital city of Bengal, was therefore called and is still known widely as *Bengal or Calcutta mica*. Although shipments of Bengal mica have been recorded in 1863 and 1884, no regular data could be had prior to 1890.

Export figures give a nearer reliable guide to find Indian production.—In India, it is very difficult to find the exact data of production of mica; the statistics that appear in official records are under-stated, sometimes by more than 50 to 75 per cent.; in other words, exports often represent more in excess by this difference over the recorded production of mica. Actually the real production ought to be exceeded by the exports, taking into account the stock lying over in the miner's hands and sales for domestic consumption.

The following may be taken as the probable factors to explain this great difference :—

- (i) Under-stating the production by the miners, particularly in the privately owned or Zamindari lands*.
- (ii) Illicit or indiscriminate mica trading.
- (iii) Production not reported.

Even the enactment of the Bihar and Orissa Mica Act has not much improved this state of affairs. In 1930 to 1936 the recorded production amounts to 361,610 cwt. against the export of 653,009 cwt. In 1929, 116,075 cwt. were exported against the recorded production of only 53,231 cwt. In 1937, 297,343 cwt. have been exported against the reported production of 133,260 cwt. These figures establish that the Bihar and Orissa Mica Act† has not achieved the results it was originally aimed at. Moreover this Act is not comprehensive as it applies only to Bihar, while reporting of mica production throughout the country is not compulsory.

* There is no doubt that all the mica won does not figure in the Return and that underestimate is employed as a means of evading royalty. Theft is prevalent.—Records of Geol. Surv. India, Vol. 46 (1915).

† It is reported that the Government of Bihar have decided to withdraw this Act.—*Author*.

In these circumstances, export figures provide the only available nearest approach to the country's total mica production, after allowing some margin for domestic consumption, re-export of imported mica after conversion into splittings and stock balance "carried forward". The annual domestic consumption has been estimated at 200 to 400* long tons. It must be borne in mind that the Indian production and exports consist entirely of sheet mica, except the supply to the United States of 1,667 and 2,708 short tons of scrap mica respectively in 1935 and 1936. Indian scrap mica, it may be noted, is far superior to that of the usual American scrap and contains in it a large percentage of low-grade sheets, suitable for manufacture of cheap loose splittings. A good proportion of Indian scrap is often secured from *dump-cut* mica.

Official figures, too, do not include certain useful sheets.—It should also be noted in this connection that in the official recorded production of mica large quantities of sheet mica, suitable for manufacture of splittings, are not included. For instance, 5,266 cwt. sheet mica of Nellore origin, useful for splittings, have not been included in the recorded production of 1935. Similarly in 1936, 12,072 cwt. of sheet mica of Nellore origin and 1,238 cwt. of Ajmer-Merwara origin which are fit for splittings have not been included in the recorded figures for 1936. In 1937, this amounted to 28,782 cwt. Taking these together, the recorded productions amount to 64,020 cwt. (3,585 short tons), 99,982 cwt. (5,599 short tons) and 133,260 cwt. (7,462 short tons) in 1935, 1936 and 1937 respectively.

Custom export figures also not quite accurate.—The value of exports as declared in the custom papers may not always be correct. While preparing the formal declaration papers for custom purposes, valuation is given generally on approximation, which does not always correspond with the real values of invoice as submitted to the banks, along with the shipping documents. Furthermore, there is a chance of under-valuing the goods in custom declarations, both for reduced expenses and freightage where the charges are scheduled on *ad valorem* basis. This matter may be investigated.

INDIA'S POSITION IN THE PRODUCTION OF SHEET MICA

From the table of world production of mica it will be found that India is the largest producer of sheet mica in the world. In 1935 and 1936, out of the approximate world sheet production annually between 8,000 to 10,000 metric tons, India's share amounts to 7,200 and 9,000 tons respectively, which work out to about 90 per cent. of the world total. The proportion

* Records of Geol. Surv. India, Vol. 46 (1915).

of blocks and splittings in the total Indian exports in 1934 to 1937 stand as follows :—

Year.	Total.	Block, cwt.	Splittings, cwt.	Percentage of splittings.
1934	92,918	20,617	72,301	78.5
1935	141,814	23,774	118,040	83.2
1936	177,664	27,235	150,429	84.6
1937	297,343	30,003	267,340	90.0
1938 (up to Sept.)	125,221	11,208	112,013	90.0

From the above exports the importance of mica splittings, compared to the demand for block mica at the present time, will be clear. The percentage of splittings is steadily swelling the peak figure in 1937 being 90 per cent. of the total mica exported from India this year. In these figures, condenser and films have been taken as splittings.

It may be noted in this connection that the mines of Kodarma and Nellore are responsible for something like 65 per cent. of the world's supply of sheet mica*.

Cost of production and manufacture.—The cost of production and manufacture of mica, especially splittings in India, as compared to other countries is so very low that other countries have found it impossible to compete with India in splittings. Firstly, Indian mica workers make very fine splittings, produce a larger outturn within a given time than the splitters or rifters in other countries, and the wages paid in India are very low. Secondly, enormous *dumps* lying over in the old-worked mines and factories supply raw materials for manufacture of splittings at merely the expense of *dump cutting*. The cost of exploitation of *uparchala* or surface outcrops of mica is small and the mica so obtained, though often defective as block mica, is very suitable for the purpose of splittings.

It has been explained in the last chapter that the time is not distant when both the *dump* and *uparchala* mica resources of this country will be exhausted and Indian mica producers shall have to compete with other mica countries on more level terms. Their mica will have to be secured from the mines direct at higher prices because of mining costs. This problem has already been forcing itself to the fore and India is urgently required to organise her mica industry so that as the crisis develops she may adapt herself in advance to meet the changed conditions with the cheapest production from the "mined" material.

* Sir Edwin Pascoe on "Mineral Wealth of India": Bull. No. 2. Vol. XXIX, 1931: Imp. Institute.

HOW TO REDUCE THE OVERHEAD EXPENSES IN MICA

In order to reduce the expenses of mining and manufacture, ideal working conditions have got to be created, *if necessary, by statute*. Co-ordination and merging of small individual interests into bigger working units are imperative needs. The mica miners and merchants in India, with a few honourable exceptions, are accustomed to reduce expenses always by sacrificing the working efficiency. In fact the absence of efficiency, lack of the right type of supervision, lack of economic methods of working and insufficiency of capital are the usual features of most of the existing mica firms, both in Bihar and Madras. Efficiency in working should be made the principal motto of a mica business. Mining companies shall have to be so organised that they may have sufficient working capital to develop mines and work them on up-to-date lines, including underground mining, efficient drainage, cheap transportation, ideal development, unimpeachable preparation of goods, reliable standardisation, and competitive co-operative marketing. Large-scale mining and production of maximum steady output would bring down the costs of production very considerably.

Smallness of capital.—Small individual ventures with sometimes only a nominal capital constitute the basic cause for the backwardness and uneconomic aspect of the mica mining industry in India, particularly in the exploring for mica. The successful economic exploitation of the mineral resources of the country depends on proper development, publicity and co-operative spirit amongst the interests concerned, and unless these essentials are well organised, no better situation in this line can be expected to develop.

Status of a mica merchant.—In the present state of the Indian mica industry, it is very difficult, if not impossible, for the foreign buyers to distinguish *who's who* in mica in India. All miners are more or less merchants and all merchants "pose" as miners. Many "mushroom" firms come into existence, particularly in times of "boom", whose only proof of a status in mica is a glaring letterhead, with no good workable mines or stock-in-trade. The bank references about such firms only give information about the monetary worth of a party, and nothing is stated more particularly about the party's reliability in regard to standard supplies and business integrity, etc.

STANDARDISATION

Mica miners and dealers in Bihar.—The dressing and grading of mica by one miner or dealer at present varies greatly from that of another. The "fair averages" of the grades and qualities are seldom maintained. The "fair stained" of one is "clear" of another; "stained" of one is "fair stained" of another and so on. No. 5 grade of one dealer is sometimes looked upon as

inferior in average grading to the No. 5 of another. Uniformity is absent. The grading of one party is fair or tolerably fair, whereas that of another may be generally found to be of a low standard. Buyers from abroad can scarcely depend on getting a fair and uniform standard for their money's worth. In the local market in Bihar there are a few miners who do not export their products and who enjoy an excellent reputation for fair grading and classification of their productions. The dealers and middlemen, who are at present the bulk of the shippers of mica, purchase requirements partly from these reputed producers and partly from any *Tom, Dick and Harry* in the market. The gradings and qualities are made afresh by mixing up the different lots purchased, often by taking away the finest material. These goods ultimately find a way into the market in standard designations, though in fact the preparations are of unfair average and below *standard*.

Complaints on direct supplies of mica from India have been very frequent amongst the foreign buyers since the Great War, and more particularly 1926-27, since when the Indian mica industry has in many cases fallen into unreliable, if not unscrupulous, hands. There are certainly a few dependable firms whose standards are always uniform. Some of these firms confine their trade to local sales. The shippers of mica are, in many cases, mere intermediary dealers, who carry on trade with mica purchased from the big and small miners, although they manage to advertise themselves to foreign parties as large miners.

Standardisation by a uniform all-India legislation, therefore, is a vital necessity in order to purge the trade of all the existing malpractices, so that the confidence of foreign buyers in Indian supplies may be reinstated. A considerable volume of business that used directly to come into India is already passing into other channels. Indian mica is now more relied upon if purchased from London than by direct purchases from this country. There was a time when London was almost the sole marketing centre for Indian mica and buyers from all countries flocked to London to bid for Indian mica in the periodical auction sales held in London. However, a few years before the Great War, and more particularly after it, direct contact has been established between India and other purchasing countries, *viz.*, the United States, Germany, France, Italy, Belgium, Netherlands, etc. Direct supply from India was found to greater advantage by the buyers, both in regard to the price and quality. Letter of credit for full invoice value was the usual practice in mica business. People concerned with the mica trade in those years (up to 1926-27) know well how respectable a line of business it was then. The large consumers of mica like the *General Electric Co. of Schenectady*, the *Westinghouse Electric*, *Baker Startins or Startin & Co.*, *Jaroslavl's*

Sciama, Monti & Martini, MacAllen Company, Chicago Mica Co., etc., used to place regular forward contracts direct for Indian mica, blocks and splittings in very large quantities on excellent terms of payment. Complaints on the supply were rare. Those happy days are now no more; complaints and free consignments have become the order of the day. Some of the better elements in the Bihar mica industry have been obliged to leave the mica line; firms like Bird & Co., Tata & Co., Hoare Miller & Co., etc., found things difficult for them to continue. The few large producers still existing are obliged now to stock goods in London for sale, and others who fail to arrange for it find it difficult to continue in business.

Madras mica trading.—In Madras the trading system has not deteriorated to such an extent as in Bihar; illicit trading is rare, though this influence seems to be percolating slowly into the Madras mica trade in recent years. The gradings are usually reliable, nevertheless the Madras mica industry requires a thorough overhauling. Attention is more urgent in Madras than in Bihar, as the efficient exploitation of the Madras mica deposit requires larger capital and special systems of treatment. The amount of *overburden* or sedimentary accumulations on the mineral occurrence is often thick and requires efficient removal in order to carry out the exploitation of the mineral. As a rule problems of “waste rock”, “fuel” and “transportation” are more difficult in Madras than in Bihar. The deposits there are far from exhausted and in many cases yield large sheet mica from the bigger crystals or “books”, but the working conditions are not very encouraging for small ventures.

REDUCED PRODUCTION OF MICA IN MADRAS

Judging from the records of the past years, production of mica in Madras has fallen greatly in spite of the very heavy demand for mica which has grown up in the course of the last two decades.

Nellore produced from 11,000 to 24,000 cwt. of mica annually between 1906 and 1908. An output of 1,301 cwt. in 1921 is the minimum on record. The percentage of mica production in Madras amounted to 47 per cent. in 1906 against 42 per cent. of Bihar, the next highest production being 38 per cent. in 1916. The upward and downward trend of production in this province does not seem to correspond always with the world trend of demand or depression. During the Great War (1914–18), particularly in 1917 to 1919, production of mica rose markedly everywhere, but in Madras it went down to 6,000 to 8,000 cwt. annually. In 1928 and 1929, when the general demand for mica was very high all over the world, the annual production of mica in Madras ranged between 8,000 to

10,000 cwt. Even in 1935 to 1937 the annual figure has not exceeded 16,000 cwt., although the limit has reached an unprecedented record in Bihar.

It has already been stated that this reduced production of mica is not due to any exhaustion of the mica deposit in the province. If well-organised and large-scale mining is arranged for, under proper working conditions, the output of Madras should greatly improve and may even equal the productive capacity of Bihar. Small mica ventures are not generally successful in Bihar, although under present-day conditions and with proper skilful development they continue to exist, but such enterprises will stand less and less chance of success in Madras.

PRODUCTION AND EXPORTS.

The following represent the production and exports of mica up to 1901 :—

Year.	Production.		Year.	Exports.	
	Tons.	Rs.		Tons.	Rs.
1890	309	1,47,178	(1890-91)	324	9,13,025
1891	93	87,000	(1891-92)	118	4,28,707
1892	120	98,154	(1892-93)	169	4,34,348
1893	192	1,50,360	(1893-94)	246	7,66,699
1894	185	1,45,388	(1894-95)	261	6,06,310
1895	404	3,16,614	(1895-96)	452	9,98,151
1896	335	3,42,470	(1896-97)	652	11,53,364
1897	694	1,99,003	(1897-98)	590	43,25,100
1898	385	2,25,540	(1898-99)	556	30,31,305
1899	620	9,09,514	(1899-00)	1,148	55,02,900
1900	931	(a)	(1900-01)	1,685	76,16,550
Average					
1890-1900	380	?		555	23,43,314

During the period 1890 to 1900, about 4,278 tons of mica are reported to have been produced, and against this the recorded exports amounted to 6,101 tons. The annual average of production and recorded exports have been 380 tons and 555 tons, respectively. The value of the average annual export during this period was about Rs. 23,43,314. During 1901 to 1913 the average annual reported production was about 31,882 cwt. and the recorded exports during this period amounted to 38,664 cwt. (with a declared value of Rs. 29,31,135). During 1914 to 1918, the average annual reported production was 41,332 cwt. with an export average of 49,583 cwt. valued at £383,615 or

(a) Not available.

Rs. 57,54,225. The quinquennial averages after the war, as given by the Geological Survey of India, stand as follows :—

	Reported production,		Recorded exports,	
	cwt.	Rs.	cwt.	Rs.
1919-23	38,191	17,88,683	58,600	87,08,950
1924-28	43,309	22,68,071	86,541	1,00,80,261
1929-33	43,742	20,96,765	71,338	59,36,827
1934-38				
(Estd.)	90,000	(?)	171,682	91,46,754

The data of 1937 represent the highest figures on record in weight of both production and exports, although the price per cwt. is perhaps the lowest.

The United States is the only country where complete statistical data on production, imports and exports of mica are officially recorded in all possible details. In most of the other mica producing countries figures are not only incomplete or irregular, but when reported, proportion of sheets or waste and scrap is not shown. Proportion of the different grades and qualities or specifications of prepared mica also cannot be ascertained, so far as these countries are concerned.

Imports

India does not import any mica for domestic consumption, but certain quantities of mica are imported to be reshipped or sometimes they represent returned goods. Mica is also "exported to" India, from certain producing countries, including Madagascar, for conversion into splittings and re-exported to foreign destinations. Quantities of Madagascar mica, though not very large, are imported into India and re-exported after manufacture into splittings, on behalf generally of American buyers.

Certain quantities of "built-up" mica or micanite are imported into India, for domestic consumption, chiefly from the United Kingdom. At present this class of goods is included in the category of electric insulating materials, in the Custom's schedule, but *it should logically come under the head "built-up" mica or "mica products", so as to assist in tracing the disposal and consumption of mica in India.*

However, compared to the volume of exports, imported materials of mica are relatively of little importance, both in tonnage and value.

Mica during the World War (1914-18)

During the World War, drastic restrictions were enforced by the British Government on the disposal or trading of

TABLE II.
Statistics of production and exports of Indian mica.
 Reported production and recorded export of mica.
 (Based on official returns of production and clearances through the customs.)

Year.	PRODUCTION.			Year.	EXPORT.				Per-centage of export in excess over production.	REMARKS.
	Quantity.		Value.		Quantity.			Declared value.		
	Cwt.	Long Tons.	Rs.		Cwt.	Long Tons.	Rs.	Per cwt.		
1900	18,410	m 931	..	99-00	22,599	1,130	11,00,580	Rs. As.	..	
1	20,289	m 1,031	..	00-01	31,175	1,558	16,43,310		..	
2	18,707	m 996	..	..	17,786	889	11,40,840	..
3	18,520	926	..	..	22,106	1,105	13,54,455	19
4	22,164	488	..	..	18,250	912	12,47,745	..
5	25,641	1,282	(a)	..	25,837	1,292	21,30,120	..		
6	52,543	2,629	..	..	54,193	2,710	38,81,730	3
7	52,203	..	..	..	39,055	1,953	33,95,730	9
8	53,543	..	..	..	27,572	1,379	20,92,695	..
9	32,903	..	..	..	32,640	1,632	23,42,985	..
10	22,699	..	..	..	42,593	2,130	28,34,745	77
11	33,896	..	6,52,485	10-11	48,871	2,444	31,16,670	..		
12	43,832	..	8,66,505	11-12	66,574	3,329	51,20,235	..		
13	45,422	..	9,39,360	12-13	53,891	2,694	45,38,460	..		
14	40,506	..	7,01,940	13-14	32,972	1,649	29,10,990	88 4		
15	27,140	..	7,49,700	..	33,719	1,681	31,27,440	92 12		
16	43,400	..	11,54,100	..	59,521	2,976	46,18,825	77 9		
17	49,907	..	13,77,379	..	65,729	3,286	86,29,275	131 5		
18	54,710	2,735	18,60,714	..	55,972	2,799	89,94,565	160 11		
19	45,784	..	15,96,081	..	59,098	2,955	86,34,488	146 0		
20	46,952	..	16,28,707	..	76,517	3,826	1,06,33,123	106 1		
21	32,488	..	15,93,566	..	30,944	1,547	63,94,113	206 0		

22	31,878	..	12,02,704	..	43,145	2,157	57,85,245	134	0	35
23	33,855	..	15,87,945	..	85,296	4,165	80,76,522	97	0	145
24	40,907	..	29,58,917	..	70,093	3,508	94,49,168	99	2	71
25	45,990	..	21,99,576	..	99,699	4,985	1,06,33,123	146	1	117
26	41,924	..	22,19,367	..	89,947	4,497	1,10,00,077	122	6	113
27	42,614	..	24,52,055	..	77,488	3,875	92,65,922	119	9	82
28	45,112	..	24,10,499	..	95,479	4,774	93,54,946	98	0	11
29	53,231	2,661	26,59,759	..	116,075	5,804	1,05,06,834	90	10	118
30	52,727	..	26,68,986	..	82,909	4,145	75,87,731	91	8	59
31	38,963	..	20,37,634	..	52,966	2,648	41,48,768	78	5	36
32	32,713	1,636	14,35,401	..	47,021	2,351	33,48,943	71	5	43
33	41,075	2,054	16,82,045	..	56,647	2,834	40,92,033	72	4	38
34	55,706	2,785	20,76,599	..	92,918	4,646	69,30,525	64	7	66
35	58,754	3,301	25,52,612	..	141,814	7,096	80,34,681	56	7	121
36	86,672	5,005	32,43,271	..	177,664	8,883	91,76,511	51	11	77
37	104,478	6,663	?	..	297,343	14,867	1,43,60,036	48	11	123
	28,782 ‡									

* 5,266 cwt. of waste fit for splittings from Nellore not included.

† 12,072 cwt. of waste from Nellore and 1,358 cwt. waste from Ajmer, both fit for splittings not included.

‡ 28,119 cwt. waste from Nellore and 663 cwt. waste from Ajmer, both suitable for splittings not included

§ Converted at ex. 1s. 4d. per rupee.

|| Fiscal years.

(a) not available.

m — Metric tons.

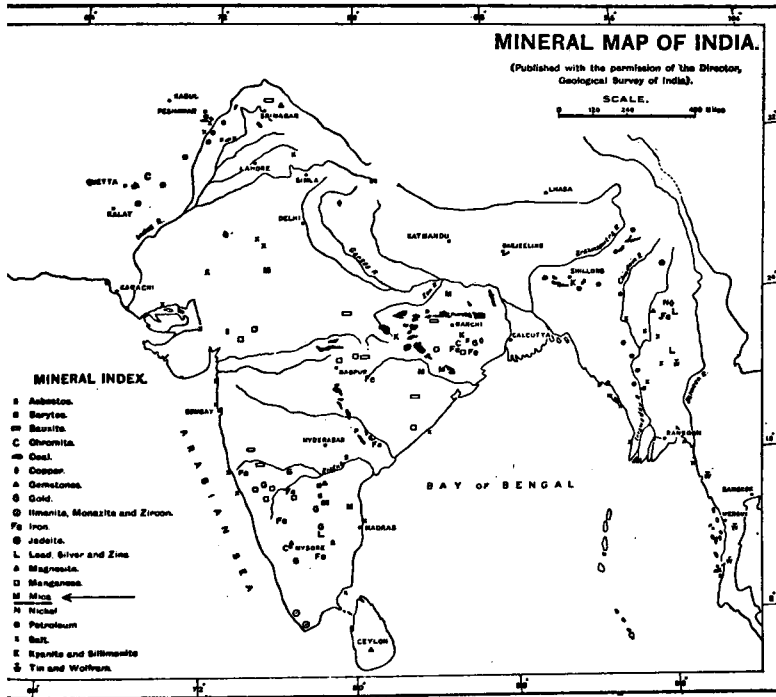
TABLE III.
Distribution of production by Provinces and States (in cwt.)

Year.	All-India total.	BIHAR (Formerly Bengal).*					MADRAS.					RAJPUTANA (Ajmer- Merwara).	STATES.					
		Hazaribagh	Gaya.	Others.	Total.	Per cent.	Nellore.	Nilgiri.	Others.	Total.	Per cent.	Gwalior.	Shahpore.	Jaipore.	Mysore.	Travancore.	Total State.	Burma.
1890	T 309	..	..	..	T 290	..	..	..	T 100	..	..	..	..	..	..	..	..	..
91	230	..	..	..	" 93	..	..	..	137	..	..	..	..	..	..	..	..	..
92	122	..	..	..	" 120	..	..	..	2	..	..	..	..	..	..	..	..	..
93	196	..	..	..	" 193	..	..	..	4	..	..	..	..	..	..	..	..	..
94	185	..	..	..	" 180	..	..	..	T 3	..	..	..	..	..	..	..	..	..
95	403	..	..	..	" 376	..	..	..	" 23	..	..	..	..	T 23	..	..	..	..
96	335	..	..	..	" 311	..	..	..	" 22	..	..	..	..	" 23	..	..	..	..
97	693	..	..	..	T 445	..	..	..	" 246	..	..	..	..	" 23	..	..	..	..
98	T 425	..	..	..	" 267	..	..	..	" 151	..	..	..	..	" 23	..	..	..	T 18
99	" 620	..	..	..	" 356	..	..	..	" 262	..	..	..	..	" 23	..	..	..	" 18
1900	" 931	..	..	..	..	..	..	..	59,221	..	..	..	..	" 23	..	..	..	T 51
1	" 1,031	..	..	..	..	..	..	..	3,659	..	..	..	..	" 23	..	..	..	..
2	" 996	..	..	..	..	..	..	..	1,890	..	..	..	..	" 23	..	..	..	..
3	" 936	..	..	..	..	..	..	..	289	..	..	..	..	" 23	..	..	..	..
4	22,164	..	..	..	16,520	74	..	..	4,840	20	..	..	..	" 23	..	..	..	..
5	25,641	..	..	..	14,601	57	..	..	8,280	32	..	..	..	" 23	..	..	..	..
6	52,543	..	..	..	22,230	42	..	..	24,420	47	..	..	..	" 23	..	..	..	..
7	52,203	..	..	..	28,579	55	..	..	15,865	30	..	..	..	" 23	..	..	..	..
8	53,543	..	..	..	36,060	67	..	..	11,249	21	..	..	..	" 23	..	..	..	..
9	32,903	..	..	..	22,084	..	..	..	8,948	..	..	..	..	" 23	..	..	..	..
10	22,699	..	..	..	18,356	80	..	..	3,586	11	..	..	..	" 23	..	..	..	..
11	T 2,317	..	..	..	25,225	..	..	..	7,462	..	..	..	..	" 23	..	..	..	..
12	..	..	..	..	29,653	..	..	..	13,484	..	..	..	..	" 23	..	..	..	..
13	..	..	..	..	32,579	..	..	..	10,861	..	..	..	..	" 23	..	..	..	..
14	40,506	25,883	5,012	2,380	33,275	82	..	..	5,989	15	..	..	..	" 23	..	..	..	..
15	27,139	16,163	4,810	1,222	22,195	..	..	..	3,894	14	..	..	..	" 23	..	..	..	..
16	43,399	20,303	4,749	1,768	26,820	61	..	..	15,675	38	..	..	..	" 23	..	..	..	..
17	40,907	27,227	5,837	673	34,137	83	..	..	6,050	15	..	..	..	" 23	..	..	..	..
18	54,719	29,939	6,855	8,792	45,607	83	..	..	6,544	12	..	..	..	" 23	..	..	..	..
											290					308		

TABLE IV.
Distribution of exports of mica from India into the major or importing countries.

TOTAL EXPORT.																	
Year.	Block.		Splittings.		Mica Blocks and Splittings.		United Kingdom.		United States.		Germany.		Japan.		France.		Others.
	Cwt.	Rs.	Cwt.	Rs.	Cwt.	Rs.	Cwt.	Per cent.	Cwt.	Per cent.	Cwt.	Per cent.	Cwt.	Per cent.	Cwt.	Per cent.	
1908-09					26,392	..	..	..	..	..	..	..	..	..	..	..	..
1909-10					33,963	..	..	..	..	..	..	..	..	..	..	..	..
10-11					42,593	..	..	..	..	..	..	..	..	..	..	..	..
11-12					48,871	..	..	..	..	..	..	..	..	..	..	..	..
12-13					66,574	..	..	..	..	..	..	..	..	..	..	..	..
13-14					53,891	..	..	..	..	..	..	..	..	..	..	..	..
Average					45,381	33,06,210	25,133	..	7,689	..	7,300	..	..	..	..	..	1,364
14	not separately recorded prior to 1921				32,972	..	..	..	..	..	..	..	..	..	..	..	..
15					33,719	..	..	..	..	..	..	..	..	..	..	..	..
16					59,521	..	..	..	..	..	..	..	..	..	..	..	..
17					65,729	..	..	..	..	..	..	..	..	..	..	..	..
18					59,954	£937,906	59,954	..	..	..	..	..	..	..	..	..	..
19					49,583	..	..	..	..	..	..	..	..	..	..	..	..
20					59,098	86,34,488	54,177	..	3,872	..	..	..	..	..	..	..	1,049
21					76,517	1,06,54,380	46,300	..	27,056	..	..	..	..	..	..	..	3,161
22	4,011	18,42,469	17,651	32,15,314	30,944	63,94,113	19,376	..	8,304	..	1,469	..	..	..	..	..	1,795
23	9,001	17,80,494	34,144	40,04,751	43,145	97,85,245	15,905	..	18,234	..	5,752	..	..	..	..	..	3,254
24	12,401	16,46,944	70,895	64,29,578	83,296	80,76,522	20,213	..	52,886	..	5,822	..	..	..	..	..	4,375
25	15,258	28,81,623	54,837	65,67,545	70,095	94,49,168	27,114	..	31,923	..	4,528	..	..	1,179	..	..	5,301
26	14,952	33,21,061	84,747	73,12,062	99,699	1,06,33,123	36,118	..	39,928	..	16,395	..	..	1,186	..	..	6,072
27	15,882	34,04,399	74,125	75,95,678	89,941	1,10,00,077	31,618	..	47,038	..	4,984	..	..	1,340	..	..	4,967
28	14,259	32,82,248	63,229	50,81,724	77,488	92,63,972	38,298	..	18,410	..	11,014	..	..	3,876	..	..	5,890
29	12,413	30,81,724	82,066	62,73,407	95,479	93,54,946	42,556	..	23,968	..	15,286	..	..	3,983	..	..	9,686
30	17,799	41,40,349	98,276	63,66,485	116,075	1,05,06,834	40,132	..	48,348	..	10,190	..	..	7,506	..	..	9,899
31	14,824	28,61,021	68,085	47,26,710	82,909	75,87,731	38,478	..	23,982	..	7,788	..	..	5,050	..	..	7,611
32	8,276	14,95,203	44,698	26,53,565	52,966	41,48,768	22,891	..	12,378	..	3,831	..	..	4,810	..	..	9,056
33	6,693	13,82,135	40,328	19,66,808	47,021	33,48,943	22,389	..	11,264	..	5,013	..	..	788	..	..	7,567
34	15,702	24,29,357	40,945	16,62,676	57,717	40,92,033	22,505	..	19,812	..	6,161	..	..	1,067	..	..	7,102
35	20,617	35,20,930	72,301	25,09,595	92,918	69,30,525	29,606	..	39,517	..	10,013	..	..	1,763	..	..	12,019
36	23,774	43,34,680	118,040	37,00,001	141,814	80,34,681	37,448	..	69,397	..	12,813	..	8,274	3,713	..	..	10,169
37	27,235	45,72,240	150,429	46,04,271	177,668	91,76,511	43,049	..	93,080	..	19,053	..	9,125	7,743	..	..	5,674
	30,003	57,47,478	267,340	84,12,558	297,343	1,43,60,036	65,784	..	185,143	..	18,854	..	11,815	2,698	..	..	13,049

Empire mica, Indian mica in particular. As a result of this policy, the mica industry in general, in spite of a very heavy demand and an unprecedentedly high level of prices, experienced a serious set-back during the early war years. In April 1918, the following notification was issued by the British Government



(cablegram to New York by the American Consular representative in London):—

“Ministry of Munitions orders on and after April 15th, 1918, no mica may be purchased or delivered when within United Kingdom except under license. All persons must report to the Controller of non-ferrous materials, amounts of stocks, purchase, sales and deliveries and any contracts or orders made or given to or by them, requiring use of mica*.”

* Mineral Industry, 1917.

A Mica Ordinance was passed in India, to control the movements of Indian mica and all supplies within the Empire were controlled by the British Ministry of Munitions and had to be despatched to England. The reaction of these war measures affected the Indian mica trade very adversely. Mr. G. H. Tipper* of the Geological Survey of India described the effects of these restrictions in the following words :—

“Many mines after the outbreak of war closed down and production decreased by 40 per cent. during 1915. In 1916 the value of mica as a munition product became better realised and demand for better qualities of ruby mica from Bihar became insistent. A Government buying scheme was instituted and all stocks unduly withheld were requisitioned. Efforts were made to increase production, which rose almost to its pre-war figures. During 1917 and 1918, the demand for munition purposes became still more urgent and every effort was made to stimulate production. Prices were regulated by the Munitions Board in London and shipments were not allowed except to the United Kingdom. Restrictions were placed on the manufacture and shipment of splittings. In two areas, mining operations were carried out on behalf of the Government”.

Annual export of mica (blocks, splittings and films)

Annual exports of mica during the four years preceding the Great War, *i.e.*, 1910 to 1913-14, varied greatly between 42,593 cwt. (2,385 short tons) and 66,574 cwt. (3,728 short tons), but in 1914 and 1915, as a result of the general disorganisation caused by the war, it came down to about 33,000 cwt. (1,848 short tons) and 34,000 cwt. (1,904 short tons) respectively. With the outbreak of war, the German market was of course entirely lost and purchases of Indian mica by other consuming countries including the United States, under permit through London, were naturally very much reduced. In 1916, 1917 and 1918, however, when proper attention had been given to the importance of mica, the exports improved annually to 55,972 cwt. (3,134 short tons) and 65,729 cwt. (3,686 short tons), and this in spite of the fact that enemy countries were unable to secure Indian mica and restrictions were imposed elsewhere.

Since the termination of the Great War in early 1919, exports of Indian mica continued steadily to increase up to 1930. The average annual export between 1919 to 1930 was about 76,475 cwt. (4,282 short tons). From 1931 to 1932, an unprecedented depression prevailed in the general world trade and the mica trade also was hit very hard, the recorded export in

* Records Geol. Surv. India, Vol. LII, 1921.

1932 coming down to 47,021 cwt. (2,633 short tons) valued at Rs. 33,48,768. The exports of mica from India in 1935, 1936 and 1937, however, surpassed all the previous records, with 141,814, 177,664 and 297,343 cwt. or 7,942, 9,949 and 16,701 short tons respectively. This amounts to an annual average of over 11,500 short tons since 1935.

MICA AS A MUNITION MATERIAL

The importance of mica as a valuable material for electrical purposes has already been shown while discussing it in regard to the Great War of 1914-18. The race in armaments that has been developing in the past three years, as a result of the political situation in Europe and the Far East, is partly responsible, perhaps, for heavier exports of mica from India since 1936 and 1937. A considerable proportion of these exports may possibly represent "stock" for the eventuality of war conditions, resulting again in scarcity of mica amongst the non-British nations, as was experienced in the last World War. Stocks* in U. S. A. at the end of 1937 were almost three times as at the close of 1936.

Mr. Archibald Dickson, in his contribution "Mica, a Valuable National Asset", in the *Mining World* of 16th June, 1923, writes on the importance of mica in war: "that the comparative failure of the German air campaign, during the later stages of the last war, was due to a lack of mica". Although it is difficult to substantiate the fact by convincing data, circumstantial details lend strong support in justifying the presumption and the record-breaking exports of mica from India between 1935-1937, the years of intense war preparation in Europe, America and Japan, further confirm it. Japan of late has been a heavy purchaser which is presumably due to her present war needs and air campaign in China. The exports of 1935 to 1937 amount to 516,821 cwt. valued at Rs. 3,15,71,228, aggregating annually at 172,274 cwt. valued at Rs. 1,05,23,743.

STABILITY AND PRICES

The price of mica has not proportionately advanced along with the demands. In the year 1906, the year of the highest pre-war production and export of mica, the declared export value of Indian mica was about Rs. 73-8-0 per cwt. In 1913, it improved to Rs. 84-12-0. In 1919, 1920 and 1921, the average price advanced to Rs. 146-1-0, Rs. 139-4-0 and Rs. 206-10-0 respectively. The price realised in 1921 was the highest on record since the Great War. From 1922 a period of depression

* Mining Journal, dated 3rd September, 1938.

in mica started and the price declined to Rs. 97 per cwt. in 1923. In 1925, 1926 and 1927, the price recovered to Rs. 106-13-0, Rs. 122-6-0 and Rs. 119-9-0 per cwt. respectively, but since 1929 the price of mica has fallen, possibly irrecoverably, to below Rs. 100. In the previous peak year of export, *i.e.*, in 1929, with an export of 116,075 cwt., the price per cwt. was Rs. 90. In course of the three years 1935, 1936 and 1937, although the demand for mica has gone up spectacularly to unprecedented figures, the price of mica has steadily decreased to Rs. 56-7-0, Rs. 51-13-0 and Rs. 48-13-0 per cwt. respectively.

Co-operative Marketing

The following factors seem to be the principal contributories responsible for such low price for mica in India :—

- (i) Vastly increased export of low-grade splittings at the expense of costlier block mica.
- (ii) Export of a good proportion of waste and scrap.
- (iii) Under-valuation of exportable merchandise.

Besides the first two natural causes and the third probable factor, "cut-throat" competition amongst the Indian mica sellers is also primarily responsible for such low prices of mica, even in times of such accelerated demands. The Indian mica industry is pitifully disorganised and there is little co-operative spirit amongst the mica men in trade.

Due to deterioration in the grading and classification of many suppliers, a comparatively greater proportion of Indian mica is now passing through London than it has been the case for several years. Large mica merchants are now stocking goods in London for spot sale and forward deliveries and those who cannot afford to do so have either to retire or rest satisfied with local sales and cut-throat prices.

There are three principal mica areas in India, namely, Bihar (formerly known as the Bengal mica field), Madras and Rajputana. Of these, Bihar is the largest, Madras following next in importance and Rajputana is a poor third.

THE BIHAR MICA BELT

This area contains the most important ruby muscovite mica deposit in India, quality of which is considered the finest in the world. The belt lies within the province of Bihar and traverses, obliquely, the districts of Hazaribagh, Gaya and Monghyr. It runs in an east-north-easterly direction and measures a strip of land about 60 miles long and 12 to 14 miles broad. A large number of the more important workings

of this belt occur in or about the Kodarma Government forest area. The Bihar mica belt produces about 75 to over 80 per cent. of the total production of mica in India.

Special features

The schists are of great variety* and are metamorphosed rocks of diverse origin, some sedimentary, others igneous. The foliation planes of the schists and gneisses are generally in conformity and the whole structure suggests that the two have been folded together, the present appearance being due to denudation. The gneisses granite or "dome gneiss" (as it is often called from its characteristic mode of weathering) is composed of quartz and microcline with biotite and hornblende and accessory spodumene, zircon and apatite. Experience has conclusively shown that the more micaceous schists are the more favourable. The great development of pegmatite in areas close to spreads of the gneiss has suggested a generic relation between the two.

IMPORTANT MICA MINING CENTRES IN BIHAR

Hazaribagh

Locality

Bendi (24° 31' : 85° 28' 30")	Chakai
Charki (24° 34' : 85° 28' 30")	Buria
Domchanch (24° 28' 30" : 85° 45')	Singho
Gawan (24° 37' : 85° 58' 30")	Malia
Ghoranji (20° 33' 30" : 86° 12')	Bindro
Kodarma (24° 28' : 85° 39')	Terapur
Jorasemar	Mushnodi Gadi
Dhab (24° 35' : 85° 50')	"
Kabrabut	"
Tisri (24° 35' : 86° 7')	Dhorakhola
	Bandarchua
	Kharakdiha

The area in which the above localities lie contains the best mica reserve in India (of the world?). The well-known area of the *Mushnodi Gadi* comprises three villages named Jorasemar, Dhab and Kabrabut and the Government during the Great War, at the instance of the British Ministry of Munitions, selected this area for mica mining and worked mines at Jorasemar through the Geological Survey of India. Details of the working have been given elsewhere.

* G. H. Tipper : Records Geol. Surv. India, Vol. LII, 1921.

District Gaya

Locality

Rajauli (24° 39' : 85° 33' 30")	Dharpahia
<i>Saphi</i>	Ghiadhaur
Bhelowa	Jatasandh
Benlonjona	Jowatari
Dandi (Darhi)	Mohonaria
Sarkari Phulwaria	Khagarwa
Lachhmi	Sugoya
Sarsajhwa	Thanhi
Tandahia	Chatkari
Kendua	Bilarwa
Samseria	Seothowa
Pathlaia	Simratori
Hasua	<i>Faguni</i>
Baswaria	Dagdagwa
Bandarloria	Kari
<i>Belam</i>	Lalki Samseria
Aglagwa	

This famous area passed through the ownership of Sunderlal Ramkumar, J. S. Mull, Mohanlal and Mosamats Ful Kumari and Sundar Kumari and contains some of the most prospective mica mines in India.

District Monghyr

Locality

Debour (24° 35' 30" : 85° 35')
Singur*
Chatkari†
Maheswari‡ (24° 42' : 86° 19')
(Mahisri)
Nawadha (near Jhajha) (24° 47' : 86° 26' 30")

Manbhum.—Good muscovite mica deposits occur in this district and 29 and 148 cwt. of mica have been produced in 1935 and 1936 respectively. In 1920, 1921 and 1922 0.5, 4.0 and 4 cwt. respectively appear as productions in the G. S. I. Records.

* This famous mine produced a typical white mica and was reported in 1898 to have worked for 30 years (Mineral Industry, 1898).

† The "Bandemataram" mine at Chatkari was first worked by the late Babu Monoranjan Guha-Thakurta.

‡ During the Great War, Government worked mica mines here, through Bird & Co. The working report is not available.

Locality.—Telkufi Moko.

Bhagalpur.—This district also contains very good quality mica deposits and in recent years large clear mica sheets have been obtained.

Locality.—Badyanath.

The following are the reported productions:—

1916	..	..	19 cwt.
1917	..	..	4 "
1918	..	..	3 "
1919-35	..	..	?
1936	..	..	13 "

Singhbhum.—Books of muscovite measuring 3 by 2 inches have been found by Dr. Dey of the G. S. I. in a small pegmatite vein, about half a mile north of Laubera ($22^{\circ} 33\frac{1}{2}' : 86^{\circ} 4'$), in the district of Singhbhum (Records G. S. I., Vol. LXIX, 1934).

Palamau.—Dr. Dey has also noted in the pegmatites considerable deposits of mica, near Daltongonj, Lesliganj, Kini and Khorhi. At Kini and Khorhi, specimens of mica up to 5 inches diameter were observed (Records G. S. I., Vol. XXXII, 1905).

Santal Parganas.—Amba Pahar.

Sambalpur.—Ishaq, Jamuna, Daluli, Sambalpur.

Jhumri Tilaiya (Kodarma) and Giridih are the principal mica marketing and manufacturing centres. Tilaiya or Kodarma is the largest market for block mica and Giridih claims to be the largest centre of mica splittings. Giridih is famous for manufacturing of the finest class of splittings.

Messrs. F. F. Chrestien & Co., Ltd., are the biggest pioneer mica firm in Bihar, owning the largest acreage of mica lands and some of the richest deposits. Their mica mines are mostly situated in the undernoted areas:—

Lokai, Dhab, Kakni, Charki, Dhorakola, Bendro, Singho in Gawan area; Debour, Kalakthambi, Domchanch, Lachmibathan, Kakni, Delia, Charkapahar, Cherwa, Chitrapur, Birney, Balboli, Chatrabar, Mashnodi, Dhab, etc., in Kodarma area.

In 1902, 61 mines were operated in the Bengal mica field, producing 768 tons of mica, of which Messrs. F. F. Chrestien & Co., Ltd., alone were responsible for 628 tons. 5,254 persons were engaged in Bengal mica mining.

No reliable details about the important mica mines of the Bihar field are available, although this field contains many rich mica mines. A detailed survey by the Government, however, is now in progress in this area.

PIONEERS OF THE BIHAR MICA INDUSTRY

The following names may be mentioned as pioneers in the Bihar mica field:—

1. Mr. F. F. Chrestien and his associate Mr. Nil Madhab Ghosh*.
2. Mr. Raj Krishna Sahana.
3. „ W. R. Macdonald.
4. „ Akhoy Kumar Datta.
5. „ Monoranjan Guha-Thakurta.
6. „ L. Meirowsjy *alias* L. Moore.
7. „ Henrich A. Brandt.
8. „ S. O. Fillion of Ottawa.
9. „ W. D. Clyborn.
10. „ A. Mervyn Smith.
11. Rai Saheb Sundermull.

The following names appear in old records, who either did mining themselves or made indirect contributions to the development of the *Bengal* mica industry:—

1. Dr. P. Breton (1826).
2. Dr. J. McLelland (1849).
3. Capt. W. S. Sherwell (1851).
4. Mr. F. R. Mallet (1874).

Colour and quality of Bihar mica.—The mica produced in this province is predominantly of the ruby muscovite type, with a characteristically beautiful “ruby” colour, which is a special feature of Bihar mica. Another, but secondary, characteristic feature of this area is the fact that garnets found in association with mica in Bihar occur in the crystal habit known as the icositetrahedron (G. S. I. Records, Vol. LXX, 1929–33). Green, brown and white micas are also found in Bihar, while that of Sambalpur is pink, almost amethystine in tint. The Bihar pegmatite yields also many accessory minerals, *e.g.*, tourmaline, garnet, apatite, beryl, pitchblende and columbite (G. S. Records, 1921 : Vol. 53).

Lithium mica in Bihar.—Geological Survey reports of an occurrence of lithium mica in scaly aggregates in the pegmatites of Northern Hazaribagh near the village Pehraj. One sample has been examined and found to carry 3.71 per cent.

* Mr. F. F. Chrestien, born in Khanakul, Krishnanagar, Bengal, and in service with the East Indian Railway as a Civil Engineer over the Jhajha construction (main) line, was first interested in mica in about 1870. In 1880, Mr. Chrestien took entirely to mica business, having realised its commercial importance in America and settled down at Tisri. A direct contact was established with the American market, through the agency of Messrs. Eugene-Munsell and Co. (formerly Munsell Rollo and Co.) of New York. Mr. Chrestien's mica business was converted into a limited liability company in 1910. The mining properties of the company comprises of about 300 square miles in Kodarma and Ganwan zones, and the normal annual production of this firm alone is estimated at about 750 short tons of knife-trimmed block mica.

of lithium*. This mineral has been found in masses up to 8 cwt. in weight.

Importance of Bihar mica deposits.—The following extract is taken from the speech of the Hon'ble Mr. J. D. Sifton (later Governor of Bihar and Orissa), delivered in the Bihar Legislative Council, while introducing the B. & O. Mica Bill, 1927 :—

“The demand for mica, and particularly for mica of the best quality, has advanced by great strides in the past 30 years, owing to the development of the electrical machinery and equipment for which this mineral is at present absolutely essential, and unless a substitute for mica is found the demand will continue to grow. During the last war, importance of mica for electrical plant, motors, aeroplanes and other uses was so much realised that it was necessary for the Government to take charge entirely of the production and supply of mica to make sure that all the mica available was put to the best use of the British Empire and its allies. In any future war the mica supply will again be a matter of most vital importance and we have here, in this province in the Kodarma mica field, the most important deposit in the world, so far discovered. This Government, in a sense, is a trustee for a most important imperial asset. The mica industry, therefore, is of more than local importance. The supply is by no means inexhaustible and it becomes the duty of the local Government, as trustees of this important deposit, to conserve the available supplies and to keep the industry in a healthy and prosperous condition.”

Mining rent and royalty.—The Government Reserve Forest near Kodarma comprises an area of about 8 square miles. This is divided into 40-acre ‘squares’, which are leased out by Government at Rs. 50 per *square*. The lease is granted for 30 years with option of renewal on expiry, transfer being subject to Government sanction. The lessee is required by the terms of the lease to work continuously on one-fourth of the squares he holds but the rule is seldom enforced with literal strictness. This area has been extensively worked and contains hundreds of mines.

Nearly 80 per cent. of the rich mica deposits are in Government lands for which Government claims a royalty of 5 per cent. *ad valorem* on the pithead value of mica, in addition to the surface rent of Re. 1-8 and dead rent of Re. 1 per acre annually. Certificate of approval costs Rs. 50 with an annual renewal fee of Rs. 10.

Outside the Reserve Forest area the lands belong to *zemin-dars*. Many of the mines are undivided estates which practically form a sort of *family stock company*, each member of the

* Bull. Imperial Institute, 1932.

family claiming a percentage of the rent of a given area. Titles about the mineral rights are not infrequently in confusion.

As early as 1898, Messrs. F. F. Chrestien & Co., Ltd., operated 110 mica mines in Bihar, against 31 by Raj Krishna Sahana and 28 by W. R. Macdonald*.

THE MADRAS MICA BELT

The second largest area containing very rich mica deposits occurs in the eastern half of the Madras coastal plain, between latitudes 14° and 15° , where the belt stretches across the district of Nellore. Mica also occurs in the States of Travancore and Mysore. The mica belt covers an area of about 60 miles long and 8 to 10 miles broad, divided into four administrative zones within British India, namely (i) Gudur ($14^{\circ} 9' : 79^{\circ} 54' 30''$), (ii) Rapur ($14^{\circ} 12' : 79^{\circ} 36'$), (iii) Atmakur ($14^{\circ} 37' : 79^{\circ} 41'$) and (iv) Kavali ($14^{\circ} 54' 30'' : 80^{\circ} 3'$). Deposits in the other districts are not commercially very important. Mica chiefly occurs in the western parts of the districts where the land begins to rise to the "ghats".

Special features

The main belt is sickle-shaped, tapering to the south-east and to the north-west-east. The mica district of Nellore† itself "consists of a central V-shaped fundament of well-foliated gneisses" (Bull. Imp. Inst., Vol. III). The mica lands are mostly in low-lying plains, heavily covered by alluvial and sedimentary overburden.

IMPORTANT MICA LOCALITIES

Nellore District

Locality

Gudur ($14^{\circ} 9' : 79^{\circ} 54' 30''$)	Mangalpur.		Turimerla.
	Vodur.		Untukur.
	Patragunta.		Tummalalapur.
	Buranam.		Griddalur.
Rapur ($14^{\circ} 12' : 79^{\circ} 36'$)	Chennur.		Mudigodu.
	Sydapuram.	Atmakur	Prabhagiripatnam.
	Chaganam.	($14^{\circ} 37' : 79^{\circ} 41'$)	Amma Varipalem.
	Nandalagunta.		Taliperla.
	Ananta Moduga.		Bathulapalate.
	Varupalli.		Sri Kolann.
	Inikurti.	Kavali	Dundegam.
	Kalichedu.	($14^{\circ} 54' 30'' : 80^{\circ} 3'$)	Uppalur.
Marupur.		Guda Vallur.	
Biradavalu.			

* Mineral Industry, 1898 : Mines and Minerals of the British Empire, 1908, by Ralph S. G. Stokes.

† Mica in Nellore by Mr. A. Krishniya, Trans. Min. and Geol. Inst. India, Vol. V, 1910.

The following are some of the most important mica mines in this area :—

Tallabodu Shah.—The outcrop of mica here, according to Mr. Krishniya, is about 4 furlongs in circumference and as the name "Tallabodu" implies, it is a huge spindle-shaped deposit which, except at the top where the pegmatite outcrops, is covered by hornblende and mica schists. The deposits lie at either end of what appears to be a broad syncline.

Mr. Ralph S. G. Stokes, late Mining Editor, *Rand Daily Mail*, of Johannesburg, S. A., who visited the mica mines in India in 1906, reported that this mine was turning out as much as 50,000 lb. of mica per month at the highest with average record of 30,000 lb. cut mica.

The "T. B." mica is greenish spotted but not of very high quality. The mine is a large steady producer and Mr. Krishniya writes that it maintained an average daily production of 1,000 lb. trimmed sheet mica for over 10 years, with records of about 2,500 lb. or gross income of Rs. 2,000 daily in its active days, employing over 800 labourers.

Pallimitta.—It lies north of Sydapuram village. Mr. Stokes reported in 1908 that this mine was producing annually 250,000 lb. to 300,000 lb. of first-class mica for about 15 years. Production is both clear and stained.

"D" Mine.—About 1½ miles west of Inikurti village on the Podalakur-Rapur road. Mr. Stokes reported on it "This mine is one of exceptional interest, having been opened up with great success by an Englishman, Mr. Sargent. The deposit is a long lens 350 feet long by 150 feet wide, carried (in 1906?) to a depth of 60 feet by open-cut and mined for further 50 feet. Its yield was 1,000 lb. *per diem* in its more active days." The quality is silvery white, the finest in the district and is said to command a good price.

Lakshminarayan.—This is also a large deposit and is well reputed in the district.

Mr. Stokes observed that the above five mica mines rank amongst the greatest mica deposits of the world.

Sankara.—Three miles west of Griddalur village. Mr. Krishniya writes that it is a vein over 100 feet long and 40 feet across which is reported to grow richer at greater depths. Daily maximum yield exceeded 600 lb. at times.

Kalichedu.—This is another very rich deposit. It is in a field normally producing a green muscovite type of mica, but Kalichedu mica represents an exceptionally typical whitish ruby type of mica. Kalichedu pale ruby brand is well known in the London and Continental market and competes with the Bengal ruby mica generally as a "second quality" ruby. It was also marketed in London and the Continent under "BQ" brand. The maximum daily output of this mine was about 2,500 pounds.

Inikurti.—This was once a most famous mica mine in Madras area and produced very large mica crystals. One of its crystals measured 10 feet over the cleavage surface and 15 feet across the leaves (weighing probably about 85 tons), which is perhaps the largest mica crystal produced and so far known in the world. This is the first mine successfully worked by Mr. E. H. Sargent. It was exceptionally rich and the pegmatite was 300 feet long by 150 feet wide. The quality of the production was best light green.

Nilgiris

Muscovite mica occurs in several localities in the south-east Wynaad. From this area about 350 to 400 cwt. of mica are annually obtained.

The following are the chief localities of mica-bearing pegmatites which lie to the south-east of Wynaad :—

- (i) Gudalur. (ii) Devala. (iii) Nellakota.
(iv) Pandalur. (v) Cherambadi.

Of these the best mica of the district is known to occur in the neighbourhood of Cherambadi. The trend of the veins corresponds with the stroke of the foliation of the country rock and is usually east-north-east towards south-west, crossing the strike of the auriferous reefs at a high angle*.

District Coimbatore.—Muscovite has been found in corundum-bearing feldspar rocks near Karatapalayam ($11^{\circ} 3' : 77^{\circ} 35'$) and in numerous pegmatite veins in the same neighbourhood and near Padiyur ($11^{\circ} 3' 30'' : 77^{\circ} 33'$). Attempts to work it, however, proved unsuccessful owing to the unsatisfactory nature of deposits from an economic point of view.

District Vizagapatam.—Phlogopite in even sheets 4 to 5 inches in diameter have been found in the Waltair estate.

District Ganjam.—Veins of coarse pegmatite charged occasionally with mica have been found in the villages Gora-bandhi, Bodiamba and Jallundi situated a few miles from Russelkonda ($19^{\circ} 85' 30'' : 84^{\circ} 39'$). The Jallundi was the most promising of the three. The quality of the mica, however, was poor and very frequently penetrated by quartzite crystals.

District Malabar (Wynaad).—Promising veins of mica have also been discovered in the following localities, but their commercial prospects are not known :—

- Cherambadi ($11^{\circ} 32' : 76^{\circ} 22'$).
Devala ($11^{\circ} 28' : 76^{\circ} 22'$).
Gudalur ($11^{\circ} 30' : 76^{\circ} 33'$).
Nellakota ($11^{\circ} 34' 30'' : 76^{\circ} 27'$).
Pandalur ($11^{\circ} 29' : 76^{\circ} 24'$).

* Holland's Monograph on Mica Deposits of India : Memoirs of G. S. I., Vol. XXXIV, p. 65.

The books of mica in this area usually occur in the centre of the pegmatite veins with dyke-like masses of quartz on one side and almost quartz-free on the other.

As early as 1902, 69 mines were in operation in Madras, producing 228 long tons, the working areas being in Nellore, North Arcot and the Nilgiris with about 2,965 persons employed in mica mining.

Colour and quality of Madras mica.—Madras mica is characteristically of green muscovite type, somewhat pale green in colour and slightly stained, with the only typical exception of a ruby and brown type of muscovite mica, available from the Kalichedu mine. The green colour is thought to be due to the traces of chromium in its composition. The garnets of both Nellore and Hazaribagh are of the same variety, although they have different crystal shapes (G. S. I. Records, Vol. 57, 1925).

Dressing of Madras mica.—Madras mica is dressed by shears and is classified in rectangular sizes with meticulous care for assessment of duty on the mined output. Bengal sickle-trimming has also been introduced in several mines, including Kalichedu (introduced originally by Mitter & Co., Calcutta).

Mining rent and royalty.—Rent is charged at Rs. 50 (as "surface" rent) per acre annually plus Re. 1 per acre as "dead" rent for right of prospecting. Royalty is assessed at the rate of 5 per cent. on the pithead value of mica, fixed on the following schedule :—

		(Rate per lb.)			
		Stained mica.		Clear mica.	
		Rs.	As. P.	Rs.	As. P.
Class	I 4 sq. inches and under	..	0 2 0	0 3 0	0
"	II above 4 sq. inches and not above 8 sq. inches	..	0 4 0	0 6 0	0
"	III above 8 sq. inches and not above 16 sq. inches	..	0 10 0	2 0 0	0
"	IV above 16 sq. inches and not above 32 sq. inches	..	1 8 0	3 8 0	0
"	V above 32 sq. inches and not above 48 sq. inches	..	3 0 0	5 0 0	0
"	VI above 48 sq. inches and not above 64 sq. inches	..	4 8 0	7 0 0	0
"	VII above 64 sq. inches and not above 80 sq. inches	..	6 0 0	9 0 0	0
"	VIII above 80 sq. inches and not above 96 sq. inches	..	7 8 0	11 0 0	0
"	IX above 96 sq. inches and not above 112 sq. inches	..	9 0 0	13 0 0	0

and so on in proportion on this basis.

The size is calculated on the basis of the largest rectangle available from each individual sheet. Scrap mica is charged for at As. 8 per maund.

Zamindari land.—The Raja of Venkatagiri owns extensive mica lands in the Nellore district, and charges rent according to British rates, *viz.*, Rs. 50 per acre annually for mining and Re. 1 per acre annually for prospecting.

Pioneers.—The following names may be mentioned as notable pioneers in the Bihar mica industry :—

1. Mr. Sargent.
2. „ Wickham.
3. „ A. Subba Naidu.
4. „ A. M. Kuddus Badshah Saheb.
5. „ P. Chenga Reddy.
6. Madras Mica Co.

MADRAS STATES

Travancore State.—Mica occurs in Travancore* both in charnockites and in leptynites. The mica is usually phlogopite, but muscovite is also occasionally seen.

Two modes of occurrence have been noticed. In the Bunular mine, it is found to occur in a dyke of dunite and at Vathoorkava near Trivandrum it occurs in association with a dyke of norite. Besides these and similar occurrences in or in association with basic dykes, there are occurrences in pegmatite. A deposit near Grumeli is an instance of this kind of occurrence. Here large "books" of mica are found inter-crystallised with quartz and some feldspar in a pegmatite.

The most important centre of mica mining in Travancore has been Eraniel. Mica mining has been conducted in this *taluk* off and on for about 30 years, but the quality of marketable mica produced does not seem to be very high. Mining beyond the zone of weathering should give a better quality of mica, but there is no certainty whether a given mica vein will persist to any great depth from the surface. Many of the deposits have been found to pinch out at a short depth.

Amber coloured phlogopite, biotite and muscovite occur in the *Eraniel taluk* in the following localities. Attempts to work these, however, have not been successful.

Tipperamalai (?).
Tolicode (8° 14' : 77° 16').

* Records of the Department of Geology of Travancore, Vol. I., 1921.

Coastal sands containing quartz, monazite, kaolin, zircon, garnet, ilmenite have been worked in some places in the State. Productions of 175, 37, 41 and 53 cwt. appear in the Records G. S. I. for 1920, 1921, 1935 and 1936 respectively.

MICA IN RAJPUTANA

The third important deposit occurs in Rajputana, Central India, of which the major part falls within the British territory of Ajmer-Merwara. The quality of the mica is spotted ruby. The following are the important localities of mica occurrences in Ajmer-Merwara :—

Ajmer :

Near Ajmer ($26^{\circ} 27' : 74^{\circ} 41'$).

Bhenai ($26^{\circ} 3' : 74^{\circ} 50'$).

Talana ($26^{\circ} 19' 30'' : 74^{\circ} 55'$).

Merwara :

At Kalinjar ($26^{\circ} 0' : 76^{\circ} 9' 30''$).

Sawatmal ($25^{\circ} 54' 30'' : 74^{\circ} 13' 30''$).

Suliakhera ($25^{\circ} 49' : 74^{\circ} 8' 30''$).

Dr. A. M. Heron, Director, Geological Survey of India*, makes the following observations in regard to the working of mica deposits in Rajputana :—

“The mica deposits of the central plain of Rajputana have been worked intermittently to a small extent, principally during the Great War, but compared to that of Hazaribagh and Nellore, the mica is small in size and is much more liable to be cracked. Experience in other parts of India and elsewhere has shown that the best country rock for mica in pegmatite is muscovite schist, but this is rare in Rajputana and the chances of finding mica deposits of real importance are slight.”

District Ajmer-Merwara.—The majority of pits came into existence during the Great War, when mica was used extensively and deposits of even poor quality and extent were worked. With the fall in the price of mica and demand for better quality materials, most of these mines closed down.

The bigger of the two mines is situated about $2\frac{1}{2}$ miles N.W. of Shokla ($26^{\circ} 13' : 74^{\circ} 52'$), muscovite occurs in large books but its quality is not very good. The other pit worked was of small dimension, its location being near Baori ($26^{\circ} 12' : 74^{\circ} 59'$). The muscovite is in small books and of poor quality.

*The Mineral Resources of Rajputana. Trans. Min. and Geol. Inst., India, Vol. XXIX, 1935.

The following represent the location of the chief old pits in Ajmer-Merwara :—

Village.	Distance of pit from the village.
Bhatiani (26° 13' : 74° 49')	1½ to 2 miles N.
Shokla (26° 13' : 74° 54')	1½ to 2½ miles N. and S.W.
Ahera (26° 15' : 74° 59')	1 mile S.W.
Baori (26° 12' : 74° 59')	¼ mile N., also S. of village.
Dantul (26° 5' : 74° 50')	1 to 2 miles E. and N.N.E.
Deolia (25° 55' : 74° 54')	1¼ miles N.
Champaneri (25° 56' : 74° 54')	½ to 2 miles N. and N.N.E. and N.N.W.

Ajmer	Tellaira	Gadi (Garhi)
Bhenai	Bogla	Dudpura
Kalinjar	Kalera	near Beawar
Rawatmal	Ratanpura	Bisundni
Suliakhera	Thuni Thak	Beawar
Ramsar	Fehari	

Production of mica commenced in Ajmer-Merwara in 1905.

MICA IN OTHER BRITISH INDIAN DISTRICTS.

BENGAL PRESIDENCY

Bankura and Sikkim-Tibet.—These occurrences have not been commercially prospected or found workable.

The mica belt, now lying within the administrative province of Bihar, was formerly within the Presidency of Bengal and was as such known as the "Bengal mica field".

MADRAS PRESIDENCY

Coorg administration.—Muscovite mica of good quality was discovered in Coorg before 1897. It was reported that five or six localities were able to furnish sheet free from warping. The mica-bearing pegmatites extend over a wide area (Mineral Industry, 1897). Deposits in the pegmatite veins were found at Pallibitta (12° 14' : 76° 1') traversing a group of schists similar in character and origin to those associated with the deposits of Bihar and Nellore. The plates obtained by the Geological Department in case were large enough to yield 5" × 7" to 12" × 14" in size and were favourably reported from London. No development seems to have been undertaken for commercial exploitation of the occurrences in Coorg.

CENTRAL PROVINCES

Balaghat district.—There are old mica workings in the Baihar Subdivision. Some mica has been extracted as the result of exploratory work at Chitadongri ($22^{\circ} 8' : 80^{\circ} 31'$) and Bamni ($22^{\circ} 48' : 80^{\circ} 41' 30''$) in 1869. No further output is on record from this area.

Bilaspur district.—Numerous pegmatitic veins have been found to occur at Komochoki ($22^{\circ} 36' 30'' : 82^{\circ} 7'$), but the mica obtained did not exceed the size of 2 square inches, which in quality was second rate.

NANDGAON STATE, C. P.

Mica occurs in a small pegmatite vein about 20 yards long by $2\frac{1}{4}$ yards wide and striking north and south through fine-grained biotite gneiss in the bed of a stream at Tilairwar ($21^{\circ} 2' : 80^{\circ} 47'$), Nandgaon State.

The quality of the muscovite is good white and unspotted, but the maximum size of the mica "books" does not exceed $1\frac{1}{2}$ square inches. The occurrence is of no economic value (Records G. S. I., Vol. LXIV, 1931).

BASTAR STATE, C. P.

Plates of muscovite measuring 4 to 5 inches across were found in 1899 in a coarse granitoid rock, exposed in the Baordhig River to the south of Jungani ($19^{\circ} 45' : 81^{\circ} 43'$). The specimens obtained by the Geological Survey, however, were from the weathered outcrop but as they were damaged by gliding planes it has been thought that the prospects below ground are unattractive. (For lepidolite in the State *see* footnote on p. 134.)

THE PUNJAB

The Punjab, Kangra district.—Mica occurs in large plates at Mahan and Bhunsi ($28^{\circ} 71' : 77^{\circ} 7'$) and Kangra (Bhabec).

Crystals of brown muscovite, measuring up to 5 or 6 inches diameter and 1 or 2 inches thick, have been observed in the granite on the Satligreng at Wangtu Bridge ($31^{\circ} 32' : 28^{\circ} 4'$).

THE PUNJAB STATES

Gwalior.—Mica deposits have been worked in this State between 1925 to 1929 and the following productions have been reported :—

1925	..	..	120 cwt.
1926	..	..	320 "
1927	..	..	240 "
1928	..	..	140 "
1929	..	..	25 "

Shahpura.—No fewer than 15 deposits were regularly worked for mica under the impetus of war but at present only

those 4 miles west of Thanal, $\frac{1}{2}$ mile east of Biliyas and 4 miles south of Khamar ($25^{\circ} 45' : 74^{\circ} 50'$) are intermittently worked. The first named yields clear ruby mica and the other two spotted in books of fair size. One-third of the output of the dressed mica goes as royalty to the State (Trans. Min. and Geol. Inst., India, Vol. XXIX, 1935).

Patiala.—The Geological Survey of India reports the occurrence of muscovite mica in lenticular veins of coarse-grained granite intrusions in Aravali rocks in the Narnaul Tehsil. The localities specially mentioned are noted below :—

Gatasher ($27^{\circ} 58' : 76^{\circ} 6'$).

Saraili Musmuta and Panch Nanta ($27^{\circ} 53' 30' : 76^{\circ} 4'$).

“Books” of mica up to 9 by 6 inches in size are reported to have been obtained.

CENTRAL INDIAN STATES

Jaipur.—Mica measuring $10\frac{1}{2}$ by $5\frac{1}{2}$ inches was sent to the Colonial and Indian Exhibition from the State, as early as 1886. The quality was found to be inferior to the mica produced in the Bihar mica belt.

The following productions have been reported in the official records :—

1927	..	4 cwt.	1932	..	70 cwt.
1928	..	(a)	1933	..	70 "
1929	..	37 "	1934	..	151 "
1930	..	73 "	1935	..	160 "
1931	..	100 "	1936	..	95 "

Jhabua (C. I.).—Mica occurs at Kanas ($22^{\circ} 31' 30'' ; 74^{\circ} 36'$) and Ramapur ($22^{\circ} 39' : 74^{\circ} 35'$), but the deposits so far investigated revealed no commercial prospects.

Tonk.—Muscovite mica of good quality, in plates measuring 5 to 6 inches, across, has been found at several places in the Chattarbhaj Hills in the N.E. of Tonk ($26^{\circ} 10' : 25^{\circ} 51'$). In recent years some of the deposits have been commercially worked and good ruby mica is reported to have been obtained.

Kishengarh.—Promising veins have been discovered in this State, one mile to the S.W. of Dadia ($26^{\circ} 25' : 75^{\circ} 7'$), about a mile N. of Neagaon ($26^{\circ} 5' : 75^{\circ} 5'$) and 2 miles from Sarwar ($26^{\circ} 4' : 75^{\circ} 4'$), on the northern side of Nasirabad road.

Sirohi.—Plates of good quality muscovite, measuring 5 or 6 inches square, have been obtained near Rapira ($24^{\circ} 3' : 73^{\circ} 1' 30''$).

Rewa State (C. I. A.).—Mica occurs at Baraghatta ($23^{\circ} 58' : 82^{\circ} 47'$) in Singrauli, two miles to the S.E. of Pipra. It occurs in a low-lying ridge, about 300 yards long and 50 yards wide,

running in very coarse pegmatite rock which consists chiefly of quartz, muscovite mica, tourmaline and feldspar. This tourmaline is of the black variety known as schorl. Some of the tourmaline crystals have beautiful outline and are from 1 to 2 inches across.

Prospecting carried on in 1912 revealed sheets from 2 to 4 inches square. The depth of the trial pits was about 15 feet.

Another locality found of similar coarse pegmatite is near Nainaidhye ($23^{\circ} 58' : 82^{\circ} 38'$), 6 miles due west of Pipra. The pegmatite occurs in a small hillock. The pegmatites of Singrouli may be genetically related to the similar rocks of Bihar.

Udaipur State (Mewar).—Mr. H. C. Jones (Records G. S. I., Vol. 49, 1918) examined the belt of pegmatite-bearing schists and granites known to run through the State. Pegmatites were found near Nansa, offering very favourable prospects.

Some of the important localities which were worked for mica during the war by F. F. Chrestien & Co., Ltd., are Amlī, Nausa, Sorti, Benali, etc., in Saharan district. Some of these have recently been leased out again at $8\frac{1}{2}$ per cent. royalty with a guarantee for certain minimum sale. The mica is spotless ruby type and is reported to occur in fairly large books (Trans. Min. and Geol. Inst., India, Vol. XXIX, 1935).

Dr. Heron, of the Geological Survey of India, reported in 1931 that the pegmatite dykes of northern Mewar often contain marketable muscovite mica in considerable amount. This mica is stainless and obtainable in pieces up to 7 to 8 square inches. Superficial diggings were tried with fair success during the Great War (1914–18).

A good occurrence has recently been reported to occur in the neighbourhood of Nonsa, to the north of Gangapur ($25^{\circ} 13' : 74^{\circ} 18'$).

Jashpur State (Feudatory State).—Muscovite mica occurs in various sizes measuring up to 5 by 3 inches in the pegmatites of this State; the material visible at the outcrops is stained and no development has yet been undertaken commercially to determine their economic prospects. Dr. Dey of the Geological Survey of India has reported occurrences in the pegmatitic veins of the following localities :—

Jagmara ($22^{\circ} 47' : 84^{\circ} 8'$).

Rengola ($24^{\circ} 48' : 84^{\circ} 7'$).

Damerghat ($22^{\circ} 47' : 84^{\circ} 6'$).

Keondpani ($22^{\circ} 45'$).

Taratoli ($22^{\circ} 44' : 84^{\circ} 14'$).

Bartoli ($22^{\circ} 42' : 84^{\circ} 9'$).

Jharghaon ($22^{\circ} 42' : 84^{\circ} 12'$).

Barnijartoli, $1\frac{1}{2}$ miles E. of ($22^{\circ} 42' : 84^{\circ} 13'$).

ORISSA STATES

Mayurbhanj.—Mica occurs in pegmatite exposed at intervals along the Sankrai River in the neighbourhood of Jamgadih ($22^{\circ} 6' : 86^{\circ} 34'$). Plates measuring more than 8 square inches have been obtained from the outcrops near Sirsa ($22^{\circ} 14' 30'' : 86^{\circ} 42' 30''$) and Bangarposi ($22^{\circ} 9' : 86^{\circ} 35'$). It also occurs at Tiring (? Tiringdih $22^{\circ} 31' : 86^{\circ} 8'$) and Rai Bidi ($77^{\circ} 77' 30'' : 86^{\circ} 4'$) in the Bamanghati Subdivision of the State.

Bamra State.—Near Riamal, east of Brahmani Subdivision in the State, deposits of mica have been found in the pegmatites, but the size is small, being about 2 square inches.

Mica has also been traced at Khajuri Khaman, S.E. of Barkot in this State. There are pegmatites in which books over 18 inches across are said to have been obtained.

Dr. M. S. Krishnan of the Geological Survey of India reported, in 1932, having noticed "books" of muscovite mica up to 2 inches diameter in the veins of pegmatite, west of Tangarmunda ($22^{\circ} 5' : 84^{\circ} 21' 30''$), Bamra State.

Gangpur State.—Near Sarapgarh in the western part of the State an occurrence of muscovite is reported.

Bonai State.—Dr. M. S. Krishnan also reported on the occurrence of similar "books" of mica, which were found just south of Potatangar ($22^{\circ} 0' : 84^{\circ} 33'$), Bonai State. These "books" however were full of flaws (Records G. S. I., Vol. LXVII, 1932).

MYSORE STATE *

Mysore mica is practically of the muscovite variety. It is usually dark coloured in thick "books" and light reddish brown in thin sheets.

The following localities are known to contain mica-bearing rocks :—

(1) Hassan district :

- (i) On the eastern slope of the S.E. spur of the Somarigudda range, Δ 3526.
- (ii) A mile S.W. of Klyadi (Arsikere taluk).
- (iii) Half a mile N.W. of Δ 3647 near Yalgunda Forest Lodge.
- (iv) One mile S.E. of Hardur.
- (v) On ridge, one mile off from Krishnagar, two miles W. of Hole-Narsipur.
- (vi) The Kahbur block.
- (vii) At Sitalpur hill, 6 miles S.E. of Hole-Narsipur.

* Records of Mines and Geology, Mysore, Vol. XVI, Part I, 1917, and Mica in Mysore, Review of Mineral Production in Mysore, Bull. No. 11, 1915-29, by A. M. Sen.

- (2) Mysore district :
At Mundoor, near Undivadi Vadasamudra and near Tagadur.
- (3) Sringeri Jahgir :
Near Kikri, Sringeri Jaghir.

Some work was carried on in connection with the exportation of mica at the Vadasamudra block in the French Rocks sub-taluq. A quantity of 2,629½ pounds was collected during the year (1917?) which together with the balance of output of the previous year amounted to 4,828 pounds, the whole of which was sold for Rs. 1,630-13-3. The royalty paid to Government was Rs. 81-9-6.

The following productions appear in G. S. I. Records :—

1920	..	..	55 cwt.
1921	..	..	69 "
1922	..	..	120 "
1923	..	..	32 "
1924	..	..	15 "
1925	..	..	114 "

In the official records of the State, production has been reported from 1915.

BOMBAY PRESIDENCY

Narukot.—An occurrence of mica has been traced on a hill called Dhola Sadur lying to the S.W. of Jambhugoda (22° 21' : 73° 48'), but the mica appeared to be only in fragments.

Chota Udaipur (Rewa Kantha).—In Gabadia Hills within 3 miles of the town of Chota Udaipur (22° 18' : 74° 74' 4"), an occurrence of mica has been recorded, but further details are evidently not available.

MICA IN BURMA

As early as 1895, mica was found near Chaukkyia in Twiunngge township and in the various parts of the Megok township; 7 or 8 people were engaged in working the mica deposit in 1895 and about 32½ cwt. of mica were obtained, valued at about Rs. 80. Productions of 1½ tons and 5½ tons have been reported in the G. S. I. Records for the years 1895 and 1898 respectively.

Pegmatites of mica have been found associated with the granite mass mapped by Murray Stuart about 10 miles due east of Fort Hertz. Dr. Barnes in course of prospecting collected about 11 lb. of mica which though of low grade was quite saleable. Big books of mica do occur but the surface yields seem to be excessively stained.

Occurrences have also been reported in the undernoted localities :—

Myitkyina district : 1-2/5 miles west of Kawarowug ($25^{\circ} 28' : 95^{\circ} 35'$) on the path to the Siby Hka, where muscovite mica occurs in small books, some of which are about 2 to 3 inches in thickness. The pegmatite strikes almost north and south and is about 3 feet wide.

Another locality is situated $1\frac{1}{4}$ miles N.N.E. of Lachung-gahtaqug ($25^{\circ} 27' : 96^{\circ} 34'$) in the head-waters of a small stream running W.N.W. Small "books" of mica were seen scattered on the surface and on digging into the pegmatite to a depth of 3 feet, mica was seen to continue in small "books".

Bastar State, Central Provinces

Lepidolite.—Near Mundval ($18^{\circ} 39' : 81^{\circ} 56'$) is found an occurrence of fine-grained lepidolite in a pegmatite dyke cutting green stone. The mineral occurs over a length of nearly a mile, in the centre of the pegmatite dyke. Mr. Crookshank of the Geological Survey estimates that the mineral will amount to about 15 tons for every foot in depth of the pegmatite extracted. The lepidolite contains 3.34 per cent. lithium oxide.

Chapter VII

MICA IN FOREIGN COUNTRIES

ASIA

MICA IN CHOSEN (KOREA)

It was at the close of 1906 that deposits of mica in Tansen-gun became known to the Japanese, though it was known to the Koreans in much earlier times. In December 1910, muscovite deposits began to be worked by Heigen-gun Heiando. The first shipment of Korean mica to Europe was a lot of about two tons phlogopite mica, from the *Yonko mine*, which was worked by the *Nikkan Umno-Kabushiki-Kaisha*. Sanction was given to this Japanese Company in 1909 to set to mining at once*.

Economically important deposits of muscovite are fewer in Chosen than those of the phlogopite. As in Canada, the phlogopite mica is found in association with pyroxenite and altered limestones of pre-Cambrian age. These rocks are developed chiefly along the Machonnyong mountains, which extend northward from the treaty port of Joshin in the north-east portion of Chosen. Muscovite, on the other hand, is found in many places in the gneiss and granite areas which make up the greater part of the country†.

DISTRIBUTION OF MICA DEPOSITS IN CHOSEN

The distribution of mica, according to the two principal types of mica deposits in the country, is given below :—

Muscovite mica.—Heigen-gun (Heigen district), South Heian; Kosei-gun, South Heian; Angaku-gun, Kokaido; Shinsen-gun, Kokaido; Koshu-gun, South Chusei; Shoshy-gun, North Keisho; Anto-gun, North Keisho; Shinko-gun, South Kankyo; Wojo-gun, Kogendo.

Phlogopite mica.—Suian-gun, Kokaido; Hosan-gun, South Kankyo; Joshin-gun, North Kankyo, Tansen-gun, South Kankyo; Kitshu-gun, North Kankyo.

* Mica in Chosen, Bull. on the Mineral Survey of Chosen, Vol. I Part 2, by Shigitaro Kawasaki, 1916.

† Mica by H. S. Spence, p. 29.

Biotite mica.—Koshu-gun, South Chusei; Heiko-gun, Kogendo; Shinko-gun, South Kankyo*.

Of the mica mines worked, the Hoshi-kazan (Hoshi mine) and the Kitsu Umbo Kozan (Kitsu mica mine) are best known.

Quality : The quality produced in Korea is both muscovite and phlogopite, the latter being predominant.

In 1924 the output of mica in Korea has been reported at 582 tons (Hobson).

MICA IN JAPAN†

Although Japan is credited with a small mica industry, the bulk of its production seems to consist of scrap, used in grinding. The Prefectures of Yamaguchi, Sartana and Nagasaki are reported to have produced considerable quantities of mica, the output in 1922 and 1923 having been recorded at 33,069 and 949,089 pounds valued at \$8,150 and \$7,253 respectively.

Regular statistics of production and consumption are not available nor the proportion of sheet and scrap out of the recorded output is known. Production of sheet mica, however, appears to be quite nominal if any. We have to depend on the statistics of the Imperial Institute for any reliable data about Japan.

The production of mica in Japan and Chosen (Korea) is exclusively handled and consumed by Japan.

Tanokamiyama, Omi Pr., is the chief locality for crystallised mica. Well-defined crystals are of rare occurrence.

The following are amongst the known localities, but reliable information in regard to their productivity of sheets and scrap is not available :—

Biotite.—From Mayamori, Rikuchu Pr., mica occurs in granite and forms hexagonal plates 60 mm. in diameter. Biotite from Miyamoto, Kai Pr., also occurs in granite in greenish black plates, which are weathered.

Vermiculite occurs at Hajikano in the Rai Pr., which is locally known as "Hiru-isbi" or "leech stone", in hexagonal plates less than 5 mm. in diameter. This biotite mica is reported to be rich in iron and alumina but comparatively poorer in magnesia. The following represents the chemical composition :—

SiO	Al ₂ O ₃	Fe ₂ O ₃	FeO	CaO
38.45	13.35	22.73	1.71	2.22
MgO	Na ₂ O	K ₂ O	H ₂ O	Total
7.85	2.16	2.25	7.20	= 99.92

* International Trade in Mica, by J. Ulmar, 1930, N. Y., U. S. Trade Promotion Series No. 95.

† Minerals of Japan, by I. Wada, 1904.

A variety of *zinnwaldite* occurs at Tanokamiyama, forming six-sided plates with a zonal structure representing the under-noted compositions :—

SiO	Al ₂ O ₃	Fe ₂ O ₃	MnO	MgO
46.13	17.03	4.64	6.27	1.29
K ₂ O	Na ₂ O	TiO	F	H ₂ O
10.09	4.12	2.77	6.89	2.31
= 103.53				

Muscovite.—From Takayama, Mino Pr., the size of the mica obtained varies from 30 to 60 mm. in diameter. The plates obtained from Takanokamiyama are smaller, 5 mm. in diameter. The following represent the composition of the Japanese muscovite :—

SiO	Al ₂ O ₃	Fe ₂ O ₃	MnO	CaO	MgO
41.26	26.24	12.79	2.28	<i>nil</i>	1.29
43.44	29.56	6.68	<i>nil</i>	0.53	2.13
K ₂ O	Na ₂ O	F	H ₂ O		
9.54	2.80	2.0	0.98	= 99.24	
10.11	2.51	<i>nil</i>	5.14	= 100.10	

Occurrence of *lepidolite* has been reported in Suizana, Ise Pr., in coarse-grained granite of rose colour plates, sometimes 18 cm. in diameter. *Lepidolite* is also reported in the Komonom, Ise Pr., in rosy scales scattered through quartzite rock.

Japan, one of the largest importers of Indian mica.—Japan has in recent years become the third or the fourth largest buyer of Indian mica, second to or sometimes replacing Germany. The large requirements of mica by Japan is an index to the marvellous expansion of the electrical, radio, wireless and aeroplane-making industries in Japan.

“ In 1918, Japan had nearly 700 Central station systems, 530 electric power and light systems, 42 electric tramways and 48 combined railways and lighting systems together with 1,609 private and 53 government plants. Even before or during the Great War, the country was changed from an exclusive importer of electrical goods to an exporter.”* Since then, she has made further tremendous advance and India's exports of mica to Japan are annually growing.

MICA IN CEYLON

Occurrences of mica chiefly lie in the Kandy, Ratnapura and Galle districts in Central and South Ceylon, including the province of Sabaragamuwa. The deposit occurs generally in pegmatitic veins, rarely wider than 2 feet and often in association

* U. S. Mineral Resources, “Mica in 1918”.

with metamorphosed limestone. It bears a genetic similarity to the Canadian phlogopite occurrences.

Early history.—Little mica mining was done in Ceylon prior to 1918; no regular mining was undertaken till 1909 from when mica deposits were worked rather intermittently. Mica mining came to be a regular feature in the Ceylonese mineral industry from 1918. Although the occurrence of mica was known from 1897, during the Great War (1914–18) interest in mica was renewed. The British Government needed large quantities of mica for munition purposes. A purchasing arrangement was made on behalf of the importers in London and the principal mining surveyor in Ceylon was placed in charge of the scheme. Payment was stipulated at 75 per cent. of the value in Ceylon, a commission of 5 per cent. being chargeable for the expenses of the Ceylonese Government.

Poor prospects for Ceylonese mica in peace-time markets.—Cessation of hostilities, in early 1919, caused a slackening of the mining activities and most of the pits opened during the war boom of 1918–19 were soon closed down. Some of these mines, however, have been worked intermittently in times of accelerated demands and high prices. Since 1935, the general trading conditions have improved, culminating in heavy demand for mica in 1937 and this also has resulted in several leases for working mica mines in Ceylon. But mining has scarcely been encouraging or systematic, except under war stimulus.

Quality and size not quite satisfactory.—Small sizes, inferior quality and excessive cost of production do not permit sustained economic exploitation of the Ceylonese mica deposits. Sporadic working has been attempted at times, which takes a significant turn only in times of brisk demand and high price levels.

Quality of mica.—The mica is phlogopite, found often in pegmatitic veins, not generally exceeding 2 inches wide, traversing a granite rock at the boundary of limestone bands*.

“The Ceylonese phlogopite sometimes is reported to be better than the Madagascar type, for which London dealers sometimes place standing order. The manager of the Colombo Mica Works opined in 1932 that the occurrences of mica are innumerable, including the large deposits, capable of yielding clear plates of over 12 square inches.”†

MICA IN CHINA

A large deposit is said to have been exposed in an area of 50 square miles from Kiao-chau Bay. The mica-bearing pegmatite dykes are reported to be 10 feet thick. Much of it, however, was found discoloured by foreign matters.

* J. Ulmar, *International Trade in Mica*, 1930.

† *Mining Journal*, London, 31st October, 1931 and 12th March, 1932.

Mica occurs in several other provinces in this country but the mining conditions are extremely difficult to encourage systematic development. Some workings have been reported near Sunghan* in the province of Szechuan, North China, and the quality of the mica is said to be good and quite marketable and the price quoted is about 5*d.* per lb. A company was organised for working the mica deposits. No detailed statistics about the mining or disposal of mica are available.

Transportation over hills and mountains till waterway is reached is difficult.

The quality is good though somewhat cloudy. Also reported from Tschoutschong province, Shantung. These deposits lie far away from convenient channels of transportation.

MICA IN COCHIN CHINA

Cochin China is reported to produce a small amount of phlogopite but no report of output is available.

MICA IN AFGHANISTAN†

Fine quality of mica was discovered in this country by the Afghan mineralogist, Mr. Aga Khan, who has found new veins of rich mica in Tangi. In April 1930, the Afghan Legation in London invited applications from suitable corporations or firms for the examination of the deposits in question with a view to the grant of a monopoly concession. Nothing further is known.

MICA IN TIBET‡

Occurrence of mica near Tenki, a few days' journey from Giagong, was reported in 1899. The type of the occurrence is said to be green muscovite resembling the Nellore quality.

AMERICA

MICA IN UNITED STATES

Early history.—Mica mining was carried on in North Carolina by Red Indians before Europeans set their foot on the New Continent. Many ancient workings have been discovered in western North Carolina, with thousands of tons of debris lying in dumps, proving beyond doubt that mica mining was once an important occupation of the people. The purposes for which mica was employed are unknown. It is, however, presumed that mica, as in India, used to be extensively applied in the preparation of medicines, ornaments, glazing and as decorative medium, etc. Ornaments made of mica have been

* Chinese Year Book, 1919.

† Mining Journal, dated 12th April, 1930 and 9th May, 1931.

‡ G. V. Hobson, *Mica and Its International Relationships*.

found in the graves of the mound builders in the Mississippi valley. These workings, however, were restricted to the weathered portions of pegmatites in which the feldspars have been kaolinised and the rock rendered soft enough to be mined with primitive tools like picks and shovels. In this country some of these workings have led to the trace of very good mica deposits and some old worked pits on re-opening have produced large quantities of fine mica. This fact illustrates the knowledge of the ancient mica miners in the prospecting and mining of mica.

Mr. W. B. Phillips* mentions of a class of prehistoric mica miners in the State of North Carolina now extinct, who possessed considerable skill in locating valuable mica deposits and some of the ancient workings, re-opened in 1868-69, following their leads, yield excellent quality of mica.

The *Ruggles* mine, situated in the Grafton County, in New Hampshire, opened in 1803, was the first known mica deposit worked on a commercial scale. The history of modern mica mining in the United States may be said to have dated from this year. The early productions of the "Ruggles" mine used to be employed almost exclusively for stove purposes as well as, to a limited extent, in glazing on gunboats where concussion from gunfire was sufficient to shatter glass†. Soon afterwards, other deposits were opened in New Hampshire and mining was carried on irregularly until shortly after the Civil War when the first large-scale production was arranged for in North Carolina and with the advent of this State as a large mica producer mining of mica in New Hampshire began to decline. Mica mining on a commercial scale practically began in North Carolina from about 1868 and since then this State has maintained its predominant position as one of the two largest mica producing States in the entire Union. Mica mining developed in Virginia and several other States including South Dakota between 1880 and 1885. New Mexico, Colorado and Idaho came in about the twenties of the present century. Mining, however, was carried on in a desultory way till 1840, and large-scale mica mining was practically undertaken since about 1860 which had been intensified since 1890, after the discovery of the insulating properties of mica. Mr. Phillips gives the following account of the re-discovery of the North Carolina mica deposits, crediting General Clingman with the first trace in 1867-68. General Clingman accidentally happened to know of the ancient workings and succeeded in locating some deposits in Cleveland County from where he obtained several barrels of good mica. He then took up prospecting in the Mitchel and Yancey Counties and selected the best points to

* U. S. Geol. Surv., Mica in 1878.

† U. S. Inf. Cir. 6208, 1929, p. 8.

work in the *Ray mine* in Yancey County, the *Silvers (Sinkhole)* and *Buchanan (Clarissa)* mines in the Mitchell County. These mines gave him a great success. General Clingman, however, could not reap the fruits of his pioneer work, as the partners, Messrs. Sloan and Mendon, did not consider the business a profitable line and abandoned the enterprise. One Mr. J. G. Heap of the firm of Heap and Clapp, dealers in stoves and tinware and stock dovers, chanced to pass by the way of the *Silvers mine*, which General Clingman worked alone for some time after Messrs. Sloan and Mendon left him. Mr. Heap realised the importance of mica and after disposing of the above business, took entirely to mica mining. This was in 1869. For several years Heap and Clapp conducted a very profitable business realising, for some of the mica, as Mr. Heap himself assured Mr. Phillips, as much as \$11.00 per pound*.

Mica mining was practically regularised from 1880, from which year annual statistics are officially recorded.

METHOD OF MINING IN THE UNITED STATES

Small mica mines are generally operated intermittently with the least possible financial stake, till they are taken over by capitalists or mining companies, who can arrange for efficient and economic exploitation of the deposits. Most of the small miners consist of farmers, who carry on mining during the winter months when they have little agriculture to attend: these miners usually suspend mining in times of depression to resume again when demand for mica grows brisk and prices become sufficiently remunerative.

The method of open quarrying generally employed by the miners is known locally as "goppering or ground-hogging", known elsewhere as "open quarrying". Pits are abandoned often as soon as the water-level is reached.

Working by inclines.—When small operations disclose prospective deposits of merchantable mica, shaft-working is adopted, with mining equipment. Breast stoping is the usual practice in many mines. In case of "flat-lying" deposits, however, "room-and-pillar" method is more suitable. Incline is driven in the pegmatite which serves as a haulageway as well.

Shaft-working.—In case of large profitable deposits, vertical shaft, "cutting the hanging wall at depth or tinking an inclined shaft along the footwall" is the ordinary practice†. Drifts are run from this shaft into the pegmatite and the mica-bearing rock is removed by breast or overhand stoping.

* U. S. Mineral Resources, 1882, p. 662.

† Inf. Cir. 6822, 1935, p. 16.

Mica is cleaned underground by knocking off the adhering quartz or feldspar, etc., and the "mine-run" is brought up to the surface for final dressing.

There are several large mica mines in the Union which are worked on ideal lines, with the most advanced waste-saving machinery and working methods.

Special features of the United States country rocks.—This has been described as follows* :—

"The country rocks of most pegmatites are in many places indicated by projecting masses of loose fragments of compact white quartz. The country rocks of most pegmatites that carry sheet mica of commercial quality are metamorphic rocks, mainly mica schist and gneiss. In some occurrences, the pegmatites follow the planes of schistosity of the country rock for considerable distances, in others it cuts across the schistosity. Many pegmatite masses are very irregular in size, shape and continuity and some form ledges and lens-shaped bodies of considerable extent. They range in thickness from a fraction of an inch to many yards and in length from two to three times to more than a thousand times their thickness."

Hornblende is rather common in granite but is less so in pegmatite; orthoclase and microcline are the most common varieties of feldspar in the pegmatite†.

TYPES OF MICA

Mica produced in the United States is predominantly muscovite.

Lepidolite deposits have been worked in considerable quantities in the States of New Mexico, California and South Dakota. Harding near Dixon and Rinconaden in New Mexico, Pala, San Diego County in California and Keystone in South Dakota are the prominent lithia mica localities. A deposit near Leavenworth in Washington has been reported in the Mining Journal (London) of September 1926, p. 468.

U. S. production consists largely of scrap

Mica produced in the United States consists of about 85 to 90 per cent. of scrap, the balance 10 to 15 per cent. representing "punch" and "circles" including about or less than 5 per cent. of its annual requirements of mica splittings.

* U. S. Mines Bureau Year Book, Mica in 1922.

† U. S. Geol. Bull., 740, 1923, B. B. Starrett.

Percentage of scrap in the "mined output" is greater usually in the western than eastern States. This greater proportion of sheet, therefore, in the deposits of the Eastern States, has rendered mica mining more profitable there than that of the western districts. Tariff protection has of course made mica mining economically possible for scrap alone, but sheet is undoubtedly a great advantage in mica mining. The following is taken from the U. S. Bureau of Mines Year Book, Mica in 1920:—

"Most mica mines must yield good sheet mica to make the mining profitable; it has already been found possible to work mica deposits for scrap alone. Mica to be of value as sheet must yield a rectangle at least 1½ by 2 inches (*i.e.*, No. 6 of *Bengal standard*), which must split readily and be free from cracks, rulings, corrugations, wavy structures and inclusions. It is safe to say that mica mining should be attempted only where first-quality mica yielding rectangles larger than 1½ by 2 inches can be obtained."

PRODUCTION OF SHEET AND SCRAP MICA

The United States is the largest world consumer of mica, both sheet and scrap; in spite of its being the largest producer of muscovite mica on a tonnage basis, it ranks far below India in respect of sheet mica production. India practically produces 60 to 80 per cent. of the world's total production of sheet mica.

Sheet mica.—As stated above, the annual domestic production of sheet ranges at an average between 10 and 15 per cent. of the country's total production, but since 1931 this percentage has far gone down, in some years to even less than 5 per cent. evidently due to the inclusion of *reclaimed mica* in the reported total production of mica in the United States. The amount of *reclaimed mica* assumed a very significant importance since 1935. The average annual production of sheet and scrap during the 10-year period (1925 to 1934) came up to about 645 and 7,390 short tons respectively, out of an average annual production of mica during this period of 8,350 short tons. During 1935 to 1937, however, these figures have come up to about 600 to 700 and 21,500 short tons respectively, out of an annual total production of 22,300 short tons. Production of *true scrap* and *reclaimed mica* since 1935 amounts annually to about 12,000 to 13,000 short tons and 8,000 to 8,500 short tons respectively.

The maximum production of sheet mica was in 1926 1,086 short tons against India's highest recorded sheet production as represented by exports of over 15,000 short tons in 1937.

TABLE V.
Production, imports and consumption of mica in the United States (in short tons).

PRODUCTION							IMPORTS						APPARENT CONSUMPTION			Exports	
Year	Block mica		Scrap		Total mica		Block	Splitting	Others	Ground	Waste	All mica		Sheet	Waste and Ground	Total	Exports
	Tons	\$	Tons	\$	Tons	\$						Tons	\$				
1868-79	109	423,175	..	..	109	423,175	(a)	(b)	(a)	(a)	(a)	(a)	35,613	..	..	..	..
80	41	127,825	..	..	41	127,825	"	"	"	"	"	"	12,562	..	..	..	..
81	50	250,000	..	..	50	250,000	"	"	"	"	"	"	5,839	..	..	..	..
82	50	250,000	..	..	50	250,000	"	"	"	"	"	"	5,175	..	..	..	..
83	57	285,000	..	..	57	285,000	"	"	"	"	"	"	9,884	..	..	..	..
84	74	368,525	..	..	74	368,525	"	"	"	"	"	"	27,555	..	..	..	..
85	46	161,000	..	..	46	161,000	"	"	"	"	"	"	38,685	..	..	..	..
86	20	70,000	1,000	10,000	1,020	80,000	"	"	"	"	"	"	43,107	..	..	..	..
87	35	142,250	2,000	15,000	2,035	187,250	"	"	"	"	"	"	63,340	..	..	..	..
88	24	70,000	..	..	24	70,000	"	"	"	"	"	"	..	..	..	..	..
89	25	50,000	196	2,450	221	52,450	"	"	"	"	"	"	..	..	..	..	..
90	30	75,000	496	6,200	526	81,200	"	"	"	"	"	"	..	..	..	..	..
91	38	100,000	..	..	38	100,000	"	"	"	"	"	"	..	..	..	..	..
92	38	100,000	..	..	38	100,000	"	"	"	"	"	"	..	..	..	..	..
93	25	80,629	156	8,300	182	88,929	"	"	"	"	"	"	..	..	..	..	..
94	18	43,793	191	8,595	209	52,388	"	"	"	"	"	"	..	..	..	..	..
95	22	50,381	145	5,450	170	55,831	"	"	"	"	"	"	..	..	..	..	..
96	25	65,441	222	1,750	247	67,191	"	"	"	"	"	"	..	..	..	..	..
97	59	80,774	740	10,452	781	95,226	474	..	..	..	..	..	..	..	..	..	..
98	55	103,534	3,599	27,564	4,064	131,098	439	..	..	..	..	..	478	150,082	533	3,599	4,542
99	49	70,587	1,505	30,878	1,559	121,465	850	38	..	..	..	..	883	275,984	932	1,505	2,442
1900	228	92,758	5,497	65,202	5,725	147,960	946	32	..	..	..	..	978	319,560	1,206	5,497	6,703
01	180	98,859	2,171	19,711	2,351	118,570	799	39	(a)	(a)	(a)	..	838	335,054	1,018	2,171	3,189
02	187	83,843	1,400	35,006	1,587	118,849	1,075	51	"	"	"	..	1,125	466,332	1,312	1,400	2,712
03	310	118,088	1,659	25,040	1,969	143,128	674	38	"	"	"	..	712	317,969	1,022	1,659	2,681
04	334	109,462	1,096	10,854	1,430	120,316	543	30	"	"	"	..	574	263,714	908	1,096	2,004
05	462	160,732	1,126	17,856	1,588	178,588	753	44	"	"	"	..	797	403,756	1,259	1,126	2,385
06	712	252,248	1,489	22,742	2,201	274,990	1,492	41	"	"	"	..	1,533	1,044,608	2,245	1,489	3,734
07	530	349,311	3,025	42,800	3,555	392,111	1,114	56	"	"	"	..	1,169	925,259	1,699	3,025	4,724
08	486	234,021	2,417	33,904	2,853	267,925	249	25	"	"	"	..	274	266,058	760	2,417	3,127
09	905	234,482	4,090	45,047	4,995	230,529	839	84	"	"	"	..	923	618,813	1,828	4,090	5,918

10	1,238	283,832	4,065	53,265	5,303	337,097	989	500	..	34	860(d)	980	724,525	2,761	4,065	6,283	10
11	944	310,254	3,512	45,550	4,456	355,804	664	500	..	86	534	664	502,163	1,598	..	5,120	220
12	423	282,823	3,226	49,073	3,649	331,896	994	355	..	172	532	995	748,973	1,405	3,512	4,644	190
13	850	353,517	5,322	82,543	6,172	436,060	308	560	..	145	705	1,013	947,780	1,863	3,226	7,885	170
14	278	278,540	3,730	51,416	4,008	329,956	180	500	..	202	229	882	629,484	1,160	5,322	4,890	245
15	277	378,259	3,959	50,516	4,236	428,769	217	600	..	172	249	989	692,269	1,266	3,730	5,225	45
16	433	524,485	4,433	69,906	4,866	594,391	352	850	..	181	392	1,383	1,027,356	1,816	3,959	6,249	70
17	638	783,874	3,429	52,908	4,067	806,762	328	1,275	..	45	484	1,648	1,430,048	2,284	4,433	5,715	40
18	822	731,810	2,292	33,130	3,114	764,940	370	913	..	6	596	1,289	1,541,129	2,111	3,429	4,403	40
19	773	483,567	3,258	58,084	4,031	541,651	362	1,049	(c)	..	..	1,411	1,488,769	2,292	..	5,442	60
20	843	546,972	5,723	167,017	4,565	713,989	649	1,584	"	..	..	2,233	3,189,377	(b)	..	6,798	150
21	371	118,513	2,577	56,849	2,948	175,362	164	646	67	..	..	877	1,091,906	"	..	3,825	70
22	539	194,301	6,641	114,045	7,186	308,346	213	532	157	11	..	913	1,330,622	"	..	8,099	567
23	1,031	311,186	8,054	129,695	9,086	440,875	552	2,151	934	28	..	3,665	2,404,848	"	..	12,751	902
24	730	212,035	4,709	87,242	5,439	299,277	373	1,810	671	46	..	2,900	2,326,906	"	..	8,339	759
25	897	321,962	9,695	173,537	10,592	495,499	323	1,620	475	33	..	2,451	1,798,827	"	..	13,043	1,211
26	1,086	410,184	7,043	136,643	8,129	536,827	432	2,615	70	42	..	3,159	2,450,834	4,133	7,043	11,288	760
27	756	212,482	6,280	110,139	7,036	322,621	420	1,294	4	15	1,294	1,730	1,630,309	2,470	7,574	8,766	1,438
28	841	230,956	7,760	132,422	8,601	363,378	706	1,748	2	8	1,748	2,052	1,426,395	2,885	9,818	10,653	1,831
29	1,018	286,321	6,253	117,901	7,271	404,222	701	2,526	..	10	(b)	3,238	2,223,408	4,245	(b)	10,509	3,094
30	733	177,307	6,732	109,100	7,465	286,407	510	1,163	(c)	4	1,839	3,479	1,283,616	2,408	8,571	10,944	2,366
31	481	111,830	6,621	99,415	7,102	211,245	227	764	..	2	2,065	3,048	620,784	472	8,691	10,151	2,620
32	169	45,882	7,040	83,777	7,209	139,659	149	472	55	7	1,360	2,032	287,667	790	8,400	9,241	1,549
33	182	53,179	8,751	98,159	8,933	151,338	350	671	268	9	1,618	2,897	473,757	1,203	11,648	11,830	1,563
34	292	90,268	7,719	99,791	8,011	190,059	408	1,073	159	4	3,505	5,115	762,622	1,773	12,834	13,126	1,751
35	468	161,150	18,852	243,951	19,320	405,101	392	1,520	..	20	2,993	4,878	908,384	2,380	23,725	24,198	1,499
36	659	203,879	20,955	260,594	21,615	464,473	455	2,238	66	25	3,893	6,678	1,205,568	3,347	24,828	28,293	1,777(p)
37	847	285,244	25,196	354,737	26,043	639,981	572	3,966	41	36	6,723	11,339	2,067,599	5,463	31,919	37,382	1,795(p)

* Scrap not separately recorded up to 1929.

(a) Not available.

(b) Not shown separately.

(c) 184 tons unmanufactured and 1,924 tons manufactured mica.

(d) Refuse from cuttings of domestic and imported sheet. (U. S. Bureau of Mines.)

(e) Imported ground.

(f) Cut and trimmed.

(1) Includes 6,667 short tons of reclaimed mica valued at \$111,345.

(2) " 8,258 " " " \$127,343.

(3) Estimated.

(4) Up to 1926, not separately reported.

ORIGIN OF TARIFF ON IMPORTED MICA IN THE UNITED STATES

The domestic output of mica up to 1884 proved sufficient to supply all the requirements of the United States but the greatly increased imports of fine quality ruby muscovite sheets from India from this year seriously affected the domestic mica industry and led to the introduction of the McKinley duty, placing imported mica on the dutiable list in 1890, at a rate of 35 per cent. *ad valorem*. Even this did not improve matters as would appear from the undernoted extract from the Mineral Industry, Vol. I, 1892 :—

“The Indian mica occurs in such large quantities and can be mined so cheaply that competition has been almost hopeless in spite of the recent *ad valorem* duty of 35 per cent. imposed by the McKinley tariff.”

This rate was revised by the Dingley Act, from 24th July, 1897, to the following schedule :—

6 cents per lb. for “unmanufactured” mica.

12 cents per lb. for “cut or trimmed” mica, with additional 20 per cent. *ad valorem*.

Importation of small sheet and scrap mica was practically rendered prohibitive by the increased tariff. As a matter of fact, the government of the United States has consistently followed the policy of giving adequate protection, revising tariffs from time to time as the circumstances in the industry called for.

The following represent further revisions since 1897 :—

From 1905 :

5 cents per lb. for “unmanufactured mica”.

10 cents per lb for “cut or trimmed mica” with 20 per cent. *ad valorem*.

From 3rd October, 1913 :

4 cents per lb. on “unmanufactured mica” valued at not above 15 cents per lb.

25 per cent. *ad valorem* on “unmanufactured mica” valued at above 15 cents per lb.

30 per cent. *ad valorem* on “cut mica”, mica splittings, “built-up” mica and all manufactures of mica.

15 per cent. on ground mica.

From 22nd September, 1922 :

4 cents per lb. on "unmanufactured mica" valued at not above 15 cents per lb.

25 per cent. *ad valorem* on "unmanufactured mica" valued at above 15 cents per lb.

30 per cent. *ad valorem* on mica "cut or trimmed" and mica splittings.

40 per cent. *ad valorem* for mica plates and built-up mica and all manufactures of mica, of which mica is a component material of chief value.

20 per cent. *ad valorem* on ground mica.

Under the tariff of 1922*, scrap mica was dutiable at 10 per cent. *ad valorem* under paragraph 1457 as "waste not specially provided for":

From 18th June, 1930 :

25 per cent. *ad valorem* on "waste and scrap" valued at not more than 5 cents per lb.

15 per cent. *ad valorem* on "untrimmed phlogopite mica" from which rectangular pieces not exceeding in size 1 inch by 2 inches may be cut.

4 cents per lb. on other mica, valued at not above 15 cents per lb.

4 cents per lb. plus 25 per cent. *ad valorem* on other mica, valued at above 15 cents per lb.

40 per cent. *ad valorem* on "cut mica".

25 per cent. *ad valorem* on films and splittings not cut or stamped to dimensions and not above 12 ten-thousandth of an inch in thickness.

40 per cent. *ad valorem* on films and splittings not cut or stamped to dimensions and not above 12 ten-thousandths of an inch in thickness.

45 per cent. *ad valorem* on mica films and splittings "cut or stamped to dimensions".

40 per cent. *ad valorem* on mica plates and "built-up" mica.

20 per cent. *ad valorem* on ground or pulverised mica.

Imported waste up to 1930 was taken in the customs, under the general classification "waste not specially provided for"

* U. S. Bureau of Mines Inf. Cir. 6205, 1929.

and in 1928 one company alone was reported to have purchased about 3,000 tons of scrap, most of which came from India and Africa. In recent years about two-thirds of the total imports came direct from India and further quantities of Indian mica including manufactures have been imported by way of Britain and other European countries*.

DISTRIBUTION OF MICA OCCURRENCES IN THE UNITED STATES

Alabama.—This State is not a large producer of mica. The pegmatites cut the enclosing rocks at all angles and occur as lenses, sheets and irregular masses, which have in most instances been kaolinised to a depth of 20 to 50 feet. The mica-bearing pegmatites are confined to the central part of the State, the best deposits being in Randolph, Clay and Tallapoosa Counties.

California.—Mica deposits have been traced particularly in the Eldorado County, Gold Lake in Plumas County, San Bernardino County, Lassen County, Kern County, Susanville and Salmon mountains.

Colorado.—A large quantity of mica is mined in this State, most of which however, being wedgy and tangle-foot, is unfit or defective for use as sheet mica. This mica is consumed by ground mica producers.

Mica in Colorado occurs generally in irregularly distributed pockets in the mountainous regions at elevation of about 8,000 feet from the sea-level. Colorado has little importance as a sheet producer.

Connecticut.—A good quantity of scrap mica is produced from time to time as a by-product of feldspar mining, especially in Middlesex, Hartford, New Haven and Litchfield Counties. Mica produced is generally ruled, wedgy and defective and is used for grinding. A small quantity of sheet mica is obtained from the Strickland quarry near Portland, Middlesex County.

Georgia.—Mica-bearing pegmatites occur in various localities in this State and the quality of the mica is reported to be fine. Most of the deposits lie in the Piedmont plateau. Georgia mica is usually of a good quality, surface production of course being clay-stained. Weathering extends to even 50 to 75 feet beneath the surface, rendering mining easy in the

*U. S. Inf. Cir. 6205, p. 23.

decomposed pegmatites, by means of pick and shovel. Mica deposits in this State have not been quite extensively developed yet.

Idaho.—Mining commenced for the first time in 1895 and a good quantity of sheet mica was produced in this State by "stopes and drift working". The following are amongst the noted mines:—

Levi Anderson mine (Latan County).	Morning Star.
Muscovite mine.	Sunshine.

Maine.—Good muscovite mica has been worked in this State, quarrying along with quartz and feldspar in Oxford County, Andros Coggin County (Auburn), Lincoln County, Sagadahoc County and several other counties.

Mica is obtained usually as a by-product of feldspar mining. The output is generally fit for scrap but certain sheet deposits have also been worked, notably in the *Hibbs mine* near Hebron and the *Mount mica mine* in Oxford County near Paris. Other noted mines are Black Mountain and Buckhill mica mine.

New Hampshire.—The mica belt in this State extends from Easton in Grafton County to Surrey in Cheshire County and is about 2 miles wide. The deposits in this region lie in mountainous country at elevations between 1,000 to over 3,000 feet above sea-level. The rocks are metamorphic schists and gneisses and muscovite schist interspersed with layers rich in quartz, black tourmaline and garnet.

Most of the mines are worked as open-cuts or trenches, with few operations driven underground. The sizes obtained are 10 to 12 inches in length and masses of 3 feet long have also been found. Beryl and tourmaline are the common associate minerals of the New Hampshire mica. There are several big mines, worked up with shafts, sunk to the depths of 300 feet or over, both vertical and inclined, with large chambers stoped out and numerous channels.

The famous *Ruggles mine* in this State is reported to have yielded over \$8,000,000 worth of mica since its first working in 1803.

New Hampshire produces a larger percentage of white mica than North Carolina; occasionally two and sometimes three distinct types of mica are found in the same pegmatite, as, for example, at the *French mine* of the New Hampshire Co., at Alstead, where white, ruby and green micas occur in horizons separated only by a few feet*.

† U. S. Inf. Cir. 6822, by Horton, 1935, p. 14.

Important mica mines in New Hampshire

Names of mines.	Location.	Remarks.
1. The Ruggles	Grafton County	Owned by General Electric Co., of Schenectady. This mine is one of the oldest producers and worked intermittently for more than a hundred years, producing large quantities of high grade sheet mica.
2. Ruby Mine	"	Owned by New England Mica Co.
3. Fletcher	"	
4. Wheat Mine	"	
5. Star	"	Star Mica Mining Co.
6. Pallermo	"	
7. Belden	"	
8. Golden Keene	Alstead	Golden Keene Co.
9. Keyes Mine	Grafton	
10. Hoyt Hill	"	
11. Powell	Franklin	Whitehall Corporation.
12. Union	Grafton	
13. Valencia	"	
14. Alexandria Mine	"	General Electric Co.
15. Eureka	"	
16. French Mine	Alstead, Cheshire.	New Hampshire & Mica Mining Co.
17. Parson	Cheshire	
18. Davis	"	

North Carolina.—This is the most important mica-producing State in the entire Union on the tonnage basis. The extensive pegmatite-bearing rocks, extending from Virginia to Georgia and Alabama, have attained their maximum development in North Carolina, covering here an area 70 miles wide and 200 miles in length.

Mr. D. B. Starrett* divides the mica-bearing region of this State in three tracts, namely (i) the *Blue Ridge belt* in the central, (ii) the *Cowee Black Mountain belt* to the west and (iii) the *Piedmont belt* to the east. The Blue Ridge mica is largely smoky or speckled and the Cowee Black and Piedmont mica is generally light or "rum-coloured". The occurrences in the Cowee Black Mountain and Blue Ridge belts are at elevations

* U. S. Geol. Surv. Bull. 430, 1909.

of 2,000 to 3,000 feet in the heart of the Appalachians where drainage is easy, the ground water-level not being deep and rainfall heavy. The Piedmont mines, on the other hand, lie at slight elevations in a flat country where the difficulty of drainage by tunnels renders pumping indispensable.

The following mines are amongst the noted ones in the State :—

Mine.	County.	Remarks.
1. English Knob	Spruce Pine	Carolina Mica Co.
2. Burr Knob	Franklin	Mineral Products.
3. Boyd Knob	"	Rickman Wright
4. Flat Rock	Mitchel	Flat Rock Mica Co.
5. Davis	Penland, Mitchel	J. C. Pitman & Co.
6. Hoot Owl	Estatoe, Mitchel	Carolina Mineral Co.
7. Cloudland	Mitchel	
8. Sinkhole	"	
9. Gibbs Mine	New Dale, Yancey	
10. Clarissa	Mitchel	
11. Ray Mine	"	Originally opened by G. D. Ray in 1869.
12. Hamilton	Ashe County	
13. Foster	"	
14. Walnut Knob	Avery County	
15. Plumtree	"	
16. Rock Mine	Johnson	

South Carolina.—The pegmatites occur here in mica schists and gneisses, lying mainly in the Piedmont plateau in the Oconee, Anderson and Greenville Counties. The Greenville deposit is fairly continuous and one single pegmatite of about 10 feet wide has been obtained. The vein matter and country rocks are greatly weathered to a depth of about 30 feet.

COMPARATIVE POSITION OF NEW HAMPSHIRE AND NORTH CAROLINA AS MICA PRODUCERS

New Hampshire and North Carolina are the two largest mica producers in the Union. New Hampshire normally produces about one-half and North Carolina more than one-third of the total domestic output of mica. North Carolina leads in the production of scrap and New Hampshire generally in the production of sheet mica. These two States together produce more than 90 per cent. of the country's total output of mica.

An unusual feature of the New Hampshire mica is that it began to export crude mica to England during 1926*.

* Eng. and Min. Journal, Vol. 123, No. 4, January 1927.

*Production of sheet and scrap mica in New Hampshire
and North Carolina*

(Figures in short tons.)

Year.	New Hampshire.			North Carolina.		
	Sheet. S. Tons.	Scrap. S. Tons.	Total. S. Tons.	Sheet. S. Tons.	Scrap S. Tons.	Total. S. Tons.
1921	246	537	783	115	1,353	1,468
1922	238	238	476	272	4,205	4,477
1923	418	1,078	1,494	565	5,005	5,570
1924	372	492	864	299	3,212	3,511
1925	560	1,953	2,513	296	5,095	5,391
1926	686	1,738	2,424	350	2,880	3,230
1927	360	1,284	1,644	333	2,995	3,328
1928	387	1,291	1,678	389	4,419	4,808
1929	492	1,657	2,149	447	3,245	3,692
1930	386	449	786	375	4,744	5,119
1931	221	295	516	195	5,312	5,507
1932	73	344	417	64	4,837	4,901
1933	83	532	616	81	6,918	6,999
1934	81	537	618	147	4,757	4,904
average ('24-'34)	267	1,068		332	4,520	
1935	65	395	460	256	11,831 ²	12,087
1936	143	250	393	365	10,840 ²	11,205

²Includes reclaimed mica as follows:—

1935	4,299	\$75,659
1936	5,265	\$82,903

New Jersey.—Mica has been mined in the Morris and Warren Counties and a special feature of New Jersey mica is its phlogopitic nature, more akin to the Canadian amber. The working of mica mine commenced in the State as early as 1875.

New Mexico.—Deposits of mica have been discovered near La Vegas and Petaca. *Las Tablas* at Rio Auriba County, New Mexico, owned by Mr. Phillips Hoyt, is the most important mine in the State. Most of the deposits lie in mountainous country at elevations of 6,500 to 8,000 feet. The mica produced is mostly defective and fit for scrap but on account of the distance of railroad and markets from the site of occurrence scrap business has not generally proved profitable.

Cribben Ville, Globe, American, Silver Ring, Moon Nos. 1 and 2, Queen, Stiles, etc., mostly in the vicinity of Petaca, are amongst the noted mines in the State.

New York.—Some mica of phlogopite type similar to New Jersey production has been found in St. Lawrence County of the State but no extensive mining has developed.

South Dakota.—Mica occurs in this State in pegmatites in the southern part of the Black Hills in the vicinity of Custer and Keystone, constituting in some places as much as 10 per cent. of the total pegmatites worked, varying up to 1 per cent. or less in other places. The output in active years (1907 to 1911) ranged annually between 250 to 750 short tons of rough sheet mica (Horton).

"New York" (of G. E. Co), "Custer" (of Reinhold Metallurgical Co.), "Climax", "White Star", "St. Luis", "Crown" (of Chicago Mica Co.), "Old Mike", all within a radius of 6 miles of "Custer" and "Peerless", "Hugo" (both of the Keystone Feldspar and Chemical Co.) at Keystone, are noted mines in the State.

Feldspar mines near Keystone produce mica as a by-product, usable as scrap.

Texas.—Mica has been found in the Culberson County as also in the Van Horn mountains, the quality being somewhat greenish brown in colour.

The deposits are mostly exposed by erosion of the overlying limestones and yield sheets of maximum sizes of 4 by 6 inches.

Virginia.—Mica in this State is practically limited to the region of the Piedmont plateau, S.E. of the Blue Ridge, falling in the Counties of Henry, Amelia, Goochland, Hanover as well as Amherst, Bedford, Charlotte, Franklin, Pittsylvania near the Rocky Mount and Prince Edward Counties.

Griggs and Rutherford mines in the Henry County and Amelia County may be mentioned as amongst the noted mines.

Most of the Virginia sheet mica is clay-stained, the mines being mostly shallow-worked and pegmatites decomposed to considerable depths. The quality however is generally good and the production is usable as stove plates, after elimination of clay stains.

MICA IN CANADA

Early history of the Canadian mica industry

Formerly the mines worked in Canada for exploitation of phosphate (apatite) deposits yielded mica as a worthless by-product. The famous *Wallingford* and *Blackburn* mines were amongst those phosphate mines which in later years yielded very large tonnages of sheet phlogopite mica. With the expansion of the electrical industry in the United States, mica came to be sought for at high prices and the continuously increasing demand for mica led to the development of the Canadian mica industry. Mining activities were thus stimulated for production of mica and a large quantity of mica was also recovered out of the enormous dump heaps of the Canadian phosphate mines.

"Phosphate boom" and the Canadian superphosphate industry.—There was a time in Canada when people explored

for apatite as a valuable raw material for the manufacture of super phosphate. This in time developed into a "phosphate boom" during the eighties of the last century. The Canadian super phosphate industry however, so far as the exploitation of apatite was concerned, received a fatal set-back since the discovery of immense sedimentary deposits of phosphates in the Mexican regions and several Central American States. This new factor affected the Canadian phosphate mining to such an extent that all the phosphate mines in Canada had soon to be closed down, some of which were later re-opened for exploitation of the mica deposits. Thus the waste product of one age proved to be the potential wealth of another. Mica mining practically developed into a separate industry about the year 1886, from which year there has been regular production*.

Phlogopite mica belt.—The Canadian phlogopite mica deposits occur chiefly in the provinces of Ontario and Quebec and the production is predominantly of phlogopite type from pyroxenic rocks. The belt lies north-easterly from Kingston, Ontario, on the St. Lawrence river to Ottawa and from there northward unto Quebec between the Gatineau and Lièvre rivers. The entire area measures about 150 miles long and 60 to 70 miles wide (about 1,200 square miles).

The occurrences resemble veins more closely rather than dykes, associated minerals generally consisting of pink variety of calcite, green apatite and greenish to greyish pyroxene. The country rock is a complex gneiss, evidently of sedimentary origin. The veins follow a north-south direction and dip about 45° east, appearing generally in outcrops on "domes of Laurentian gneiss rising 30 to 60 feet above the general level". The veins are in parallel series about 15 to 20 appearing in a zone, about one-fourth of a mile wide. They vary in width from a few inches to 3 or 4 feet. Much of the mica is of good quality available in sizes of several square inches†.

Muscovite mica belt (British Columbia).—Another belt with extensive deposits has recently been discovered in British Columbia, about the Big Bend of the Columbia river, in the west Kootenay Division of the Revelstoke Mining District, B.C., containing muscovite mica. The deposits are large, and situated at an elevation of 5,500 to 7,000 feet above the sea-level and are difficult for economic transport.

Nature of deposits.—This mica belt comprises of an area of about 20 miles in width and 200 miles in length and consists of schists and gneisses, containing mica-bearing pegmatites, in which biotite, tourmaline and garnet are the usual associates of mica. The quality of the deposits is reported favourably, but large

* The Mining Magazine, Vol. LVI, 1937.

† U. S. Rept. Inv. Serial 2357, 1922, p. 41.

mining has not developed yet on account of difficult conditions of transportation.

Biotite mica.—Biotite mica has been found in several places in the mica districts of Quebec and Ontario as well as in Manitoba but the quality obtained was too poor for marketing.

Lithium mica.—Lithia or lepidolite mica has been found in the Points du Bois district in Manitoba in 1924. The Canadian lithia mica competes with the lithia mica supplies from New Mexico, South Dakota and California in U. S. A. market for glass manufacture. Lithia mica, it may be noted, has no commercial value as sheet, with the solitary exception of a small output of sheets in Western Australia.

The following interesting features of the Canadian mica deposits appeared in the *Canadian Mining Journal* for May, Vol. LVI, 1937 :—

“The region in which mica deposits occur, is occupied largely by a basal complex of metamorphosed sediments, crystalline limestone, sillimanite, garnet gneiss and quartzite of the Greenville series, intruded (i) by a group of pyroxenic intrusives, gabbro, anorthosite, diorite, shonkinite, etc., the Buckingham series and (ii) by dykes, phacoliths, batholiths and masses of granite, syenites and related rocks.

“The phlogopite deposits may be classified according to their relationships into the following groups :—

- (a) *Contact metamorphic deposits proper*.—The phlogopite occurs in a zone lying along the contact of the pyroxenite and the limestone (Dacy property in Hull township, Hull County, Quebec).
- (b) *Irregular zones or aggregates of mica in metamorphic pyroxenite*.—This class is by far the most common. The phlogopite in this may occur alone or associated with calcite, apatite and other common minerals of the mica association. Typical examples of this type of deposit are in the Blackburn mine in Templeton township and the Ponpore in East Portland township in Papineau County, Quebec.
- (c) *Veins in metamorphic pyroxenite*.—Intrusives of the Buckingham series, sillimanite, garnet gneiss, quartzite and granite gneiss. The deposits of this type consist chiefly of diopside and calcite, the former on the whole predominating. They occur in crystalline limestone, granite and gneiss and are abundant and differ in no respect from the phlogopite deposits of other localities.”

Duty on mica in Canada

Mica and manufactures of mica :—

Preferential duty 15 per cent. *ad valorem*.

General 17½ per cent. *ad valorem*.

From France and Italy 17½ per cent. *ad valorem* less 10 per cent.

MICA MINING IN CANADA

Systematic mining on modern lines with mechanical equipment is generally considered risky in exploiting the mica deposits in Canada, owing to their irregularity in mode of occurrence, pockety nature in the major number of occurrences and difficult conditions of transportation. As a matter of fact, the pockety nature of the phlogopite deposits in most of the mica mines has made the mica mining operation in Canada rather difficult, particularly in drilling. This perhaps accounts primarily for the shallow-working of most of the Canadian mica mines.

Open quarrying.—This is the usual mining method. Hand or steam drills run by a light portable boiler are in general use. Air-drills run from a portable gasoline-driven compressor is the latest improvement.

On locating a deposit, an open pit is sunk, which facilitates the determination of the nature of the deposit, *viz.*, whether it is of a pockety nature or consists of a continuous persistent vein, on the basis of which the plan of development is determined. The depth reached in open-cut working seldom exceeds 75 to 100 feet.

Shaft-working.—In case of large persistent occurrences, of which several are known, shaft-working is employed. The shafts are sunk usually in a vertical direction and operations carried to considerable depths, some of which have reached 350 to 375 feet. Of these, the *Lacey mine*, *Wallingford mine*, *Blackburn mine* and *North Hill mine* are prominent. These mines are provided with the latest improved mining machinery and power is derived by means of steam or electricity.

Mining season.—Many mines in Canada are worked periodically by labour drawn generally from the farming class during the winter. Transportation is comparatively easier in winter than in other seasons.

History of some large Canadian mines

The Lacey mine.—Of the mica mines in Canada, the history of the famous "Lacey" mine near Sydenham, Ontario, dates back from 1880, when it was opened for the first time. This mine was at one time the world's largest and most important mica mine, yielding daily from 4 to 5 tons of *rough-cobbed* mica.

It was acquired from the original lessee by the present owners, the General Electric Co., of Schenectady, N. Y., in 1884. The individual mica crystals of this mine are very large and one single crystal obtained by the General Electric Co. is reported to have measured 9 feet across the plates and the vein at places attained to a width of 25 feet. The quality produced is classified in two grades, namely, (i) first class clear to dark amber and (ii) opaque milky amber. The following represents the composition of the clear quality mica produced by the "Lacey" mine* :—

SiO ₂	TiO	Al ₂ O ₃	Fe ₂ O ₃	MgO	
39.66	0.56	17.00	4.70	26.49	
Na ₂ O	K ₂ O	BaO	F	H ₂ O	Total.
0.60	9.97	0.62	2.24	2.00	= 104.83

G. E. C.'s great success.—The mine was not at first regularly worked and had been leased out for five years to a party, who after making a few attempts for some time abandoned further working as unproductive, just at a point within a few feet of an immense deposit of excellent quality mica. This deposit was exploited by their successors the General Electric Co., who met with excellent mica almost at the first attempt (1884).

The "Lacey" mine is worked by the Loughborough Mining Company of Sydenham, a subsidiary of the General Electric Co. They started operation in 1903 and from then the mine has yielded mica almost uninterruptedly up to 1928.

Mr. Spence gives the following working details† :—

"Mining has been centered on a single, very large and almost vertical vein deposit consisting of a solid mass of mica crystals with very little associated calcite or apatite. The deposit was originally worked by a shaft 185 feet deep with drifts run at 22-foot intervals along the vein. The longest drift was on the fourth level, this being carried 150 feet to the south-east and 65 feet to the north-west, a total of 215 feet. A cross-cut was also driven 60 feet to the south-west on this level to pick up a parallel vein which was followed by drifts for a distance of 160 feet to the south-east. Later it was decided to *glory-hole* the workings, and a large open pit, 60 by 70 feet, was sunk upon the main and north-east parallel veins. Most of the work in recent years has been carried out from this excavation and has consisted in drawing the pillars and caving the ground between the old stopes, the mica being recovered during

* Jour. Canadian Min. Inst., Vol. VII, p. 264.

† Mica by H. S. Spence, p. 69.

mucking operations. In 1923, a new shaft was sunk south of the main shaft to a depth of 180 feet."

The Blackburn mica mine.—This is one of the largest mica mines in Canada and was originally opened for phosphate in 1886 by the Phosphate Mining Syndicate. It was subsequently acquired by Blackburn Bros. With the decline of the phosphate industry, the mine was closed down, to be re-opened again with the introduction of mica mining in the country. This mine has produced a pretty large quantity of mica steadily for many years and has got large reserves of both mica and apatite (phosphate).

The quality produced is first class light amber and the proportion of commercially saleable mica to the gross mine-run is very high, of which, about 50 per cent. represent marketable sheets.

"Numerous openings exist on the property, which has been extensively prospected for both phosphate and mica. The principal excavation is a large open pit or *glory-hole*, nearly 400 feet long, 180 feet wide at its south-east end and 150 feet deep. Mining in recent years has been confined to the ground adjacent to the south-east end of the pit, where a number of old underground workings have been picked up and extended. These old workings consisted of three main drifts and stopes, 300 by 500 feet long, on the 180-, 240-, and 280-foot levels, and entered from a shaft 160 feet deep, sunk from a drift run from the bottom of the open pit. The mica occurs in large pockety bodies, which have been stoped out from staging erected in the drift, the large open stopes being in places 40 to 50 feet high. The drifts have been run mainly to the north and south, following irregular pockets of mica and phosphate enclosed in a matrix of green pyroxene. A few years ago a new vertical shaft, 8 by 12 feet, was put down 100 feet to the west of the south end of the open pit, to pick up the underground workings, and has been carried to a depth of 240 feet. Short drifts, run at the 100-, 150-, 200-, and 240-foot levels, connect the shaft with the workings. A shaft-house has been erected at this point and ore is raised by bucket and air-driven hoist.

The mica and phosphate bodies disclosed in the present workings are unusually large, and the mine contains large reserves of both minerals. The proportion of valuable mica to the total amount mined is also unusually high, about 50 per cent. being marketable sheet. The property has a well-equipped plant, which includes a hydro-electric power station on the creek between Dam and McGregor lakes, $2\frac{1}{2}$ miles from the mine. The head used is 22 feet, and

the developed power, 150 h.p. current, is transmitted at 2,400 volts by a 3-phase line to the mine, where it is stepped down and used to drive pumps, compressor, and various other mine equipment."*

Wallingford mine (Quebec).—This mine was also originally opened for phosphate in 1882. It is said to have produced over 3,000 tons of trimmed mica and 4,000 tons of phosphates.

Quality and special features.—The quality of the mica is first class light amber and the crystals are very large. One individual crystal of this mine is reported to have yielded \$33,000 worth of trimmed mica sheets. The occurrence is of both *fissure* and *pockety* types and the mica is first rough-cobbed at the mine and then forwarded to the trimming shops at Perkins. This mine has been a steady producer of mica for many years. Mr. E. Wallingford of Perkins, Papineau County, Templeton Que., is the proprietor, and its working equipment consists, amongst others, of one 80-h.p. boiler, 6 steam-drills, 4 steam-hoists and 6 boom-derricks.

"The working consists of a number of open pits, some of which have been carried to depths of 125 to 150 feet, sunk on pockets and leads and one large excavation, 170 feet long by 40 feet wide and over 200 feet deep.*"

The North Hill mine (Quebec).—This mine is owned by Blackburn Bros. of Ottawa and is one of the few mica mines in Canada containing persistent deposits of light silver amber shade of mica, with a vein of about 5 feet average width.

Mining equipment.—The nature of the occurrence facilitates systematic underground mining operations. This mine is equipped with a shaft house and electric hoist, the ore being raised on an inclined stepway. Air is piped from the plant at the central mine to run drills and the mine is electrically lit.

The mining work is conducted from an inclined shaft 8 by 6 feet, sunk along the lead reaching a depth of 325 feet with 6 levels, run at intervals of 50 feet each, the first level being 60 feet down. The lead is drifted for a maximum distance of 300 feet from the shaft and the mica is secured by overhead stoping methods.

Work commenced in 1908 and the production has continued intermittently to the present time.

"This is one of the few mica properties where systematic underground mining operations have been employed from the start in the exploitation of the ore-body, the system

* Mica by H. S. Spence, Ottawa, 1929, p. 63.

† Mica by H. S. Spence,

of work having been facilitated by the nature of the mica lead, which proved to be unusually regular and persistent. The deposit consists of a well-defined vein, dipping at an angle of about 60 degrees, carrying medium-sized mica crystals associated with pink calcite and apatite."*

The Lake Girard mine (Wakefield), Que.—This mine, situated 20 miles north-east of Ottawa, was once an excellent producer of mica with a large mica factory at Ottawa, but closed down in 1904. During a period of five years (1891–96), it is reported to have yielded 3,000 tons of sheet mica, with a daily record of 4½ tons of rough-cobbed mica from a depth of 210 feet. It is one of the cheapest worked mines in Canada.

Other notable mica mines in Canada

	Situation.	Remarks.
<i>The Chaibee mine.</i>	Township of Wright, Hull, Que.	Produced a large quantity for some time.
<i>The Father Guay mine.</i>	do.	do.
<i>Martin's mines in Huddersfield.</i>	Pontiac County, Que.	Greenish amber mica mottled with silver, in association with dark purple fluorite and allanite†.
<i>Taggart or Bobs Lake mine.</i>	Bedford, Frontenac County, Ont. (of Kent Bros. of Kensington).	A steady producer until 1925. Quality dark amber and large size.
<i>The Stoness mine.</i>	do.	Once a steady producer, worked from inclined shaft; gone up to 450 feet deep.
<i>The Pike Lake mine.</i>	North Burgess, Lanark County, Ont.	One of the oldest worked important mine. The Pike Lake mica sheets were shipped to France as early as 1860.

* Mica by H. S. Spence.

† This is a peculiar amber distinct from usual phlogopite.

	Situation.	Remarks.
<i>The McGie mine</i>	Quebec	Once yielded mica of good quality. Tourmaline, beryl and garnet were usual associates.
<i>Leduc mine</i>	Wakefield, Hull, Que.	Lepidolite producer. Associate minerals include amazonite, feldspar, quartz as also urinite, gummite and fluorite.
<i>Silver Leaf mine*</i>	Manitoba	Lithia mica producer. Spodumene is a by-product in this area.

Guatemala.—Muscovite mica occurs mostly in the Departments of Quiche and Baja, but large systematic production has not been successfully undertaken, presumably on account of the unremunerative nature of mica mining and unsuitable working conditions.

The Guatemala Mining and Development Co., an American concern, was the pioneer in the Guatemala mica industry. This firm developed mica properties in Quiche and Baja Verapaz. Once Sarecky and Chellas, another American firm, was the principal shipper of Guatemala mica during the Great War (1914-18).

Muscovite mica ranging from white to rum colour has been obtained in sizes from 2 by 2 inches to 10 by 12 inches. A deposit of greenish mica containing chromium exists in Salaria, Baja Verapaz†.

Bolivia.—Muscovite mica has been found in certain areas but the quality is inferior even when compared with the Indian heavily stained ruby mica‡. Bolivian muscovite is pretty hard and greenish in colour, often containing very fine cracks.

The mines so far worked, however, are reported to be quite large. The United States is the principal buyer of this mica.

Peru.—Mica deposit has been discovered near Mallendo, Peru, the port of Arequipa. The size of the production is scarcely larger than 4 square inches.

Some work has been done in pegmatite dykes and sheets of 9 square inches were found, but most of the output did not exceed 4 square inches.

* Worked by the Silver Leaf Mining Syndicate of Bradford, England.

† U. S. Mineral Resources : Mica in 1917.

‡ *Vide* letter to the author from Messrs. Jaroslaw's Erste, Berlin.

Mexico.—Small quantities of both muscovite and phlogopite mica have been mined on a small scale, but no detailed statistics are available.

Newfoundland.—Muscovite mica has been discovered in several localities in Newfoundland and in the neighbourhood of Labrador. No commercial regular working has been reported.

Mr. H. P. Wiggins* states that a very rare type of muscovite, nearly as clear and white as plate glass, was discovered and shipped to England from somewhere in the Labrador coast, the exact locality being unknown.

Costa Rica and Chile.—Small quantities of mica are entered in the United States as imported mica from these countries from which it is evident that some mica is mined in these territories. No regular statistics or further information could be had.

MICA IN ARGENTINA

Occurrence of mica has been known for many years but production did not come to a significant figure until 1919. The total exports of mica from 1910 to 1914 amounted to about 46 tons but the greatly increased munition demands since the outbreak of the Great War (1914–18) stimulated production of mica as elsewhere, so much so that 145 tons of mica were exported in 1919 alone. Production began in 1908 but the industry did not develop into regular scale till it had the stimulus of the Great War (1914–18).

Distribution.—Mica occurs in pegmatites in the Sierras of Cardoba and San Luis in the Cardoba Hills, particularly in the provinces of Cardoba, San Luis and San Juan but extending also to Catamarca, La Rioja, Tucumen and the territory of Los Andes. The mica-bearing area is widespread and there seems to be a large reserve of high-grade muscovite mica in Argentina. The veins are quite numerous and of varying dimensions as also of considerable magnitude.

Types of productions.—Mica is produced in commercial quantities in the provinces of Argentina, Catamarca, San Luis, Buenos Aires, Cardoba, La Rioja, Mendoza and San Juan.

Argentina Mining Code does not require the miner of a mineral to own land for its exploitation. Mining is generally done by individuals on a small scale† with little or no capital and the output of mica is sold to the factories or dealers in Buenos Aires. A small proportion of the sheets produced is consumed locally in the manufacture of electric heaters.

* Mr. H. P. Wiggins in the *Optician*, dated 25th October, 1912, on Mining, Preparation and Uses of Mica.

† Mica Industry in Argentina, Eng. and Min. Journal, Vol. 113, 1922.

MICA IN BRAZIL

Occurrence.—Mica occurs in Brazil in the Cayana and Popogris mountains as well as in the States of Minas Geraes, Bahia (to the east of Jacobina mountain range and near the Paulo Affonso Falls), Sao Paulo (at Juqua), Goyaz and Rio de Janeiro. These deposits are fairly accessible to railroads for transport to ports. In the interior province of Goyaz, mica is so plentiful that natives have used it for window panes from time immemorial*.

Special features of Brazilian deposits.—The feldspar of the pegmatite is altered to kaolin to a great depth in the Brazilian mica-bearing rocks, permitting thereby easy extraction of the crystals of mica from the associated minerals. The quality of the deposits becomes better at depths, surface productions not being very satisfactory.

Muscovite, the principal type.—Bulk of the Brazilian deposits of mica consists of muscovite ruby mica, like that of the United States, and competes favourably with the Indian muscovite in the London and Continental markets. Some of the plates obtained are as large as 20 by 10 inches; 6 by 6 inch; plates are available in good quantities.

Brazilian lepidolite.—Mica found in Northern Minas Geraes is of lepidolite type, with occurrences of muscovite and biotite sporadically.

Market for Brazilian mica.—Of all the micas so far marketed from the different South American States, Brazilian mica sells best in competition with the Indian ruby muscovite, particularly the Indian stained and spotted qualities. The United States, Germany, United Kingdom, France and Italy are regular customers of the Brazilian mica.

Brazilian mica has a reputation of being dressed and prepared carefully though it is much inferior to the higher Indian ruby quality. The following information has been supplied by a firm of large Continental mica specialists and users† :—

Since about five years, the mines have been exploited on an increasing scale. The main mining districts are situated in the province of Minas Geraes, about 200 to 300 miles north from Rio de Janeiro.

Quality of Brazilian mica.—In general the mica is of good quality and also clear mica is found in the mines. The colour is very light ruby. Brazilian mica can be split very well.

About five years back Brazilian mica, though rich in deposits and good in quality, was not considered a danger to Indian mica

* Eng. and Min. Journal, Vol. 114, 1922.

† Communication from Jaroslaw's Erste Glimmerwaren Fabrik.

on account of prohibitive working costs and transportation difficulties, but the situation seems to have considerably changed now and Brazil is already to be reckoned with as a potential competitor.

Brazilian labour.—Labour is inefficient in handling mica in Brazil, as a result of which a considerable proportion of the otherwise usable or saleable stuff is often spoiled in course of preparation; Bengal system of dressing has been adopted in Argentina long since.

Crude and primitive methods of mining are followed and guillotine cutting of mica is in practice. Major portion of the output represents lower grades, *viz.*, Nos. 5 and 6.

Marketing of Brazilian mica.—The Brazilian mica is sold direct to foreign countries through brokers and dealers generally against payment at Rio de Janeiro on Letters of Credit.

AFRICA

MICA IN MADAGASCAR

Madagascar is a French territory where mica properties are almost exclusively owned or controlled by French interests. The Societe des Mineraiis de la Grande Ile of the Octave-Hamburg group and the Compagnie Generale de Madagascar are the two large mica firms controlling the entire industry and the first of these two firms owns about 75 per cent. of the island's entire mica resources. They acquired the most important phlogopite deposits of the territory in 1924*.

Mica occurs in 13 out of the 40 provinces of the island. The belt lies in the easterly half of the island from the province of *Maevatanana* and *Ambatondrazaka* in the north to the *Amboromb* province in the south.

Type of deposits.—The production includes both muscovite and phlogopite, the latter being in greater preponderance than the former. The phlogopite deposits lie chiefly about the north of the island, in the provinces of Fort Dauphin and Batroka, the most important mines being situated in Ambatoaba, Sahakara and Elakolaka. Muscovite is found mainly in the northern section of the mica belt. The quality of the Madagascar amber (phlogopite) mica differs in colour and hardness from that of the similar micas obtained from other sources.

Prior to the Great War (1914–18), mica mining in this country did not assume a large industrial importance and no commercial exploitation had been undertaken on a large scale. Great national interest was attached to it from 1918–19 on account of the frantic demands derived from the shortage of mica for war purposes.

* International Trade in Mica, J. Ulmar, 1930.

Special features of Madagascar deposits.—Madagascar mica is characteristically free from imperfections and is available in large sizes even up to 25 square inches, with persistent tendency at greater depths. The large size of sheets has encouraged the manufacturers of fancy articles, *viz.*, trays, cigar boxes, fans, sailor's hats, etc., made entirely of mica.

Madagascar muscovite.—The muscovite mica produced in Madagascar is looked on with disfavour by buyers, especially in America, owing to the greater percentage of iron in its composition, which renders the mica unfit or ill-suited for application in electric insulation. The available supply of much better quality Indian mica in large flawless sheets and at cheap prices is also a reason for the dislike of the Madagascar muscovite.

Lithia mica in Madagascar.—Deposits of lithia mica have been found in several localities including Maharitra and the lithia content varies from 4.7 to 5.4 per cent. The colour is pale violet to rosy and sheets measuring 4 to 8 inches across have also been obtained, which is not quite usual in this class of deposits. The quantity obtainable, however, is very small.

Working prospects of the mica deposits.—The deposits of mica in Madagascar are readily accessible in the districts of Amboto-fatsikely (*Girod mine*), north of Lake Alaotra (*Jules Kraft mine*), in the province of Fianarantsoa (*Guagi mine*), at Arjanabonina (*Rossi mine*) and at various other points, notably in the provinces of Fort Dauphin and Betroka—where the exploitation is in the hands of the Compagnie Lonys et Bornand. New deposits have recently been discovered by the Garifalos Company in the Khandriho province. These deposits are distributed over an area half as large as that of France*.

Colour of Madagascar amber mica.—During the past several years, Madagascar has outstripped Canada and has become the principal source of supply of amber (phlogopite) mica, as will be seen from the table below. Its colour varies from brown amber to silver with a slight greenish shade.

Madagascar spotted, a strong competitor of Indian spotted mica.—Madagascar phlogopite has replaced a good deal of Indian spotted mica, and has already become a factor to be reckoned with by the Indian suppliers. Indian price, compared to that of Madagascar, stands at higher level, notwithstanding the reduction of prices in recent years. Indian spotted, however, is decidedly harder than the identical Madagascar stuff.

Quantities available are reported to be quite large and a steady progress has been made in the manufacture of splittings in Madagascar since 1925, with considerable annual exports to other countries including America.

* Eng. and Min. Journal, N. Y., Vol. 118, No. 12 : Production in Madagascar.

Madagascar now ranks as third among the world producers of sheet mica and first in respect of phlogopite.

Madagascar mica is subject to 3 per cent. export tax on a valuation fixed quarterly by the Government of the Colony in Madagascar.

Madagascar muscovite, as elsewhere, sells at much higher prices than that of the amber mica. Mr. J. Ulmar* gives the following rough indication of the range of difference :—

Clear muscovite mica.—

Block—Extra clear 1st quality 100 per cent. over phlogopite.

Spotted 60 per cent. phlogopite.

Spotted 20 " "

Very spotted " " same as "phlogopite.

Splittings—50 per cent. over phlogopite splittings.

PRODUCTION AND EXPORT OF MICA IN MADAGASCAR

(In metric tons)

Phlogopite mica.		Muscovite		Total Value.	Total Exports.	
				\$	\$	
1919	.. 21	..	24	15,550	1	} (a)
1920	.. 55	..	58	22,341	58	
1921	.. 155	(b) (a)	200	81,566	282	81,029
1922	.. 101	..	101	42,679	92	42,221
1923	.. 182	..	182	63,819	165	63,819
1924	.. 253	.. 48	.. 315	211,614	286	211,614
1925	.. 271	.. 40	.. 294	51,225	267	} (a)
1926	.. 333	.. 30	.. 326	49,605	296	
1927	.. 508	.. 48	.. 599	261,714	544	} (a)
1928	.. 902	.. 46	.. 699	342,749	635	
1929	..	..	.. 380	..	436	} (a)
1930	..	..	.. 345	..	397	
1931	..	..	.. 235	..	121	..
1932	..	..	.. 140	..	150	..
1933	.. (a)	.. (a)	.. 174	..	246	..
1934	..	..	.. 294	..	380	..
1935	..	..	.. 522	..	408	..
1936	..	..	.. 452	..	478	..
1937	..	..	.. 611	..	611	..

MICA IN THE UNION OF SOUTH AFRICA

The South African mica belt and the history of mica industry

The Leysdorp mica fields.—Mica belt in the Union occurs along the Ulugeru mountains in the Morogoru district in the low country of the North-Eastern Transvaal. This fact was discovered prior to the South African War but no serious attempt

* International Trade in Mica, by J. Ulmar, 1930, p. 57.

(a) Not available.

(b) Not separately reported.

was made—until the *Leysdorp mica mines* started operation in 1909. Transportation difficulty was a great problem until the opening of the Silati Railway in 1912, which passing along the vicinity of the mica belt made transportation somewhat easier. Most of the mines in this area fall within a radius of about 50 miles of the Mica Siding Station on the Silati Railway line. In spite of the existence of deposits of good quality mica in Transvaal, comparatively little attention has been paid to it. Mines are worked by a number of small producers with no co-ordinated efforts, except in the cases of a few large producers who are themselves well organised. In absence of such co-ordination the small producers are hard hit. Transportation still offers a serious obstacle in mining in South Africa.

Oliphants river mica field.—Another belt in Transvaal follows along the Oliphants river, below the Berg in the Leysdorp mica fields of the Pietersburg district covering an area of about 300 square miles (*i.e.*, about 50 by $\frac{1}{2}$ miles), traversed by the Silati Railway. Excellent mica mines are reported to have been found within this belt with occurrence of large books of mica up to 100 lb. or more in weight, in pegmatitic lenses in the gneiss. The lenses occur in a line of the country over a couple of miles in width and about 50 miles long. This area lies almost entirely in the Pietersburg and Leysdorp districts.

Quality of Oliphants mica.—The mica produced in this belt is of soft green variety, which is getting popular with the American grinders, who prefer it for grinding into a silvery lustrous powder, very suitable for ground mica insulation.

Nature of occurrence.—South African mica is predominantly muscovite and it occurs in coarse pegmatitic veins, associated with granite and gneiss. It is pale brown or slightly smoky colour, much of it being spotted; clear flawless sheets are also available. The mica possesses good electric insulating property and yields sheets up to 12 inches, in size the major portion of course being over 3 inches. The colour, in some cases, is dark green to brown. South African mica is generally found free from the imperfections and mineral inclusions so commonly met with elsewhere.

Practically all the output of mica shipped consists of undressed mica as *run-of-mine* or scrap and there does not seem to be any systematic arrangement for preparation according to the market requirements.

Conditions of mica industry in Transvaal.*—Mr. Ulmar summarises the condition prevailing in Transvaal a few years back as follows :—

“Between 1910 and 1912 hundreds of mica claims were taken out by prospectors, syndicates and companies in the Transvaal but the lack of a suitable market soon caused

* International Mica Trade, 1930.

most of the miners to stop operations. After a few years practically all of the claims were allowed to lapse and in 1916 operations ceased. In 1917 and 1918 work was resumed by a few of the large companies and several tons of sheet mica were produced, white men and 150 natives being employed. Splitting, grading and cutting sheds were erected and it is said that the equipment included 45 improved cutting machines. * * * A small mica factory was established at Johannesburg, which manufactured lamp chimneys, stove fronts and built-up mica board to a moderate extent."

Mica industry in the Union has not been a flourishing line and since 1923 has carried on its existence precariously. The value of exports came down from £8,422 in 1928 to £286 in 1935, the lowest figure for many years. Renewed activities however have been in evidence and the value of export in 1936 recovered to £1,098. A similar situation arose prior to the war of 1914-18 when the industry proved almost disappointing but the outbreak of war in Europe brought in a revival of mica mining on an unprecedented scale.

South African mica, so far worked, consists mostly of waste and scrap, suitable for grinding, yielding only a fractional percentage of good-sized flawless sheets, which is consumed locally. The country's annual requirement for domestic use has been estimated at two tons, which is too small for developing a large-scale industry.

The waste mica of the pale green variety of muscovite from the North-Eastern Transvaal, on account of its softness and relative freedom from staining, has been found very suitable for grinding and it yields a pure silver white lustrous powder which can be used for many purposes. Since 1924, large quantities of waste mica have been exported principally to U. S. A.

Mica production in South Africa, as the statistics show, has never been a big industry and, in recent years, it has been principally the waste mica business which has kept the producers going. The price realised for South African waste mica has been in the neighbourhood of £1 per ton free on rail*.

The following are the largest mining concerns :-

- | | |
|-------------------------------------|--------------------------|
| 1. Leysdorp Mica Mines. | 5. Union Mica Mines Ltd. |
| 2. Islington Mica Co. | 6. The Maury Mica Mines. |
| 3. Premier Mica Mines of S. A. Ltd. | 7. M. I. Adam & Co., |
| 4. Rhone Tributes. | P. B. 348, Johannesburg. |

*The Mineral Resources of the Union of S. A. Geol. Surv. Pretoria, 1936.

	Production†		Exports*
	Tons.	Value in £.	Tons.
1928 ..	3,420	8,422	3,480
1929 ..	1,464	3,593	858
1930 ..	502	1,655	(a)
1931 ..	477	1,198	526
1932 ..	250	521	241
1933 ..	549	723	513
1934 ..	278	481	227
1935 ..	193	286	244
1936 ..	343	1,098	246
1937 ..	1,387	4,180	1,465

Cape province.—Muscovite mica has been found in pegmatite veins in granite at Alicedale and Middel water in Prieska. Large commercial sheets are rarely obtainable and the yield is mostly distorted, unlevel or crumpled.

Natal.—Mica deposit has been found in the Umfuli valley near Melmoth and on Mvugana river at Fort Yolland near Eshoe. The mica occurs in pegmatite cutting hornblende schists. A very large amount of waste material must be removed in order to extract the mica, which although of good colour is frequently cracked and bent.

MICA IN RHODESIA

Occurrence of muscovite mica in veins of coarse-grained pegmatites cutting mica and quartz schists is fairly common in Southern Rhodesia; the veins are regular and more uniformly distributed than usually met within similar conditions elsewhere (Year Book, 1930). Sheet muscovite has been obtained from the localities along the Limpopo river in the Tuli district as well as in the vicinity of Urungive in Mashobaland and the Miami fields of the Lomagundi district. The *Miami mica field* in this territory comprises of about 30 miles long and 10 miles wide.

The Miami and Rusambo fields.—Of all the deposits, those of the Miami field and the Rusambo field, the latter in the Darwin district are well known. The *Rusambo field*, lying along the Mazoe valley, comprises an area of 10 miles long by 8 miles wide. These two principal mica deposits constitute the most valuable non-metallic mineral assets of Rhodesia.

Type of production.—The principal type found is muscovite; phlogopite is scarcely met with, but biotite is fairly common.

The occurrence of mica is reported to be quite extensive but the conditions of working and transportation are unsatisfactory, for which large systematic mining operations have not been

* Entirely scrap *vide* Mineral Industry, 1937.

† Metric tons.

(a) Not available.

(b) Less than a ton.

undertaken, except in case of a few well-financed companies including the "Grande Parade Mica Mine".

Mica mines are situated in the Lomagundi district between the Miami and the Misichi rivers and the mica-bearing area covers about 40 square miles. The "Lasthope" of the Basratts Mica Co. and the "Idol" of the Darwin Mica Syndicate Ltd. are well-known producers of merchantable sheet mica.

Deposits of lithia mica are worked in the south of Umtali from the Victoria, Belingroë and Salisbury districts.

Lithia mica.—Report of working of certain lithia deposits in some localities has been recorded, with an output of approximately 19 tons for the year 1927.

Mining methods.—The lode is exploited by hand-drilling and blasting. Crystals of mica, after picking out, are sent down to the cutting sheds, where they are split, graded and packed in cases of 60 pounds each net for export overseas.

Darwin—the chief mica market.—Mica is regularly worked in Darwin district; small deposits are also worked in Victoria district.

Plates obtained vary in size between 4 or 5 inches in length to several feet, but very seldom more than 6 inches thick, average being about 3 inches. Most of the production is much stained especially from surface area. Clearer sheets are found in depths below 10 to 15 feet. Mica is generally marketed in three commercial qualities, namely, clear, slightly stained and densely stained (*i.e.*, heavily stained). Bengal standard grading is followed here. The largest size is generally 72 square inches or over.

It is estimated that not more than 1½ pounds of trimmed mica is ordinarily obtained from each 100 pounds of mica as it comes from the mine. Waste is therefore excessive*.

Feldspar constituents of the pegmatite are very much decomposed to clay so that excavation is easy with pick and shovel, to considerable depths.

Average price of sheet mica has been reported at 4s. per lb. for size 2 by 2 inches to 20s. per lb. for size 8 by 8 inches. For every ton of sheet mica, about 100 tons of waste had to be handled, which fetched a value of about £3 per ton†.

The relative proportions of the various qualities and sizes produced by the Darwin Mica Syndicate, Ltd., have been reported as follows: No. 6 about 50 per cent.; No. 5 about 26 per cent.; No. 4 about 11 per cent.; No. 3 about 7 per cent.; No. 2 about 3½ per cent.; No. 1 or large about 2½ per cent.‡

* Rep. Inv. Serial 2357, 1922.

† Year Book, 1938.

‡ J. Ulmar, International Trade in Mica.

Northern Rhodesia.—Mica deposits are not as common in this part of the country as in the southern part. *The Kafne mica field* is the most important property, developed by the Lands and Mineral Prospects, Ltd. The production is of muscovite type. "Sachenga" is the oldest mica mine.

Somaliland Protectorate (Anglo-Egyptian Sudan).—Muscovite mica has been found in several areas, notably in the Mirsan plateau and the northern and southern slopes at the base of Golis Range, as far west as Mandera. In 1927 a concession was granted to prospect a large area in the Golis Range district, but the production of commercial mica was not remuneratively encouraging and the concession was ultimately abandoned*.

Kameron Islands.—Muscovite mica plates, measuring 16 by 24 inches, have been found in the pegmatites in Kameron Woematun Duala Bezirk.

Difficulties in transportation prohibit economic exploitation of the deposit.

Kenya Colony (East Africa Protectorate).—Occurrences of mica have been reported in several localities, especially at Kenzi near Sultan Hamud Station and near Chuka, on the east side of Mount Kenya.

Mica mining received the first impetus in this country during 1918-19, operations having been undertaken under Government control and a small output of 2 tons sheet mica was exported to England in 1929†.

Protectorate of South-West Africa.—Muscovite-bearing pegmatites occur in the central southern portions of South-West Africa and several dykes of muscovite were opened in the Keetmanshoop district but the output even measuring 8 inches or less in diameter proved too much flawed and unsuitable for commercial application as sheets.

Deposit of lithia mica has been worked in this territory and good production has been reported, in the Reports of the Imperial Institute, as follows :—

		<i>Production (in long tons).</i>		
		Waste.	Lithium.	Total.
1929	..	?	..	29(sheet)
1930	..	31	250	281
1931	..	(a)	100	100
1932-33	..	(a)	(a)	(a)
1934	..	?	231	231
1935	..	?	489	489
1936	..	?	852	852

* Imperial Institute Bull. Survey of Mineral Position of the British Empire, 1921.

† Imperial Inst. Bull., 1931.

Mica in Namaqualand*.—Good quality mica abundantly occurs scattered through the mineralised pegmatites of this country in nests and pockets, often several yards wide. The mica is non-striated, slightly stained with a greenish tinge to colourless in thin plates. In pockets, containing bismuth, a large proportion of mica is encrusted or stained with yellowish or greyish bi-oxidation minerals and green malachite.

The place of occurrence, however, is remote for the convenient line of transportation. A few tons of good quality mica has been recovered in large books in Aisis valley prior to 1929.

Occurrence of mica in Namaqualand, Gordonia and South-West Africa have not so far proved of commercial value.

Mozambique (Portuguese East Africa).—Mica occurs in several localities in this territory and the output comprises of splittings, films and scrap. Some good qualities are imported from time to time into the United States.

Imports into the United States

	Crude unmanufactured mica.		Splittings.		Waste.
	lb.	\$	lb.	\$	
1925 ..	2,961	1,003	nil	..	nil
1926 ..	3,176	1,056	2,142	500	nil
1927 ..	5,065	1,390	nil	..	nil
1929-30 ..	nil	..	nil	..	nil
1931 ..	1,679	152	nil	..	nil
1932 ..	nil	nil	530	..	5,676
1933 ..	nil	..	135	29	nil

Ethiopia (Abyssinia).—Deposits of muscovite mica were found in this country for the first time in 1918, in the district of Wallaga, West Abyssinia. A concession was granted for exploitation of mica interests, in the districts of Harrar, Guiper, Walloga and Hadzza, covering an area of 540 square kilometres. Italian occupation, however, must have upset the conditions and recent information is not available.

Shipment was made for the first time in 1923 to London, Czechoslovakia and the United States†. Production of two metric tons was reported in 1929‡.

Nyasaland Protectorate.—Deposit of muscovite mica has been discovered near about the Lake Nyanza as also in the

* South African Geol. Memoir, 31, 1937 and 1938.

† International Trade in Mica, p. 65.

‡ Eng. and Min. Journal, Vol. 125, No. 7, 1928, p. 285.

north and south Nyanza districts. It lies to the west and south-west of the Tanganyika Territory.

Some mica was produced in 1910 to 1912, the total being reported at 119 short tons valued at \$55,693.00*. (Production amounted to 125 tons in 1910 to 1916, as per Imp. I. Bull.)

The following productions appear in the reports of the U. S. Bureau of Mines :—

	Metric tons.		Metric tons.		
1910 to 1912	..	119	1916	..	1
1913	..	9	1917	..	nil
1914	..	5	1918	..	4
1915	..	4	1919	..	nil

**MICA IN TANGANYIKA TERRITORY
(FORMERLY GERMAN EAST AFRICA)**

Excellent mica deposits occur in this territory, chiefly along the Uluguru mountains. It was discovered for the first time in 1899†. The regions in the belt may be split up in three principal zones :—

- (i) The portion falling in the Morogoro district in the northern end of the Uluguru mountains.
- (ii) The portion falling along the *Mbakana river* in the southern part of Uluguru range.
- (iii) The area near *Mkondami* in the *Nguru mountains*, being the northern extension of the *Uluguru mountains*.

Of the above, the *Uluguru mountains* deposits are chiefly situated in the districts of Morogoro, Mbakana river and Nguru mountains. The *Usambara* deposits lie in the districts of *Mombo and Schnerffeld Roland*. The *Lindi* area falls in the districts of *Mawa and Mnera*. The other deposits are of Mahenge in the Tangiro district, and the Pongive mountains in the Ssuwi river.

In the mica regions, the gneiss, which is predominantly biotite gneiss, is cut by numerous pegmatite dykes, which dip at small angles from the vertical, and range from 30 to 70 feet in thickness. The pegmatites are not much decomposed and bent or cracked sheets are rather rare. Crystals measuring 35 by 31 inches have yielded trimmed sheets free from flaws, measuring 18 by 15 inches.

Crystals measuring about a foot across are reported to be very common. Excellent mica of a greenish or brownish colour in transparent sheets free from fractures and mineral inclusions has been abundantly obtained from the numerous nearly vertical

* International Trade in Mica, p. 65.

† Mineral Industry, 1900, p. 140.

pegmatite dykes cutting the predominant biotite gneiss. Dykes have a maximum thickness of 70 feet and contain massive quartz on the edges of which mica is abundantly found.

In Usambara, near the border of British East Africa, excellent pegmatites cut the gneissic country rock.

Quality of the Tanganyika mica production.—The quality of the Tanganyika productions is principally muscovite, dark green to brown in colour, sometimes very clear. The sheets are easily cleavable into smooth flat laminations and are unusually free from imperfections in structure or inclusions of foreign minerals. Many of the sheets even half an inch thick are reported to be clear and transparent. Crystals are large, some even 3 by 3 feet in the rough run-of-mine, producing trimmed sheets measuring occasionally about 18 inches across.

Phlogopite mica in Tanganyika.—Phlogopite deposits occur along the Ssuwi river which flows down the northern slopes but, although some good sheets have been found of golden sheen, most of the productions obtained were too much folded and cracked. Deposits are scattered over the eastern and southern parts of the country, the most valuable group being located at about 7° lat. and 38° long. in the Uluguru mountains. There is an area of strongly weathered *augite rock* (pyroxenite?) measuring 600 by 360 feet which has yielded thick plates of phlogopite mica, occurring in nests and associated with apatite, calcite, magnetite, ilmenite and tourmaline. Graphic granitic pegmatites also occur here, country rock being gneiss.

Development.—Mica mining was first started in German East Africa in 1905 under German auspices, who worked the deposits exclusively up to the outbreak of the Great War (1914–18) and the entire production was shipped regularly to Germany.

Transfer under mandate to Britain.—From 1917 the territory was transferred under a mandate to the British Government, renamed as the Tanganyika Territory and between 1917 to 1920 a total quantity of 146 tons of mica valued at about \$200,000.00 was produced under British control. Important areas were largely worked prior to the Great War, of which the principal two were: (i) one bordering on the river *Mbakana*, a tributary of the Mgeta, operated by the *German East African Mica and Mining Co.* (of late Wm. Schwarz) and (ii) the area lying to the north of the Morgoro mountain which was owned then by the *Morogoro Mica Co.* (of late A. Prusse). Mr. M. Hepner, late of the Jaroslaw's Erste Glimmerwaren Fabrik in Berlin, in a letter to the author made the following comments in regard to the productions of this country:—

“I have found that the quality of the East African greenish mica is the same like that of the Indian ruby mica but the quantities available in East Africa are very

small. There are larger mines only within some districts. There are in some districts large deposits of spotted mica of very even quality, but these mines do not work."

Demand of the Tanganyika mica is generally restricted to the ruby type in times of depression.

The following production was reported in 1900 to 1910 (under German auspices) :—

(In metric tons.)

Number of mines.		Rough mica.	Trimmed mica.	Value.
				\$
1905-6	.. 21	63	20	8,823
6-7	.. 30	73	(a)	16,345
7-8	.. 35	103	33	16,190
8-9	.. (a)	85	(a)	50,211
9-10	.. (a)	104	(a)	61,594

Total productions have been shown in the table of world production of mica.

OCEANIA

Australia.—Coarse micaceous pegmatites yielding sheet muscovite occurs throughout the area of the pre-Cambrian rocks in Australia. Deposits have been commercially exploited in Northern Territory, Western Australia and Southern Australia. Of all the occurrences so far known, deposits in the central part of the island, at the south end of the Northern Territory in the MacDonnel Range, is considered as the most valuable of all, yielding large, flawless and light coloured muscovite sheet mica. The sheets occasionally measure several feet across. Sheets of one foot across are reported to have been obtained in good quantities. One large crystal of mica measured 5 to 6 feet by 4 feet and yield nearly 800 pounds of cut mica*.

The country rocks are gneisses and schists, probably of the Archæan age with many pegmatite dykes of irregular shape and size, branching out and abruptly widening and thinning. The pegmatites contain large solid masses of feldspar and quartz with smaller crystals of mica. Large crystals were generally found on the hanging wall.

Western Australia.—Mica in this territory occurs in the Darling range, a few miles east of Perth. Fine muscovite sheets, sometimes measuring 6 to 8 inches in diameter, have been obtained from Toodyay or Newcastle Lithium-bearing pegmatites occur at Ravensthorpe, about 130 miles east of Albany, yielding lepidolite and muscovite in large sheets. Clear and

* U. S. Mineral Resources : Mica in 1918.

easily splittable lepidolite sheets have been obtained in considerable quantity and size, measuring about 15 by 12 inches, the average size being 5 to 6 inches*.

Muscovite and lepidolite micas have also been mined in the Pilbara goldfield in the extreme north-western part of Western Australia. The working has been of an intermittent nature.

The usual associates of mica in this territory include tourmaline, beryl, garnet, biotite mica and corundum. Much of the mica mined often prove inferior in quality and less than one-half ton of marketable mica is said to be obtained out of 100 tons of rock, handled in the usual condition of working.

Large clear sheets of lepidolite mica occurs in the Londonderry district near Coolgardie. The quality of this production is reported to be highly resonant and very suitable for use as gramophone diaphragm†.

Southern Australia.—Mica-bearing pegmatites occur in the schists and gneisses of the Barroosa ranges. Most prominent of the deposits in this area is found near Williamstown, about 40 miles north of Adelaide. A pegmatite dyke 10 feet wide and dipping 60° N.E. has been exploited in this locality for several hundred feet (Schaller). Coarsest mica is usually met with on the hanging wall. The mica is, however, mostly distorted, wavy and spotted. Largest sheets measured 10 by 8 inches, averages being about 5 by 3 inches.

Quality of the production has not been quite satisfactory, specially in view of the better and sufficient supplies of mica from other sources of occurrence. Mica industry has not been very successful in this territory till now and workings have so far been intermittent. The great distance of the marketing centres in England, Continent or America, coupled with the inferior quality of the deposit has proved to be the greatest obstacle to the successful mining of mica in Australia as a whole.

Queensland.—The Queensland mica belt is several miles long situated near the Rifle Creek (Cloncurry district), a tributary of the Upper (West) Leichhardt river. Transportation is difficult which renders economic exploitation of mica deposits impracticable in normal conditions. The nearest railroad station is said to be about 481 miles from Cloncurry and 68 miles by road from the occurrence.

The country rock consists of hornblende and mica schists, with numerous mica-bearing pegmatites 10 to 12 feet thick occurring over a distance of several miles. Sheets of 9 inches square in size have been obtained.

* U. S. Mineral Resources : Mica in 1918.

† Mica by H. S. Spence, p. 34.

The quality of the mica is not suitable for electrical industry and as the strongest demand for mica comes from electrical industries, success of an export trade for non-electrical mica seems somewhat doubtful*.

Tasmania.—A large deposit of phlogopite mica is reported to have been worked at South Heemskirk in the western part of the State of Tasmania. Though the occurrence is widely distributed, the quality has not proved marketable and further attempts at mica mining have been discontinued.

New Zealand.—Mica was discovered in New Zealand in 1898 at a point near Paringa†.

Muscovite occurs in large plates about the Labrador Territory at Dusky Sound, South-Western Otago and near Charleston, south of West Port. Mining of mica in this country has not developed on a regular or large scale. The proportion of sheet mica is very small. The occurrences are also not easily accessible from convenient centres of transportation. Large plates of muscovite mica also occur in granite between George Sound and Lake Te Anau‡.

Quality.—New Zealand mica is generally of a dark colour and cross-grained; most of the mica so far mined is reported to be suitable for grinding, with a very small proportion of commercial sheets. The working near Bustby Sound, however, is reported to have yielded some large muscovite sheets.

New South Wales.—Muscovite in sheets has been obtained from a locality to the N.E. of Broken Hill. No further information is available.

EURASIA§

MICA IN SOVIET RUSSIA

Early history.—Evidence is available of the development of mica mining industry in Russia in the 17th century if not still

* Inf. Cir. 6205, p. 38.

† Mineral Industry, 1897.

‡ New Zealand Geological Survey Bulletin No. 32, 1927.

§ For mica in Russia, the author has consulted amongst others the Report of Mr. I. I. Ginsberg on the Mineral Resources of the U. S. S. R. (1926-27), Dr. Misharev's report on Mama-Vitim-Chuisky deposits of mica, Joseph Ulmar's International Trade in Mica, the Soviet Year Book and Dr. C. S. Fox's contribution in Trans. of Min. Geol. and Metal Inst. of India, Vol. 34, p. 2, 1938, etc.

earlier. As early as 1681, Russia exported 92,882 lb. of mica to Holland, 86,400 lb. to England and 18,000 lb. to North America. Before India and Canada appeared in the International Mica Trade as large suppliers of muscovite ruby and amber mica respectively, Russia had been the only supplier of mica to Central Europe and North America. The Russian mica industry seems, at one time, to have flourished very well but it declined to total extinction, in competition with the newer rival suppliers, India in particular, whose supplies of large sizes and quantities of fine muscovite ruby mica at cheaper prices swayed the international market. The blow to the Russian mica industry proved so fatal that it became extinct in course of a few years, even without leaving behind any trace of the past development.

Revival of mica mining in Russia.—It was only in 1912 that some of the old pits were discovered, which were re-worked till the outbreak of the Great War (1914–18). No large commercial attempt, however, was made till the administration passed on to the Soviet authorities, who, as a part of their national reconstruction campaign and industrial planning, initiated intensive activities and thorough-going investigations were conducted in various parts of the country including Siberia. In course of these investigations and industrial survey, mica deposits, both of muscovite and phlogopite types, have been discovered in many places.

Distribution of occurrences.—The deposits are widely distributed over the country, especially in Archangel (Karelia) on the *Kola Peninsula*, in the Volyn provinces on the Black Sea coast, in the Urals, Siberia. Workable deposits are reported at Sliudianka, in the Mama region, Beryu Sinska region, Minusinska tract and smaller deposits have also been found in Maruipol circuits. Production of 75 tons of mica in 1917 and 1,500 tons in 1927 has been recorded, of which the proportion of sheet and scrap is not known.

Before the Great War (1914–18), regular mining was carried on only in Kan, Siberia, and the output was reported as 3 tons. Post-war investigations conducted towards the end of 1926 by an Expedition sent by the Moscow Institute of Applied Mineralogy resulted in the discovery of large mica deposits in the Bodai Binsk region in Siberia. The reserves available in the principal Siberian mica districts were estimated at 10,267 tons in 1932 rising to 69,203 tons in 1933. The cost of production of a pound of mica in Russia has been estimated approximately at one rouble and these deposits are considered by the expeditionists as the richest in the world (?). The Expedition brought back 5 tons of mine-run mica from these deposits.

MUSCOVITE DEPOSITS

Lena mica field in Siberia.—The mica deposits* in Eastern Siberia, occurring along the *Mama* river, flowing about the centre of the mica district into the Vitim river, a tributary of the Lena, used for a long time to be known as *Mama deposits* after the name of the river. This mica district lies within $57^{\circ} 30' : 58^{\circ} 15' N.$ lat, and $112^{\circ} 00' : 113^{\circ} 30' E.$ long. This is considered as the largest deposit†.

The increasing industrialisation in Soviet Russia has revealed the great industrial significance of the *Mama* region, though it was almost a desert up to 1926. In 1928 a Siberian Mica Trust was organised to exploit mica but no systematic working data are available.

According to the Soviet geological authorities the above mica region is mountainous and strongly dissected to form separate short and irregular ridges, not rising higher than 1,000 to 1,200 m. above the sea-level.

Quality of the *Lena mica.*—This mica is reported by Dr. Misharev as spotted with reddish-brown-yellowish tint. It is easily splittable and elastic and on assortment and dressing it gives a percentage of large size mica sheets, having a maximum diameter of 50 c.m. It is further stated to be quite equal, if not superior to, the Indian ruby muscovite, in chemical composition and electro-technical properties.

Old mica deposits have also been discovered along the rivers Sogdiondon, Kamnikha, Krasnaia, Krasny Yar, Bolshaiia Sliudi-anka, Kulakhai-dag, Ludovka, Lerdakovka, Kolotovka, Malaia Severnaia, Eremikha etc., and new mica-bearing veins are also reported to have been traced near along the Oleniy islands (along the Vitim river) as also along the Kulakhai-dag river. The majority of the past worked deposits has not been exploited beyond 3 to 4 metres in depth.

At Karelia in the Kola Peninsula about 20 to 30 small but high grade deposits have been found. Some 30 small deposits are also reported in a narrow belt 500 km. long in the eastern slopes of the Urals.

Mica is generally confined to crystalline schists and gneisses of Permo-carboniferous age and most of the largest deposits are located in East Siberia, on the Sayon Baikral Upland and the Yenisseisky range of which *Mama* in Eastern Siberia is the largest and that of Birgusa, in the East Sayon Range, is the next largest‡.

* Trans. of the United Geological and Prospecting Service of the U. S. S. R., Fascicle 154, by Dr. D. T. Misharev, ref. Dr. Misharev's letter from the Society for the Cultural Relations to Mr. R. R. Chowdhury, 1936.

† The Mining Magazine, London, June 1938.

‡ *Ibid.*

**RUSSIA IN RELATION TO INDIA AS WORLD SUPPLIERS OF
MUSCOVITE MICA**

Though the reports from the Soviet sources appear to be exceptionally optimistic, actual data of production and disposal, as could be studied from the available sources including the statistics of the United States, the largest consumer and importer of mica, and the reports of the Imperial Institute (London) do not bear out the expectations of the Soviet expeditionists and geologists. Of the reported production of mica, proportion of sheet and scrap is not known. Mica imported into the United States consists almost entirely of scrap and ground.

Proportion of sheet and scrap.—Mr. Spence* writes “according to advice received from the Director of the Geological Committee of the U. S. S. R., however, only about 10 per cent. of the production figures represent sheet mica, the totals relating to ‘run-of-mine’ material”.

The domestic sheet output barely suffices for the increasing requirements of mica with the country and there does not seem to be a likelihood of any surplus of mica over the domestic consumption in Russia for export for a pretty long time yet, unless, of course, the mica-consuming industries in the U. S. S. R. experience a set-back, resulting in a reduced domestic consumption of mica.

The following observations by Dr. C. S. Fox, Superintendent of the Geological Survey of India, who attended the International Geological Congress held in Moscow in 1937 and studied the position of mineral production in Russia personally, are quoted from his contribution on the Mineral Development in Soviet Russia in the Transactions of the Mining, Geological and Metallurgical Institute of India, Vol. XXXIV, Part 2, 1928 :—

“The specimens of *phlogopite* mica which I saw in the Moscow Conservatory were from Sliudianka at the western end of Lake Baikal south-west of Irkutsk, where very attractive quantities of this material are believed to occur, but the mica exhibited was distorted and commercially unattractive. Mr. D. T. Misharev in his report on the better known ‘Mama-Vitim-Chuisky deposits of mica’ mentions a Bolshaia Sliudianka (57° 50′ : 112° 40′ E.) among the numerous *muscovite*-bearing pegmatites of the Mama valley. There were also reports of a micanite work at Irkutsk and I was informed of mica mines at Tarsev in S. Ondegei district in Krasnoyarsk but I was unable to confirm these except the discovery of mica to the south-west of Irkutsk, near the corner of Lake Baikal. The

* Mica, by H. S. Spence, 1929, p. 36.

green muscovite in large fine sheets at the Conservatory, from the Kyschtym area, near Chelyabinsk in the Urals, was much admired. It was equal to the Madras (Nellore) mica in quality and *Specials* in size (36 to 48 square inches). By far the most attractive mica on exhibit were sheets of *ruby muscovite* from Tedinskoye in the Chupa district of Karelia (which Dr. Fox believes to be the original Russian locality, of Muscovy, which gave the name *muscovite* to these micas in granitic rocks), where it occurs in the pegmatites normally worked for microcline (feldspar). It resembled the best Indian muscovite and was of extra special size (above 48 square inches). I was given to understand that it does not occur in all the quartz-feldspar pegmatites, but that in the Krivoye vein, where it occurs with pink quartz and microcline, 250 tons of mica and 16,000 tons of microcline were obtained. The mica must be in reasonable amount as a mica factory has been established at Petrozavodsk, the capital of Karelia. We saw some pressed micanite were among the exhibits, but these were said to come from the Irkutsk micanite factory."

"Dr. Misharev records that the Mama muscovite-bearing pegmatites occur in a belt of crystalline schists 20 to 30 miles wide which tends S.W. to N.E. and lies between two granite areas to N.W. and S.E. Dykes of aplite, aplitic granite, quartz and the lenticular pegmatites of various sizes, small and large, occur in the crystalline belt and are considered as apophyses or otherwise genetically related to the intrusive granite. These intrusions occurred before the folding of the crystalline rocks was complete and thus he explains the occurrence of coarsely crystalline mica-bearing pegmatites in some anticlinal positions of the folded rocks. Further, the consolidation or crystallisation of the intrusive rocks is thought to have occurred after the folding was complete, as the large mica crystals have generally been found free from buckling and other distortion due to pressure. The mineral associates of good muscovite mica are quartz and microcline, which in an exceptional amount usually indicate paucity of muscovite. Among other minerals commonly present are biotite, black tourmaline, apatite, garnet, zincon, sphene, impure beryl, graphite and ore minerals. Work was begun here in 1928 but in 1932 it was still an isolated, uninhabited area of the U. S. S. R; however considerable attention has clearly been given to it and it is thought to be the mica belt of Siberia. The chief localities of the Mama area mentioned are Sogdiondon, Bolshaja Sliudianka, Kulakhai-dag, Kolotovka, Malaia Severnaia and the vicinity of the Oleniy island."

The Russian-American Mining and Engineering Corporation of New York has obtained a concession from the Soviet Government of Russia for 240 square miles of mica fields in Siberia. The deposits are located 600 miles north of Irkutsk near the Lena gold mines. It is a 36-year concession on a 5 per cent. royalty to the Soviet Government and freedom of export except to supply Russian demand if called upon*.

Mica is largely obtained as a by-product of feldspar and the production, as already stated, consists perhaps of scrap in the bulk, with a very small sheet percentage.

Production of mica appears in the table of world production.

IMPORTANT LOCALITIES OF COMMERCIAL MICAS

Phlogopite.—*Karelia*: Sharosero, Shedosero, Plotnavalok, Elof, Topornof, Letnot, Severnof, Orenburg.

Mam: Keronsky, Sogdiana, Sludansky, Krasnoyarsk, Asanka.

Muscovite.—*Mam*: Lugov (along Lugov river), Kololorka (along Kolotorka river), Olen Island (Vitim river), Irkutsk (Severnon river and Yeremik river).

The fiscal year 1926–27 was characterised by a tendency to develop phlogopite production and by a decreased yield of muscovite in *Karelia* and on the Biryusinska. Of the 1,520 tons of recorded production this year (run-of-mine), a total of 1 per cent. only was muscovite†.

Imports.—Russia was formerly an importer of both sheet and manufactured stuff as will appear from the following‡. Russia has of late become self-sufficient with surplus scrap and ground production for exports.

Import into Russia (metric tons)

	Total.	Sheets—Manufactured.	
1913	81	(a)	
1922	13.6	13.6	nil
1924	7		7
1925	29	2	27
1926	76	1	75

* Eng. and Min. Journal, Vol. 117, No. 12, March 1924.

† Joseph Ulmar in International Trade in Mica, 1930.

‡ Annual Report on the Mineral Resources of the U. S. S. R. for the fiscal year 1925–26, published by the Geol. Committee, Leningrad, 1927: Mica by I. Ginsberg.

(a) Not available.

EUROPE

Austria.—According to the news supplied by the Berliner Tageblatt to Reuters, extensive mica deposits were opened in Styria and Corinthia in Austria, the mineral being reported as well adapted for electro-technical purposes.

Germany, owing to the loss of her colonies, does not possess any source of mica within her political sovereignty. Here Water Zoring of Eislehen, who worked for years in German East Africa, on behalf of the German mica companies, was appointed as the Mining Engineer of the newly-formed Austrian Mica Co.

No regular statistics are available; prospects of large flawless sheets do not seem to be bright.

Germany.—Considerable quantities of lithia mica are produced in Germany but no sheet mica.

Portugal.—Lithia mica is produced in good quantities in this country. Statistics of production so far known will be found in the table of world production of mica.

England.—Mica clay is worked in large quantities in Cornwall and Devonshire in England. No sheet mica is produced.

Norway.—Very little was known about mica in Norway prior to 1913. As a result of persistent search and prospecting for mica by Germany during the Great War, deposits were discovered in the south-west coast near Skatterud, where the Gödfjeld mica field has been largely worked and developed on a pegmatite dyke nearly 100 feet thick. This Norwegian deposit was practically the only source of sheet mica to which Germany had access when she was blockaded out from other sources of mica supply, including the German East Africa (Tanganyika Territory).

The quality of the Norwegian mica is greenish and predominantly biotite, frequently with a good deal of stained and mineral inclusions within the crystals. These inclusions sometimes give it a brown appearance. The crystals are mostly small, yielding plates scarcely exceeding 1 by 1 inch.

Sweden.—Messrs. John R. Retig and Co. are reported to have started a factory to make insulating materials from mica at Gotenborg. The Company owns mines in the Bohuslan district (Schmidt).

The United States imported 924 pounds of mica valued at \$423.00 in 1928.

Rumania.—Rich veins were reported to have been discovered in the district of Mahedantz, Rumania. The quality of the deposit is good muscovite.

No systematic mining has been undertaken. The fact that there is no regular organised mica industry in this country as

yet, in spite of a large prospective market for mica in the neighbourhood (Central Europe), proves that the prospect of Rumanian mica is not bright and economic working of the mica deposit has not been found practicable.

Productions of mica as available from time to time are given in the table of world production of mica.

Czechoslovakia.—Deposit of mica has been found in pegmatites in Bohemia, yielding lepidolite in some quantities.

PRODUCTION OF LITHIA (LEPIDOLITE) MICA

This mineral is mined for use as a source of lithia content. Except Russia and, to small extent, Rumania and Norway, European countries do not generally produce commercial sheet mica. Certain countries, *viz.*, Germany, Czechoslovakia, Portugal, France and Italy, possess some lepidolite mica deposits in the form of small flakes, the output of which is consumed by the glass-making industries in Central Europe. Except for this, the mineral is of minor importance. Small exports are also reported from time to time to the United States.

Outside Europe, some of the Central and North American countries, including Canada, Mexico and South-West Africa Western Australia, etc., produce considerable quantities of lepidolite mica, which is exported to Europe and the United States. Of these, Western Australia is the only country where some of the lepidolite deposits yield a certain proportion of clear commercial sheet lepidolite of the finest quality, suitable for gramophone diaphragms. Lepidolite seldom occurs elsewhere except as aggregates of small flakes.

A deposit of lepidolite in scaly aggregates has been found in India in the pegmatites of Northern Hazaribagh near the village Pehra, north of Bhuladi and one mile south of Manimundar, masses being noticed in the last-mentioned locality up to 8 cwt. in weight*. It has not been commercially prospected or worked as yet.

It may be noted that the chief sources of lithia are (i) lepidolite, (ii) spodumene, (iii) lithiophylite, (iv) triphylite and (v) amblygonite. Lepidolite, an alumino-silicate of lithia, soda and potash, is also known as lithia mica. It occurs in micaceous aggregates ranging in colour from colourless into pink, yellow, green and brown but commonly a shade of lavender or lilac. Cæsium and rubidium are frequently found in such lepidolite†.

* Bull. Imp. Inst., 1932.

† Mineral Industry, 1914 : Victor Zeigler.

Before 1886, Saxony and Bohemia were the chief producers of lepidolite but in that year amblygonite deposits of Montebrais in Central France became known, which soon developed as the chief producer in Europe. About 1900, San Diego County, California, came in and furnished for several years several hundred tons of lepidolite annually. The Black Hills of South Dakota, Maine, Mexico, Massachusetts and Connecticut came in later as important producers. Amblygonite was also discovered in the San Fenx tin-mine.

The amblygonite deposits of the Black Hills furnish a great proportion of the lithia production in the United States. It being a phosphate of lithia, alumina is easier and cheaper in treatment, giving additionally more valuable by-product. One mass of solid amblygonite exposed in the Hope mine (U. S. A.) measured $18 \times 22 \times 40$.

ABSTRACT OF WORLD OCCURRENCES OF MICA
(Localities in italics are of commercial importance)

1. MUSCOVITE

Asia

India	.. <i>Bihar</i>	Russia (contd.)	Lake Baikal.—On the Bystraya and Sliudianka rivers
	<i>Madras</i>		<i>The Urals</i>
(States)	.. <i>Mysore</i>	Japan	.. Yamaguchi Pr.
	<i>Shahpura</i>		Sarlava Pr.
	Gwalior		Nagasaki Pr.
	Dhenkanal	<i>Chosen</i> (Korea)	
	Rewa	China	.. Ssu-chuan (Szechwan)
	Udaipur		Tschontschong (Shantung)
Russia (Siberia)	.. Kansky	Turkey	.. Smyrna
	Mama region	Afghanistan	..
	Lugov	Tibet	.. (near Tinki, Dt. Giagong)
	Kolotovka		
	Olen Island		
	Irkutsk		
	Gregof		
	Sliudianka		

Europe

Sweden	.. Upland (Falun)	Russia	.. Valcea district (Lodru mountains)
	Halsingland		Archangel
	Bohuslan (N. of Göleborg)		Mariupulsky dist.
Norway	.. <i>Gödfjeld</i> .—Kragero district.		Volyn
Rumania	.. Mehedintz dist.	Ukraine	.. Kola Peninsula

America (North)

Canada	.. Saguenay Dt., Que British Columbia Newfoundland Labrador Strait of Belle Isle Cariboo County	United States (contd.)	South Carolina New Mexico Massachusetts Connecticut Pennsylvania Georgia Alabama
United States	.. <i>North Carolina</i> <i>New Hampshire</i> Idaho Maryland New York		<i>South Dakota</i> (Black Hills) California Colorado Maine

America (Central)

Mexico	.. Mexico Lower California Hidalgo Jalisco Durango		Oaxaca Ejutla Guadalajara
Guatemala	.. <i>Dept. of Quiche</i> <i>Chimaltenango</i> <i>Baja Verapaz</i>		Guatemala Alta Verapaz <i>Huehuetenango</i>

America (South)

Argentina	.. <i>Cardoba</i> <i>San Luis</i> Catamarca Buenos Aires La Rioja Mendoza <i>San Juan</i>	Brazil	.. Bolivia Mollendo <i>Bahia</i> Sao Paulo <i>Goyaz</i> <i>Minas Geraes</i> Rio de Janeiro
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Africa

Madagascar	.. <i>Ambatondrazaka</i> Fianarantsoa	Rhodesia (contd.)	Ambatondraraka province (<i>Rusambo field</i>) Fianavantsoa <i>Sachenga</i>
Tanganyika Territory	.. <i>Uluguru moun-</i> <i>tains</i>		
Union of South Africa (Olifant River mica field)	<i>Eastern Transvaal</i> Petersburg Leysdorp Natal Cape Colony	Rhodesia (North) East African .. <i>Protectorate</i> Nyasaland Prot. South-West .. African Prot. district)	.. Kenya Colony (Keetmanshoop district)
Rhodesia (South)	.. <i>Ambovombi</i> province (<i>Miami field</i>)	Abyssinia .. Cameroons ..	

Oceania

Northern Australia	.. <i>Port Dauphin</i>	New Zealand	.. Charleston Otago
Central Australia	.. Hart Range	Queensland	.. Rifle Creek and Leichhardt
Southern Australia	.. (Barossa; Williamstown)	New South Wales	..
Western Australia	.. Pilbara goldfield		

2. PHLOGOPITE

America

Canada	.. <i>Ontario</i> (Fron- tenac, Lenark and Leeds counties)	United States	New York, Jeffer- son County
	<i>Quebec</i> (Hull and Papineau coun- ties)	Argentina	(La Aurora and La Balila)

Asia

Russia	.. <i>Karelia</i>	Russia (contd.)	Birinssinsky region
	<i>Mama region</i>	Chosen (Korea)	
	Kerensky	Ceylon	.. Kandy, Ratnapura and Galle
	Sliudansky region	India	Travancore and Cochin States
	Asanka		
	Sogirana		

Europe

Switzerland	.. (Campolongo, St. Finland Gotthard)	.. At Pargas
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Africa

Madagascar	.. <i>Ambo Vanbe</i>	<i>Fort Dauphin</i>	Fianarantsoa
	<i>Betroka</i>	<i>Vangain Drano</i>	Ambositra

Oceania.

Tasmania	.. (South Heemskirk)
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3. LEPIDOLITE

Asia

India	.. Dt. Hazaribagh	Russia	.. Schaitanka and Alabaschka (now Sverdlovsk)
	Bastar State	(Urals)	

Europe (Central)

Moravia	.. at Mt. Hradisco near Rozena (near Penig)	Austria	.. Styria and Corinthia
		Portugal	..
		England	.. In the granites of Michael's mount, Cornwall
Germany	.. Walkenburg in Saxony		..
Czechoslovakia		France	..

America

United States	.. at Pala, San Diego County, California (also Black Hills S.D.)	Brazil	Hebron, Paris, Auburn and Canada
			.. Minas Geraes Wakefield Que.

Africa

South-West ..
Africa

Oceania

Western ..
Australia

Lepidolite always occurs associated with granite or pegmatite.

4. PARAGONITE**Europe**

Switzerland	.. Mt. Campione	Russia	.. Krutoi Klutoch in the Nizhni Issetsk dist. The Urals
Italy	.. Zillerthal, Tyrol		

America

United States	Unionville, Delaware County	Pennsylvania
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Paragonite occurs in all places, except in the Unionville deposit, in the form of mica schist composed of small grey and yellowish scales.

5. ZINNWALDITE**Europe**

Germany	.. At Zinnwald and Altenberg on the	borders of Saxony and Bohemia
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America

Alaska	.. York region, associated with cas-	siterite and topaz
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PART IV

PRODUCTION AND PREPARATION OF MICA

Chapter VIII

MANUFACTURE OF BLOCK MICA

Commercial qualifications.—Mica is employed for various purposes in different industries, on account of its various important properties, the most important of which are stated below :—

1. High di-electric strength and specific inductive capacity.
2. Good electrical and thermal insulating properties.
3. High heat resistance and relative infusibility.
4. Chemical stability and resistance to chemical attack.
5. Perfect cleavage parallel to one direction (plane).
6. Non-porus and impermeable to moisture.
7. Great flexibility and elasticity of laminæ.
8. Transparency of varying degrees from clear to translucent.
9. Hardness of products suitable for practical uses.
10. Properties for optical, resonant and other purposes.

Mica irreplaceable.—It should be noted that mica is not replaceable in most of its applications and as such constant and ample supplies are indispensable for the maintenance and development of the ever-growing electrical, radio, wireless and aeronautical industries.

Separate specifications are prescribed by different classes of users of mica according to the specified object for which the mica is needed and based on the technological properties specially needed for the purpose. In selecting mica for industrial use the general qualifications usually kept in view are :—

- (a) Easy separability of laminæ along the basal cleavage.
- (b) The degree of clearness or transparency that would suit the particular purpose, without causing detriment in efficiency.
- (c) Hardness and heat resistivity.
- (d) Resonance, flexibility and elasticity.

Electrical mica, however, has to be selected with particular care in regard to the di-electric strength, hardness and thermal resistivity.

In the commercial preparation of mica, it is not practicable to keep in view all the technological requirements and put to test every individual piece to see if it conforms correctly to all of them. It is therefore necessary to demand essential and easily

discernible safeguards, so as to make the prepared mica generally conformable to some agreed specifications, *viz.* :

- (i) Degree of clearness as specified.
- (ii) Freedom from imperfections and foreign mineral inclusions.
- (iii) Easy splittability and freedom from wedge or cross grains (*jatai*).
- (iv) Degree of flexibility and hardness as specified.
- (v) Deep re-entrant or "fancy" cuts (*i.e.*, wrong zig-zag dressing of mica, by cutting it far towards the centre, in an effort to cut off the objectionable spots, stains or defects and retain the maximum possible but often unusable area).

COMMERCIAL DEFECTS OR IMPERFECTIONS OF MICA

The physical imperfections and distortions of mica are mostly due to the disturbed or imperfect crystallisation while in course of formation or during any movements of the earth's crust, or due sometimes to the penetration of mineral inclusions, etc., during the above process or other physical causes. The following may be considered as the most important defects generally objected to in the trade :—

- (1) "*Cross-grained*" or "*jatai*".—The sheet is called cross-grained when it breaks transversely in course of splitting.
- (2) "*Wedge mica*".—This term is applied to such sheet mica which is thicker at one end and thinner at the other. Wedge mica when split yields films or splittings of uneven thickness.
- (3) "*Tangle-foot*" or "*Tangle-sheet*".—It is the same as cross-grained mica, which lacks separability of the laminæ which are easily torn in course of splitting.
- (4) "*Ruled mica*".—Mica is called "ruled" when it contains different planes of separation than the cleavage planes. "Ruled mica" is also called in America in other terms such as *Ribbons*, *Fish bones*, *Herring bone*, *Horse tail*, etc.
- (5) "*Fancy, triangle or zig-zag cutting*".—In dressing mica with sickle or knife, and in the process of removing the objectionable features from individual sheets, cutters are sometimes accustomed or instructed to trim it into such zig-zag shapes or areas that, although the gross available area in the individual piece measures larger than it would otherwise have been, a large proportion of wastage is left over in the hands of the user in its actual employment in the works. By such dressing

the seller manages to dispose of much of his otherwise smaller-sized material or inferior mica at a price which is only payable for sound superior grades of sheets. This manner of dressing is therefore seriously to be objected to and abolished from trade by the concerted efforts by all concerned, permitting of course a very limited latitude towards the edges.

- (6) "*Clay or mud stain*".—Mica containing clay, earth or mud and mud stains on or between the laminæ or edges is generally called "mud-stained mica" and in order to make the mica fetch maximum value, it should be cleaned as much as possible.

Mica obtained from or near about the surface is usually mud-stained and the proportion of mud or clay tends to diminish in the productions from greater depths.

- (7) "*Air bells, air bubbles or air inclusions*".—This is considered a defect in high-class mica, specially required for finer electrical, radio or aeronautical applications including wireless appliances. Such high-grade mica should as far as possible be free from inclusions if not air bubbles.

For ordinary purposes, however, it is not a serious defect; these air bubbles or inclusions can be removed or minimised, where permissible, by splitting the sheets along the laminæ containing the air bubble or inclusion, though the sheet is thereby rendered thinner.

- (8) "*Mineral stains*".—Mineral inclusions and stains, especially that of iron, render mica unfit for use in electrical appliances, as iron seriously affects the di-electric property and relative efficiency of the mica sheets.

COBBING OF MICA IN THE MINE

The cobbing in the mine should make the block mica (sheets) as free as possible from the adhering dirt and waste or defective materials, without sacrificing economy by cutting off the least usable area. Only commercially sound mica should be transported to the factory or storage godowns, where possible, in order to bring down the working expenses within economical limits. Of course low-grade defective sheet mica is also marketed when the price covers the transportation costs with a little margin, as this serves to reduce the working costs of the mine as a whole. This "pit-mouth" or "rough mica" is known in India as *Khadka abrak*, which requires further dressing before marketing.

The cost of cobbing operation in the mine should be kept as low as possible and it should not ordinarily exceed half to one anna per seer (about 2 lb.) in times of depression.

COBBING OF MICA IN THE FACTORY

The sheds in which mica is cobbled in the factory are called the trimming shops. Cobbled mica is brought down to the trimming or dressing sheds in the factory, where the sheets are given final treatment prior to sorting into the different marketable sizes and qualities.

Some miners get the mine-run mica at the mica factory without cobbing it in the mine. All-round economy, avoidance of all wastage and saving of time, money or material without sacrificing the efficiency of the operations at different stages, should be made the cardinal aim towards achieving success in mica mining and manufacture. If there is any chance of the raw inexperienced cobbers at the mines damaging mica to a great extent, the ultimate loss may be very considerable and in such a case the expense of transport of the uncobbed mica from the mine to the factory is considered worth while.

COMMERCIAL PREPARATION OF MICA FOR THE MARKET

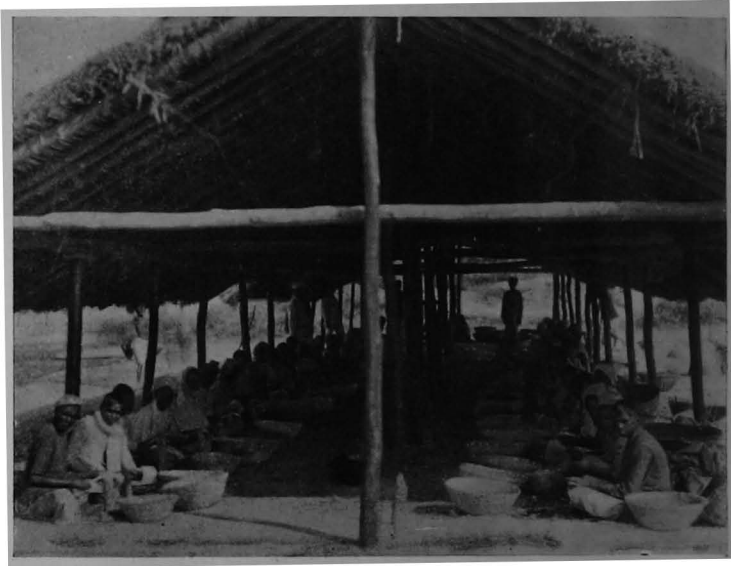
Cobbing.—Crystals of mica, after extraction from the mine, are first treated by cobbing, *i.e.*, cleaning it of all the adhering matters. The "ruled", "buckled", "wrinkled", "wavy" or otherwise defective parts are eliminated by cutting off the same with a special cobbing knife. Such *rough mica* is taken every night to the factory and stored in the godown after weighment.

S. D. B. mica: sickle-dressing, known better as Bengal sickle-dressing of mica.—To cob the "mine-run" or rough mica in India, wooden pegs or posts of 2 inches diameter are driven into the ground, their height above the ground being about 18 inches. The cobbers or cutters then sit on the ground, one at each peg, and holding the books of mica against the opposite side of the pegs dress it with the sickle ("hasua"). The resultant stuff is called the sickle-dressed mica, known in international trade as *Bengal sickle-dressed mica*.

This mica is again treated with a knife and any defects including all cracks and flaws are removed. It is then known in trade as "S. D. B." (sickle-dressed mica) mica.

Knife-trimming.—Rough-cobbed mica is issued every morning to the cutters and is treated in the trimming or dressing sheds of the factory with knife. The block is rifted or split into sheets, generally 1/8 inch to 1/16 inch or 1/32 inch thick or still thinner sheets. Loose bits, if any, are broken off and the

torn or frayed edges and flaws are cut out. Skilled rifiers or cutters are given this job as they can give a greater economic output, within the specified time, making the mica at the same time commercially flawless and saleable at good price, without sacrificing the least sound portion that might easily go in. This is a very delicate and important job in the technique of mica trimming, as a slight negligence or ignorance often causes a considerable loss, either by way of wasting or spoiling away a good deal of sound mica or causing deterioration in its value, due to the retention of flawy or objectionable pieces in the lot



[By permission of the Director, G. S. I.
Fig. 9.—Cutting shed and sickle-dressing operation, Jorasemar Mica
Factory. (After C. S. Fox.)

for sale, including excessive triangle-cutting. *Mica trimming is thus a specialised art, which is performed to perfection in India.*

Expert workmanship in cobbing and trimming of mica as well as sorting processes deserve special consideration in the technique of mica manufacture. The bulk of the mica trade in Bihar at present has fallen in such hands who care little for this and have nowadays been producing stuff which on entry into the international trade creates prejudice on Indian productions as a whole.

Advantages of S. D. B. mica.—Mica thus prepared is classified for customs or tariff purposes in the United States as “uncut or unmanufactured mica”, unlike the rectangular



[By courtesy of Messrs. F. F. Chrestien and Co., Ltd.
Fig. 10.—Mica cutters at work at Domchanch.

trimmed or machined and punched sheets. The advantages of sickle-dressing of mica may be summarised as follows :—

- (i) Less wastage.
- (ii) No square corners to fray out in course of handling or processes.
- (iii) Bevelled edges, facilitating easy splitting of the trimmed sheets into thinner laminations or splittings.

Thumb-trimmed mica.—In America, during or after rifting, the sheets are *thumb-trimmed*, which is a common practice there. *Thumb-trimming* means the breaking off of the crystals with the finger-ends, eliminating inferior objectionable parts along the edges of the sheets.

Thumb-trimmed mica is looked on with disfavour by the buyers, though the sellers unfairly profit by it, owing to the disposal of a good part of the otherwise waste mica at the price of the flawless sheets. This somewhat corresponds with the pithead mica or *khadka abrak* of the Bihar mica field.

The thumb-trimmed mica in Canada is generally sold to the manufacturers or dealers in Ottawa, who maintain cutting

shops or mica factories. These dealers purchase the entire output of "mine-run" generally at a lump price, and again re-dress the mica and re-sort it into the different marketable sizes and qualities or patterns, discs, washers and segments, etc. Splitting knife is preferred for dressing thumb-trimmed mica while in course of final treatment, cutting off the rough frayed edges and other objectional defects that might lie over the sheets.

Thumb-trimmed mica in the United States.—Of the gross output of mica from a particular mine, approximately 30 to 35 per cent. represents marketable thumb-trimmed sheets, the balance being waste and scrap mica, which is either ground or sold out to the grinders as raw waste and scrap. This system of selling the mine's output in *thumb-trimmed form* in the United States is not likely to continue long, owing to its excessive wastage and Bengal sickle-dressing is gradually replacing it. Want of cheap trained labour, however, is a serious obstacle in introducing this system; no waste-saving machine has yet been developed. Cobbing, cleaning, sorting, grading and cutting of mica have essentially been manual operations everywhere.

Thumb-trimming, an uneconomic process.—Mr. Spence* condemns this practice and makes the following observations :—

"While thumb-trimming entails less labour on the part of the producer than knife-trimming and also probably nets him a greater return, since he is selling a proportion of waste at the price of sheet, Canadian mica would undoubtedly have secured a better reputation and established itself more firmly in the world market had this system of trimming never been introduced as a standard grade. As a device of the producer to increase his sales and also his profits, the system was tolerated in the earlier days of the industry when competition was less keen, standards lower, and the demand for Canadian amber mica more insistent. To-day, its continuance is against the best interests of the industry, which could not but benefit if it were discarded in favour of knife or sickle-trimming."

WRONG SICKLE-DRESSING OF MICA

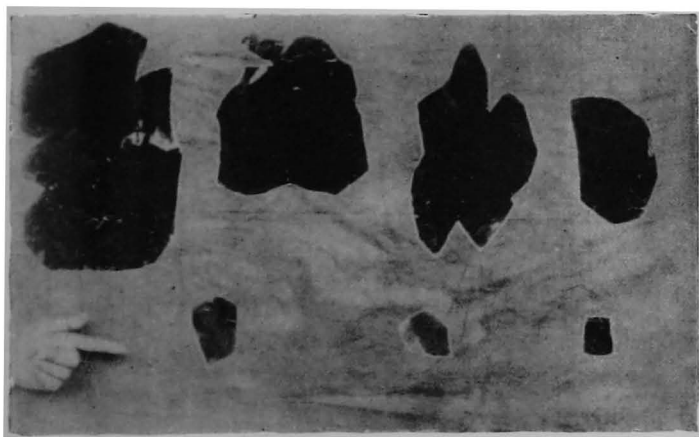
The following is an extract from Messrs. Jaroslaw's letter to the author (dated H/Ln., 6th October, 1932):—

"The dressing of mica has become, since the war, worse and it is necessary to bring the dressing again to a correct and common standard. The same thing applies to the assorting although the manner of assorting is not so

* Mica, 1929, p. 54.

important like the dressing.* * *I send you by this mail a characteristic sample of a piece wrongly dressed and a sample of the piece correctly dressed. The wrongly dressed piece should have been cut into three pieces, the three pieces each to be assorted in another grade. A buyer of mica getting such badly dressed mica has not only the loss of larger waste when cutting the mica into squares or rounds or other forms, but if he is compelled to cut such a badly trimmed piece into some pieces and to assort the parts into other grades, he has an enormous loss as the smaller grades are much cheaper than the larger grades."

The author severely commented on the unfair method of grading and preparation of mica in *India Mica, Vol. I*; so far



[By permission of the Director, G. S. I.

Fig. 11.—Showing the right and wrong (triangular) dressing of S. D. B. mica. (After C. S. Fox.)

as the awkward triangle or zigzag cutting of mica is concerned, it has for its object the identical motive "to net a higher return" by selling off a proportion of waste or inferior mica at the price of the high-class flawless sheets. The above observation should act as an eye-opener to the mica-men in India, so that India may not have to rue for the present practice at a time when things will drift beyond redress. The author, however, does not expect any change in the outlook and trading practices of these people, unless the Government intervenes and gives a lead towards *standardisation with a plan of co-operative marketing.*

Importance of sorting.—The cutters and sorters of mica in India who constitute the workers of a mica factory are amazingly dexterous in this class of work due to their traditional practice, so much so that they can, at a glance and without the use of a template, judge the exact maximum size that a given specimen of mica will yield, and this saves a lot of time in the process of dressing or sorting. This naturally reduces the cost of the product to the maximum economic limit. These operations are performed in America generally by girls. Sorting of mica consists of grading the mica into different marketable qualities and sizes.

SHEAR TRIMMING

In the Presidency of Madras as also in the United States and Canada, “shears” or “guillotine knives” are employed for dressing mica sheets. According to this method, thick mica sheet is cut with its edges normal to the normal plane unlike the bevelled edges of the sickle-dressed mica of Bihar. For this purpose ordinary garden shears or guillotine knives are commonly used.

Mr. Hobson* describes the process of shear-trimming as follows :—

“One handle of the knife is removed and the tang of the blade is fastened into a block of wood in such a way that the long axis of the blade lies at an angle of 45° to the horizontal with the cutting plane of the blade vertical and the cutting edge below. The operator squats down, holds the block steady with his feet, and taking the sheet of mica in his left hand cuts by moving the free shear blade up and down.”

The mica thus trimmed is known as the “Madras-trimmed” mica and is graded according to the surface rectangular area on the basis of standard fixed by the Government.

Madras-trimmed mica is occasionally preferred by certain customers for lesser wastage, when the sheets in rectangular shapes are required for special purposes.

In the United States, the shear or guillotine-cut mica is split into thin foliage or films and cut into rectangles, circular shapes or oblong sizes and the mica is treated for the customs purposes as “uncut or unmanufactured mica”.

Disc or washer punching.—The smaller sizes of mica in the United States and Canada are punched into discs or circles

* Bull. Inst. Min. & Met., No. 270, March 1927.

and washers by means of compound dies in power machines, cutting both the central as well as the outer holes in one operation. These washers usually vary in size ranging from $\frac{5}{8}$ to 2 inches in outside diameters, the inner hole being between $\frac{1}{4}$ to 1 inch. These washers are made up into any required thickness with a suitable binder.

Rotary trimmer and mechanisation of splitting of mica.—

Attempts at mechanisation of the process of splitting have been made by different experts in America and some mechanised splitting devices and rotary trimmers have also been patented, the actual employment of which however has not yet been widely in evidence.

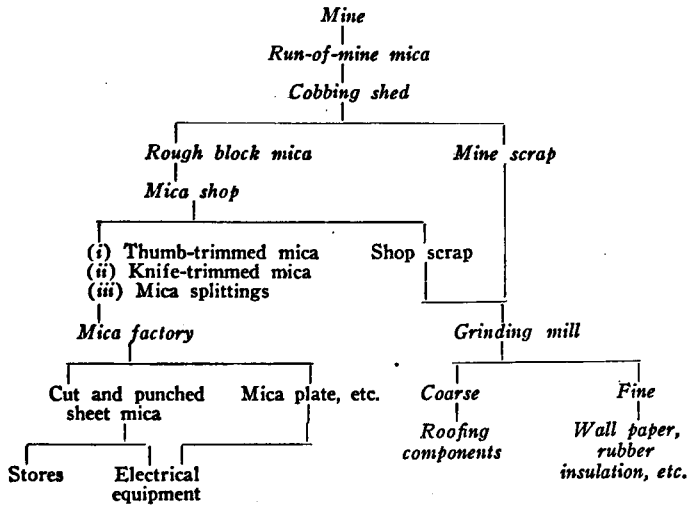
Shipment of block mica.—After dressing, mica is passed on to the graders or sorters who are the most skilled workers in a mica factory. Sometimes sorters have to remove some flawy films or defective portions of the individual "S. D. B." sheet, in order to bring up the quality to "standard". Thus some wastage is bound to accumulate usually in the process of sorting as well (known as "sorting wastage"). The general estimate of the shipment block from "S. D. B." is roughly taken at 9 : 10 with $\frac{1}{20}$ of films and $\frac{1}{20}$ of wastage. One maund of "S. D. B." mica therefore is taken to yield 36 seers of shipment block, 2 seers of films and 2 seers of wastage.

Splitting blocks.—After selection of the exportable block mica, *i.e.*, shipment quality, from the "S. D. B." outturn, the rest sells as splitting block. Sometimes special *strip* sizes are taken out for specified purposes. Exportable blocks should usually be at least 10 to 11 mils thick. In course of sorting, thinner sheets are separated in a lot, which is generally used as splitting blocks or sold as thick *chillas*.

Splitting blocks are not normally marketed as exportable block mica, except as *thin split mica*, called for nowadays for condenser or other special requirements, the latter being supplied uncalibred or calibred to a specified range of thickness, *viz.*, 8 to 13 mils, etc. Demand for splitting mica far exceeds that of standard (shipment) blocks and as such it is imperative to use a good proportion of standard block mica as well for manufacture of splittings, where price permits. Splitting blocks should be so dressed as not to leave excessive wastage in splitting; normally the wastage ranges between 10 to 40 per cent. of which 25 per cent. may be taken as an usual average from the blocks of reputed miners. The proportion of sale of Indian mica blocks and splittings can be gauged from the fact that out of 293,343 cwt. (14,867 long tons) of mica exported altogether in 1937, 267,340 cwt. (13,367 long tons) represent mica films and splittings.

FLOW CHART OF THE PROCESSES OF TREATMENT OF MICA IN CANADA, PRIOR TO MARKETING

Mr. Spence has summarised the different stages of the treatment of mica in Canada in the following flow chart :—



The producers of mica in Canada sell their output in the undernoted forms :—

1. Rough-cobbed mica.
2. Thumb-trimmed mica.
3. Knife-trimmed mica.
4. Fit-cut pattern mica in rounds, rectangles, discs, washers and segments, etc.
5. Mica splittings, called in trade as *thin split mica*.
6. Mica scrap or waste mica.
7. Ground mica.
8. Built-up mica or micanites in sheets, tapes, tubes and special shapes or sizes.

The knife-trimmed mica usually sells at about 20 per cent. higher prices than the thumb-trimmed mica sheets.

SORTING OF MICA: DIFFERENT COMMERCIAL QUALITIES

RUBY MUSCOVITE MICA (BENGAL MICA)

Mica, broadly speaking, may be divided into three principal qualities, namely:—

1. *Clear.*
2. *Slightly stained.*
3. *Stained or spotted.*

The lines of industrial requirements of mica are numerous nowadays and competition for cheaper stuff in both grades and qualities, sometimes at the sacrifice of efficiency, has been very keen; since the Great War (1914–18) many sub-qualities have been introduced, sometimes with slight degrees of distinction, if any.

The following are the current commercial qualities:—

Description.	Trade abbreviations.
<i>Muscovite ruby mica.</i>	
1. Ruby clear : (a) Superfine clear ..	Sup. Cl.
(b) Clear ..	Cl.
2. Clear and slightly stained ..	Cl. & SS.
(sometimes called slightly stained) ..	SS.
3. Fair stained	F.S.
4. Good stained	G.S.
5. Stained*	Std. or R.S.
6. Heavy stained	H.S.
7. Black spotted	B.S.
8. Black stained	
9. Badly stained	

Several mixed qualities of ruby mica have also come into general use as follows:—

- (i) Ruby clear to fair stained.
- (ii) Ruby clear to good stained or stained.
- (iii) Ruby clear to heavily stained.
- (iv) Ruby fair to heavily stained.
- (v) Ruby fair to slightly stained or stained.
- (vi) Ruby clear and slightly stained to fair or good stained.
- (vii) Ruby good stained to heavily stained.
- (viii) *Ruby mixed mica* containing, generally, some or all of the different qualities of ruby mica in varying proportions.

Ruby mixed mica is sold by many original miners and the lots of some of the reputed and reliable miners consist

* Stained mica is also sold in first and second qualities, the first quality ruby stained differing very little from the good stained quality.

usually of a fair average proportion of higher qualities, including some percentage of even Cl. & SS. and clear mica. Ordinary miners' lots, however, scarcely contain anything of even fair stained quality. The latter type, as has been stated before, has now become common in Bihar now exploiting the absence of statutory standardisation and control, to the detriment of the Industry as a whole.

In sorting mica uniformity should be maintained in each lot, as far as practicable.

After sorting out the lot of cobbled or dressed mica (S. D. B.) the remaining defective stuff or rejections is kept apart for sale as cheap stuff, which is used as raw material for making cheap loose splittings.

Certain defects of sheet mica are so detrimental to its commercial worth that they sometimes reduce the value of the lot very considerably. Flawlessness and transparency constitute most important points in the trading of mica.

GREEN RUBY MICA (OF MADRAS)

Green mica produced in different places in Southern India, from Travancore to Nellore, may be distinguished as one or other of the undernoted qualities, according to the colour of the mica concerned :—

- (i) Clear green.
- (ii) Spotted green.
- (iii) Pale or light green.
- (iv) Bottle green.
- (v) Green dotted or spotted mica.
- (vi) Yellowish mica.
- (vii) Brown mica.

The muscovite or potash mica is known as white mica all over the world, though the amber green or phlogopite mica when split into thin sheets, flakes or films looks clear and colourless as muscovite.

In Bihar there is an inferior white stuff which, though whitish or silvery in texture and soft, is not exactly clear white like Bengal ruby muscovite. Its insulating power or di-electric strength as well as thermal resistance are very low; this type of mica, therefore, seems to be unsuitable for good insulation service.

Silver-speckled white.—Splittings made of it are very soft, but such splittings should not be preferred in the manufacture of high-insulation micanites. This type of mica is produced in one or two localities in Bihar, the miners or dealers of which pass it into the market as soft white mica for high electrical work. Splittings made of it have a good demand, particularly in the continental market under the style of *soft white mica splittings*.

BLACK MICA

This mica is produced in Bihar, Madras and Central India, including Ajmer-Merwara, in large quantities and is often found in the same mine containing clear ruby muscovite crystals. Madras production generally has a greenish tinge and is very hard as well. Bengal black spotted, produced in certain localities in the districts of Hazaribagh and Gaya, has a world-wide reputation for hardness and is sold at good prices. Madras spotted may better be called green spotted.

Ebony-black mica.—A type of fine flawless sheet mica is produced in the Madras side generally, which is deep black as ebony and is quite hard.

Red-spotted black mica.—There is another type of mica, produced in Madras and Ajmere, which is black stained with red spots or lines. Market for this as well as the *ebony-black* mica is restricted and the prices fetched are considerably lower than the hard black-spotted mica of Bihar and Madras, which enjoys an excellent reputation in Europe and America.

Ajmere mica.—Ajmere mica is very rarely free from black spots or red stains and is generally softer than the stuff obtained from Bihar and Madras. Moreover waves and undulations preponderate in the production from Central India, Ajmere in particular. Ruby and black spotted, produced in the Shahapura State since 1935, appear to be better than the mica of Ajmere.

Udaipur (Mewar) ruby mica.—A quality of ruby mica mined in this State is being marketed in Kodarma lately, which in hardness and colour matches the Bihar ruby stained very well. The deposit is reported to be a very promising one.

Black spotted: first and second qualities.—Black-spotted mica is usually sold in first and second qualities, the first being harder in texture, quite level and flat, and flawless in all respects. The second quality black spotted is somewhat softer, containing considerable proportions of waves and minor commercial defects, permissible in inferior class of work.

Besides the above, the "cross-grained" (*Jatai*), "tangle-sheet" or waste and scrap mica also sell in the United States market for grinding purposes, boiler insulation, fibre board manufacture, roofing components, etc. This class of mica has a growing demand in the United States.

CLASSIFICATION OF MICA IN THE UNITED STATES

The domestic production of mica in the United States is marketed in the form of sheet, punch and circles and is classified into three principal qualities, namely:—

- (i) *Clear.*
- (ii) *Slightly stained.*
- (iii) *Heavily stained or spotted.*

These three qualities are often reduced to two only, viz., (i) *clear* and (ii) *stained*, the latter consisting of the last two of the above-mentioned qualities.

Muscovite for glazing, commonly known as *stove mica*, is classified according to quality as No. 1 or No. 2 *stove mica*.

BENGAL RUBY MICA AS STANDARDISED IN THE UNITED STATES OF AMERICA

Bengal ruby mica for use in the United States has been more or less standardised by the following limits of distinction by the American Society for Testing Materials* :—

- (1) *Clear*.—Free of all mineral and vegetable inclusions, waves or buckles, hard transparent sheets.
- (2) *Clear and slightly stained*.—Free of all mineral and vegetable inclusions, cracks, waves and buckles but may contain slight stains and air inclusions.
- (3) *Fair stained*.—Free of mineral and vegetable inclusions and cracks; hard; contains solid and air inclusions and is slightly wavy.
- (4) *Good stained*.—Free of mineral inclusions and cracks but contain air inclusions; some vegetable inclusions; may also be somewhat wavy.
- (5) *Stained*.—Free of mineral inclusions and cracks, but may contain considerable clay and vegetable stains and may be more wavy and softer than the better qualities.
- (6) *Black stained or spotted*.—Same as stained but contains mineral inclusions. In this class all the commercial qualities of heavily stained, black spotted or black stained are included†.

MUSCOVITE RUBY INDIAN MICA IN LONDON

While fixing the prices of Bengal ruby mica in London in January 1918, British Government standardised the following qualities (commercial) :—

- (a) *Clear* (Government Standard).
- (b) *Partly stained* (Government Standard).
- (c) Second quality clear.
- (d) Second quality part stained.
- (e) Fair stained.

* A. S. T. M./D. 351-33 T : Minerals Year Book, U. S. Bureau of Mines.

† In India, of course, heavily stained and stained are quite different qualities from that of black spotted. Heavily stained is marketed as the lowest grade of ruby muscovite mica with heavy mud stains and commercial flaws like waves or silver lines; black spotted is a class in itself with varying proportions of iron oxides and black stains or spots in it.

- (f) Ordinary stained (certain percentage of rust and clay allowed).
- (g) Densely stained.
- (h) Soft white.
- (i) Black spotted.

Good stained is comparatively a recent introduction and is in large demand, which was unknown before the last war (1914-18). The so-called *first quality stained* is almost identical with *good stained*. Ruby stained mica is sold by certain dealers in Bihar in first and second qualities. In the former, the bulk consists of good stained, whereas in the latter the proportion of stained or heavily stained or densely stained preponderates*.

CLASSIFICATION OF CANADIAN AMBER (PHLOGOPITE)

The Canadian phlogopite or amber mica is classified under the following heads :—

- (i) *Light amber.*
- (ii) *Silver amber* (also called as first quality amber).
- (iii) *Medium amber.*
- (iv) *Dark amber* (also called as second quality amber).

It may be noted that the lighter class of amber is considered a better insulator on account of its lesser proportion of iron contents.

CLASSIFICATION OF MADAGASCAR AMBER (PHLOGOPITE) MICA

The Madagascar phlogopite is classified under the following denominations, based on the varying degrees of colour-cum-hardness :—

- (i) *Silver amber or soft Madagascar amber.*
- (ii) *Brown amber or medium Madagascar amber.*
- (iii) *Amber to silver black or hard Madagascar amber.*

Splittings are made generally from the first two qualities, *i.e.*, silver and brown amber. The hard amber, not being very suitable for the splitting purposes, is selected apart, which fetches a good price, for application in stoves, heaters and similar heat-resisting appliances.

* India Mica, Vol. I, by R. R. Chowdhury.

Madagascar muscovite.—Madagascar muscovite mica is classified into two principal qualities, namely, (i) *clear* and (ii) *stained*.

Madagascar muscovite, it may be noted, is not preferred to Indian muscovite by the electrical manufacturers, in view of its greater proportion of iron oxides.

Indian spotted mica is competed by the Madagascar phlogopite in London and the Continent, the former proving dearer in comparison, but the Indian spotted is decidedly of harder nature. The quantities produced are quite large and a good splitting line has developed in the Madagascar mica mining industry, the products being exported mainly to Europe through French interests as well as to the United States direct.

The recent basis of classifications has been described* as follows :—

1. *Dark amber.*—The real genuine amber as reddish amber and the variations to dark shades.
2. *Green amber.*—Silver coloured mica.

These descriptions have been chosen from the exterior look, which still varies according to the various sources of supply and does not offer absolute guarantee for the qualities and properties which such Madagascar phlogopite possesses. Amber mica does not in fact represent a uniform quality*, but is merely a general description.

Madagascar amber mica has, however, a high resistance to heat, but is rather soft.

Resistance against heat.—In general the dark amber and the reddish-brownish amber (occasionally although very seldom green amber) show a resistance against heat, but they do not calcine and puff up at 90°C. Some of these qualities do not calcine but puff up slightly and can still be said to be resistant against heat.

Softness and tenderness.—Almost every quality of amber mica is so soft that its deterioration is the same as that of the copper in commutators; the grade of softness is therefore considerably higher than of Indian mica.

CLASSIFICATION OF MICA IN BRAZIL

Very light ruby colour is the characteristic of Brazilian mica and the mica is readily splittable.

*By courtesy of Messrs. Jaroslaw's Erste Glimmerwaren Fabrik in Berlin. Their letter to the author S/E. 3, 19th January, 1938.

The mica is classified into the following qualities :—

<i>Claro</i>	..	<i>Clear.</i>
<i>Semi-claro</i>	..	<i>Fair stained.</i>
<i>Semi-manchado</i>	..	<i>Good stained to stained.</i>
<i>Manchado</i>	..	<i>Stained to very slightly spotted.</i>

Brazilian mica does not have the same characteristics as the Bengal ruby mica and the designation of the Bengal or Indian qualities is not exactly applicable to the Brazilian or any other class of mica produced in other countries.

Messrs. Jaroslaw of Berlin have compared the characteristics of Indian and Brazilian muscovite ruby mica as follows :—

“The difference between the Brazilian mica called *semi-claro* to *manchado* and the Indian mica is that the Brazilian mica shows larger air bubbles. The *semi-manchado* quality sometimes looks like the so-called white mica, however, without being anyhow identical with white mica, because the air bubbles in Brazilian mica are larger and do not possess the extraordinary fine and throughout the whole surface uniform spread as is the case with white mica (*Indian ruby muscovite mica*).

“*Semi-manchado* mica besides this shows slight brown shades while the *manchado* has these brown shades still more intensively.

“The electrical properties of Brazilian mica are good. They are only a little below those of Bengal mica of such qualities which can be compared with Brazilian mica—as Bengal mica is understood in this sense, the mica which is found in the northern mining districts, *viz.*, in and in the neighbourhood of Giridih.”

USES OF MICA AND THE FORMS IN WHICH IT IS MARKETING

Description.	Forms and preparations.	Uses.
1. Sheet mica	Uncut or unmanufactured. Thumb-trimmed, Rough-cobbed, Knife-trimmed, Sickle or Indian-trimmed, Shear or Madras-trimmed.	Punch, condenser, stoves, electric and diaphragm mica

The larger sizes of sheets are generally meant for heater elements, electric irons, toasters, percolators, etc., as well as condensers and the small sizes are used as segments, discs and

washers, of which an infinite variety of shapes and sizes are die-punched on power presses.

Description.	Forms and preparations.	Uses.
2. Mica splittings	(i) Book-packed, pan-packed, dust-loose or ordinary loose forms.	Consumed in the manufacture of built-up mica boards, tubes, tapes, etc.
	(ii) Cut or manufactured splittings or films.	Washers, films or condensers, electric, phonograph, manufacture of built-up mica and other manufactures of splittings.
3. Scrap mica	(i) Unground	{ (a) Wet ground Wall paper, moulded insulation and fancy paints. (b) Dry ground Rubber insulation, etc.
	(ii) Ground	

Mica is applied in the form of sheets, washers and cylindrical shapes for various devices and different qualities of mica are usually specified for such particular purposes (according to the degree of efficiency, consistent of course with the price-factor), some of which may be named as follows :—

Quality of mica.	Purpose for which usually applied.
(i) Clear ruby mica	(a) Electrical condensers. (b) Radio valves.
(ii) Clear transparent mica sheets.	Doors and windows of anthracite stoves and the like.
(iii) Ruby spotted and amber.	(a) Cable joints.
	(b) Commutator segments and separators.
(iv) Ruby green—spotted and certain varieties of amber mica.	(c) Armature binding.
	(d) Heat resistors.
(v) Ruby and certain varieties of amber.	Heating and cooking appliances.
(vi) Amber mica	Spark plug.
(vii) Any easily cleavable flawless mica.	Plush separators.
(viii) Spotted and amber	Undercut.
	Washers.

Chapter IX

STANDARD GRADINGS OF MICA

The grading of mica in the different mica-producing countries is based more or less on the Indian ("Bengal") grading and on the United States standard measurements. The Indian standard has become the general basis for the international mica trade.

The Canadian standard with slight modifications follows the method adopted by the United States standard. The *Bengal grading* has been adopted in most of the South American and African countries, *viz.*, Argentina, Brazil, Union of South Africa, Rhodesia, Tanganyika Territory, Madagascar, etc.

THE BENGAL SYSTEM OF SIZING MICA

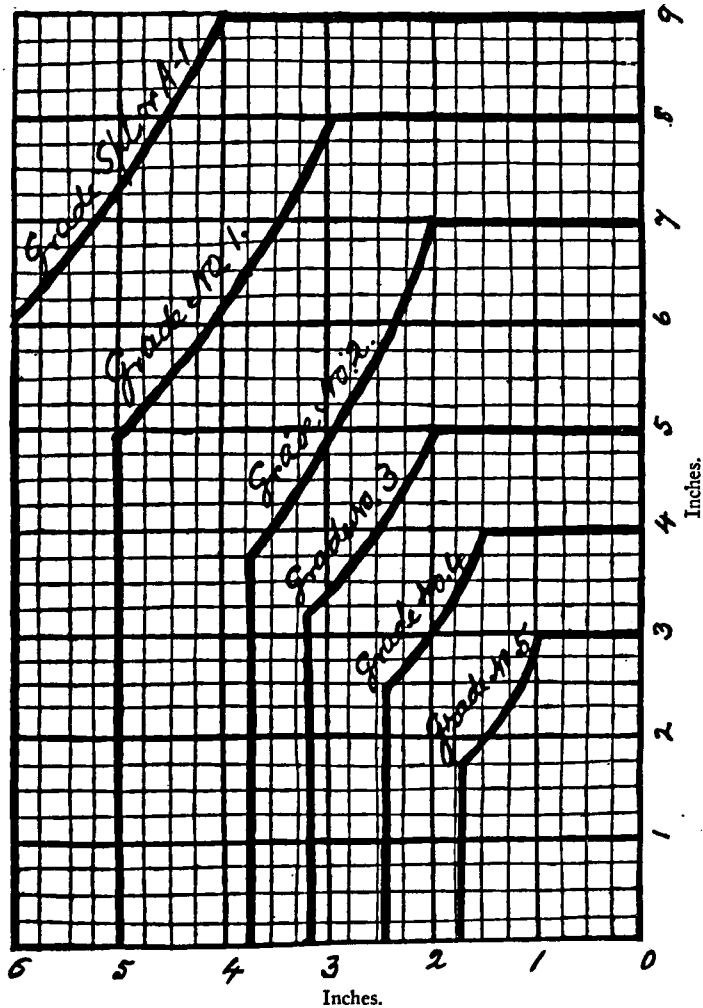
The standard measurement of the Bengal grading or rather the Indian classification of mica has been based somewhat arbitrarily on the surface area of the usable portion of mica, available in each individual sheet. The following represents the standard measurements :—

Bengal standard gradings of mica

Designation of the gradings.	Measurements as in practice in the trade.	Measurements as recorded in the Survey of India Records (Vol. LXIV).
	(Area in sq. in.)	(Area in sq. in.)
No. 7	.. .. . Below 1	Less than 1
No. 6	.. .. . From 1 to 2½	1 to 2½
" 5½	.. .. . " 2½ to 2¾	2½ to 3
" 5	.. .. . " 3 to 5¾	3 to 6
" 4	.. .. . " 6 to 9¾	6 to 10
" 3	.. .. . " 10 to 13¾	10 to 15
" 2	.. .. . " 14 to 23¾	15 to 24
" 1	.. .. . " 24 to 35¾	24 to 36
Special or A-1	.. .. . " 36 to 47¾	36 to 48
Extra Special or AA-1	.. .. . " 48 to 59¾	
Over Extra Special or AAA-1	.. .. . " 60 to 69¾	
" Over Extra Special or AAAA-1	.. .. . " 70 to 79¾	
" " Over Extra Special or AAAAA-1.	.. .. . " 80 to 99¾	
Over Over Over Over Extra Special or AAAAAA-1.	.. .. . " 100 and over	

In the United States of America, one A-1 grade is introduced above No. 1 grade, which in measurement is the same as the Indian special size of mica (i.e., from 36 to 48 square inches).

Chart for classifying mica into the Bengal grades.



Source: India Mica, Vol. I, by R. R. Chowdhury.

THE MIDDLE AVERAGES OF THE BENGAL GRADING

A grading is deemed up to standard, when each of the individual sheets in the lot measures the area as described above, *in fair proportions* between the maximum and minimum specified limits. To judge this, the following offers a convenient guide :—

A lot of mica blocks, say of No. 4 grade, is considered a *fair* and passable grade if all the pieces in the lot measure, in usable area, fairly between 6 to $9\frac{7}{8}$ square inches. These minimum and maximum limits arbitrarily standardised for each grade is a source of much of the confusion and misunderstanding prevailing in the mica trade, inasmuch as the superiority or inferiority of a lot of mica depends considerably on the *average or fair proportions* of different sizes, within the range from the smallest to the largest sizes. The presence of merely "top" sizes, say, for instance, in a lot of No. 4 grade mica, comprising sheets between 9 to 10 inches or even 8 to 10 inches makes the grade superior to the standard, and similarly the presence of pieces, mostly between 6 to 7 inches or thereabouts, would render the lot inferior to the normal standard in the estimate of the prospective buyers.

The safest guide would therefore be to base the *fair average* proportion of sizes on the basis of the *middle average* of the grade concerned. A lot consisting of pieces, mostly below this *middle average*, is not looked on favourably, whereas a lot with the major proportion of sheets above this *middle average* is considered a superior grading. A rough indication of the *middle averages* of the different Bengal gradings is given below :—

Standard grade.	..	..	Middle average.
No. 6	..	..	2 square inches.
" 5	..	..	4½ " "
" 4	..	..	8 " "
" 3	..	..	12 " "
" 2	..	..	19½ " "
" 1	..	..	30 " "
Special	..	..	42 " "

If in No. 2 grade mica most of the pieces represent an area of about 21 square inches, the assortment is considered a large size and, as such, superior to the normal grading. If, on the other hand, the *middle average* in the lot is about 17 square inches, the grading is considered a bad and unsatisfactory one. In this way materials can be assorted larger or smaller within the relative maximum and minimum of the standard measurements.

"*Fit-cut mica*".— "Cut mica", or mica cut to specified dimensions in squares, rectangles, rounds (otherwise known as "circles" or "diameters", etc.) and zig-zag shapes for stove plates and other purposes, is known in the local trade as "fit-cut

mica". Very good prices are paid for sound "cut mica", but there is a complaint amongst the foreign buyers that "cut mica" from the Indian suppliers scarcely represents the buyer's specifications to precision, both in respect of the dimension and thickness.

"Cut mica of random thickness".—This class of mica sheets is sometimes in good demand; the sheets are to be cut or stamped to specified dimensions, not generally larger than 2 by 2 inches to 2 by 3 inches. The sheets are usually cut slightly larger than thinner sheets actually employed in condensers by the users.

Condenser films.—Buyer's specification sometimes includes calibring or gauging to particular thickness, which usually ranges between 0.001 to 0.0045 inch or even 0.005 inch with allowance of 0.0005 *plus/minus*. Each of these films or sheets must be flawless, plain and resist about 20,000 volts per mil.

Uncut condenser mica.—There is a large demand for condenser mica sheets or "thin split mica"*; selected-to-cut a special size. In such supplies, the individual sheet must not leave an excessive wastage and must not be larger than 1½ times each way than the dimension specified "to cut".

"Selected-to-cut mica".—Sheet mica is generally sold in India in large quantities, selected "to yield" the specified dimensions and the suppliers prefer to take engagements for "selected-to-cut-size" mica instead of mica precisely "cut-to-size", even at lesser price, owing to the advantage that the dimensions in the former permits wider latitude in regard to size and wastage, which is an important consideration from the seller's point of view. These sheets are sold in weight so that the sellers are paid for the material including the ultimate wastage to a considerable extent. Sufficient discretion, however, has got to be exercised in the sorting of the "selected-to-cut-size" mica, so that the final wastage in the actual employment of the mica may not go beyond the tolerable limits.

The demand of the Indian consumers of mica sheets for electric insulation, heat insulation, glazing and other purposes mostly consists of this class of mica.

*It is worth while here to note the observations made by Mr. A. Gunther of Jaroslaw, Berlin, in a letter (H/R dated 17th April, 1931) to the author:

"It is even impossible to export from India split mica for condensers, etc. It is not possible to foresee sizes and thicknesses which in any moment will be asked in Europe or America, and as the sizes and thicknesses are constantly altered for the different users and nearly no order is equal to the other, it is better to split the raw mica in that country where the split and cut mica is wanted, although the *wages* are higher than in India".

The export of condenser films and thin mica split to 8 to 13 mils or otherwise, calibrated or uncalibrated, has largely increased in recent years.—
Author.

THE MADRAS SYSTEM OF SIZING MICA

In the Madras Presidency (Nellore mica field) mica blocks are trimmed by shears into rectangular dimensions. Such rectangular cut mica is graded on the basis of the Government schedule, given in Chapter VI (p. 185). The size of the plate is based on the maximum rectangular area it would yield.

There is a great disadvantage in transacting business in this class of mica, in view of the fact that this mica is sold in entire lots by the miners, like the thumb-trimmed or "run-of-mine" mica of Canada, consisting of various sizes and particular selected size or sizes are not allowed to be bought even at special prices. In the market there may be an enquiry for certain sizes, but the dealers or buyers, for a matter of that, cannot block up money in purchasing a whole lot of mica, out of which a large proportion of sizes not immediately in demand will lie over unsold for an indefinite time. To obviate this risk and for other facilities, the Bengal system of sickle-trimming of mica, according to the Bengal standard measurements, has been introduced and widely adopted in the Presidency. Madras mica is now available in Bengal dressing and gradings.

U. S. SYSTEM OF GRADING

Punch.—According to the American system of sizing of domestic mica the smallest grade of mica is called "*punch*" size, which must be sufficient in area to yield a circle of at least $1\frac{1}{2}$ inches in diameter in the *stained quality* and $1\frac{1}{4}$ inches in diameter in the *clear quality* of mica.

Circle.—The next higher size is called "*circle*" which should be capable of yielding a circle of at least 2 inches in diameter.

Rectangles.—In rectangular shapes the smallest size is $1\frac{1}{2} \times 2$ inches as will be found from the undernoted standard dimensions :—

(i)	<i>Punch</i>	(a) Stained up to $1\frac{1}{2}$ inches.
		(b) Clear up to $1\frac{1}{4}$ inches.
(ii)	<i>Circle</i>	2 inches.
(iii)	$1\frac{1}{2} \times 2$	"
(iv)	2×2	"
(v)	2×3	"
(vi)	3×3	"
(vii)	3×4	"
(viii)	3×5	"
(ix)	4×6	"
(x)	6×6	"
(xi)	5×8	"
(xii)	8×8	" and over.
(xiii)	8×10	" and larger.

TABLE
Comparative standard sizes of different mica-producing countries.

	INDIAN STANDARDS.		AMERICAN STANDARDS.			No.	Tanganyika, m/m.	Chosen, in.	Grade.	Madagascar, sq. in.
	Bengal grading, sq. in.	Madras grading, sq. in.	U. S. A., in.	Canada, in.	South America, in.					
O.O.O. Over Extra	100 and over	X 112½ to 128	..	..	..	..	..	..	..	..
O.O. Over Extra	80 to 99½	IX 96½ to 112	8 × 10	8 × 10	..	..	..	..	..	..
O. Over Extra	70 to 79½	VIII 80½ to 96	..	..	..	..	..	..	..	..
Over Extra Spl. ..	60 to 69½	VII 64½ to 80	..	..	..	..	..	..	..	..
Extra Spl. (AA-1)	48 to 59½	VI 48½ to 64	8 × 8	..	..	..	..	..	..	..
Spl. or A-1 ..	36 to 47½	V 32½ to 48	6 × 6	6 × 8	..	Ex. Spl.	100 × 300 to 380 to	..	O.O. Over	48
1 ..	24 to 35½	..	4 × 6	5 × 8	36 to 48	Spl.	180 × 180	..	O. Over	36 to 48
2 ..	15 to 23½	..	4 × 6	9 × 9	24 to 36	No. 1	75 × 300 to 350 to	..	..	..
3 ..	10 to 14½	IV 16½ to 32	3 × 5	4 × 6	15 to 24	2	170 × 170	5 × 5 to	1	24 to 36
4 ..	6 to 9½	III 8½ to 16	3 × 4	3 × 5	10 to 15	3	150 × 150	6½ × 6½	2	15 to 24
5 ..	3 to 5½	II 4½ to 8	2 × 3	2 × 4	4 to 10	4	120 × 120	3½ × 3½ to	3	10 to 15
5½ ..	2½ to 2½	I 3 to 4	2 × 2	1 × 3	3 to 6	5	200 to 240 to	2½ × 2½ to	4	6 to 10
6 ..	1 to 2½	..	..	..	..	..	95 × 95	3½ × 3½	5	3 to 6
7 ..	Less than 1 sq. in.	..	..	..	..	..	35 × 100 to 150 to	1½ × 1½ to	..	..
			circle punch.	1 × 2	..	6	80 × 80	2½ × 2½	..	..
			..	1 × 1	..	7	25 × 70 to 90 to	1½ × 1½ to	6	1 to 3
							60 × 60	1½ × 1½	..	..
							25 × 40 to 70 to	..	..	..
							40 × 40	..	..	..
							25 × 30 to 40 to	..	..	..
							30 × 30	..	..	..

Standard Gradings of Mica

When properly trimmed, the uncut mica sheet is approximately $1\frac{1}{2}$ times as large as the maximum standard rectangle that may be cut out of it. The sheet mica is graded on the basis of the rectangular dimensions of the individual sheets such as 1 by 3 inches, 2 by 3 inches, 3 by 4 inches, 3 by 5 inches, etc., which may exactly be cut out of the pieces, whereas in India the standard of classification is based on the usable area in square inches, available from each individual sheet. Each of the above rectangular gradings includes in its range those pieces as well which are larger than the size actually designated or next below, until the sheet exactly comes up to the next higher standard grade. For instance, sheets $4\frac{1}{2}$ by 5 inches, $4\frac{3}{4}$ by 5 inches, 4 by $5\frac{1}{2}$ inches, $4\frac{1}{2}$ by $5\frac{1}{2}$ inches, etc., *i.e.*, between 4 by 5 inches and 5 by 5 inches or 4 by 6 inches are to be denominated as 4 by 5 inches unless it fully measures 5 by 6 inches or 4 by 6 inches. In this way, a sheet yielding a rectangle of $4\frac{1}{2}$ by $6\frac{1}{2}$ inches falls under the standard dimension of 4 by 6 inches although in actual measurement the area of the sheet comes to be bigger than 4 by 6 inches.

COMPARATIVE STANDARD GRADINGS OF MICA IN THE PRINCIPAL MICA-PRODUCING COUNTRIES

CANADIAN SYSTEM OF GRADING

The sizing of mica in Canada is based on the U. S. A. standards with the following alterations in the grouping of the dimensions. The area of the rectangle that can be had from each individual sheet of mica is the determining factor for gradation. The dimensions are standardised as follows :—

Standard sizes in Canada

- | | |
|------------------|---------------------|
| 1. 1 × 1 inch. | 5. 2 × 4 inches. |
| 2. 1 × 2 inches. | 6. 3 × 5 „ |
| 3. 1 × 3 „ | 7. 4 × 6 „ |
| 4. 2 × 3 „ | 8. 5 × 8 „ and over |

MADAGASCAR GRADINGS

(Based on Bengal standards)

The local Bureau of Mines have introduced the following standard dimensions in Madagascar for both muscovite and phlogopite mica.

Grade O.O. (Over Over)	from 48 square inches and over.
O. .. ..	.. ,, 36 to 48 square inches.
1 .. ..	.. ,, 24 to 36 " "
2 .. ..	.. ,, 15 to 24 " "
3 .. ..	.. ,, 10 to 15 " "
4 .. ..	.. ,, 6 to 10 " "
5 .. ..	.. ,, 3 to 6 " "
6 .. ..	.. ,, 1 to 3 " "
6 small .. ..	.. ,, 1 and smaller sizes.

CHOSEN GRADING (KOREA UNDER JAPAN)

Chosen is reported by Japanese sources to produce both the muscovite and phlogopite types of mica, but reliable detailed data are not available. The entire output is consumed by Japan.

Mica is classified into the *first* and *second* qualities, based on colours, commercial defects, imperfections, hardness and dielectric strength, etc. The sizes from Nos. 1 to 6 are given below :—

No. 1 ..	from 5" × 5" to 6 $\frac{1}{2}$ " × 6 $\frac{1}{2}$ ".
No. 2 ..	.. ,, 3 $\frac{1}{4}$ " × 3 $\frac{1}{4}$ " to 5" × 5".
No. 3 ..	.. ,, 2 $\frac{1}{8}$ " × 2 $\frac{1}{8}$ " to 3 $\frac{1}{4}$ " × 3 $\frac{1}{4}$ ".
No. 4 ..	.. ,, 1 $\frac{3}{8}$ " × 1 $\frac{3}{8}$ " to 2 $\frac{1}{4}$ " × 2 $\frac{1}{4}$ ".
No. 5 ..	.. ,, 1 $\frac{1}{4}$ " × 1 $\frac{1}{4}$ " to 1 $\frac{5}{8}$ " × 1 $\frac{5}{8}$ ".
No. 6 ..	.. ,, 1-1/16" × 1-1/16" to 1 $\frac{1}{4}$ " × 1 $\frac{1}{4}$ ".

Chapter X

MANUFACTURE OR COMMERCIAL PREPARATION OF MICA SPLITTINGS AND FILMS

HISTORY OF THE DEVELOPMENT OF THE MICA SPLITTING PROCESS

Since electricity has been harnessed to the service of mankind, the use of mica has grown up in increasingly large quantities. In the early days of the development of the electrical industry, only sound natural sheet mica used to be employed. Flawless clear mica sheets of big sizes, such as 6 by 15 inches etc., could be easily had at reasonable prices, as the demand was comparatively small, and though such big sizes of mica constituted only 5 to 15 per cent. of the total commercial output of the mines supply was sufficient. It was, however, soon realised that, as the electrical industry rapidly advanced, it would be impossible in no distant time to obtain adequate supplies of large sizes of flawless sheet mica to meet even a fraction of the ever-increasing requirements.

Built-up mica sometimes preferable to natural mica.—Moreover certain objections soon grew up against the use of the natural stuff for special purposes, which, in fact, has resulted in the development of the micanite or built-up mica manufacturing industry. Some of the inconveniences of natural sheet mica in actual industrial application, which have been successfully overcome by the use of built-up mica or micanites, are enumerated below :—

- (i) A large natural mica sheet is generally liable to contain objectionable inclusions or defects within or between the laminations, vitally affecting the high efficiency of the mica sheet, which has to be bought at a very high price.
- (ii) Natural mica is limited both in dimension and thickness and available supply of large flawless mica sheets is getting fast exhausted. Natural mica cannot be conveniently made to meet the required size and thickness quite accurately.
- (iii) The cost of flawless mica sheet of suitable size and quality for electric insulation is getting prohibitively high, with paucity of supplies and thus

the actual employment of large natural sheet mica is becoming uneconomic. A time is apprehended to come in future when the available world supply would fail to meet the growing demands, unless of course hitherto unknown deposits of commercial electrical sheet mica are discovered.

The property of perfect basal cleavage permits a thin sound mica sheet to be split up to very thin laminations even to the precision of 1/10,000 to 1/12,000 of an inch; this, coupled with transparency, elasticity and high di-electric strength, has given mica a far-reaching significance—leading to its successful utilisation in the form of small splittings and built-up mica products.

LARGE SIZE SHEET MICA GETTING SCARCE EVEN NOW

The uncertainty and risk of mica mining has made the mining of mica at great depths very difficult and costly and beyond the reach of miners of moderate means and the proportion of large flawless sheets is usually greater in most cases at depths in India. Only about 1 to 5 per cent. or less of the total mine-run actually finds way into the market and the remainder is thrown away as waste. Moreover, of the gross marketed mica, scarcely 2 to 10 per cent. represent large sheets from No. 3 and up. Thus, if the value to be fetched by such small percentage of the mined mica actually marketed fails to cover up adequately the costs of production of the total mine-run with a fair surplus, mica mining would not be worth while.

This and other connected problems led experts to make an earnest search for an economic solution and in 1892 (some put it at 1893 ?) Mr. C. W. Jefferson of Schenectady, N. Y., and A. H. S. Dyer* conceived the idea of splitting the smaller grades of mica into thin films and building them with suitable binder into plates or boards (*i.e.*, built-up mica sheets) of any desired size and thickness. Mr. Jefferson patented his invention and with the collaboration of Messrs. Munsell and Co., of New York, founded the *Mica Insulator Co. of New York*, for the purpose of using his patented invention and to manufacture mica insulators with small flakes of mica, for which there had been no use till then, and which were thrown away as waste.

Rifting of mica, a manual operation.—Rifting or splitting of mica is essentially a manual operation and has not been successfully mechanised, in spite of various efforts in America. India enjoys a monopoly in the supply of splittings; Indian labour or rather the splitters in Bihar are marvellously skilful in the technique of splitting mica, their wages also being very low.

* U. S. Patent No. 483646, dated 4th October, 1892, and Canadian Patent No. 44094, dated 28th August, 1893.

Canadian splittings.—The Canadian amber splittings are not very efficient for high-potential use, as its di-electric strength compared to muscovite is very low. A good deal of amber mica, however, is used for inferior classes of work and its consumption generally increases in times of scarcity of ruby muscovite mica. Amber mica, however, is a better heat insulator than muscovite and wears evenly with the copper segments of commutators; it is therefore preferred for certain kinds of heat-resisting and commutator micanites.

ORIGIN OF SPLITTING MANUFACTURE IN INDIA

About the year 1895 Mr. Franklin Brooks of the Mica Insulator Co., of New York, Mr. H. S. Munsell of Munsell and Co., of New York, and Mr. S. O. Fillion of Ottawa visited India and were entertained by Mr. F. F. Chrestien at his Tisri mica factory. They found enormous *dumps* of mica lying over the mining and factory area, which contained sound splittable small pieces of mica. Mica from No. 4 down used then to be thrown as waste into "dumps". Mr. Munsell is said to have trained a few boys and girls of the locality in the art of splitting mica, with the help of sandpaper in case of thin sheets. This is the first manufacture of splitting in India.

Splittings are made from block mica, split usually 0.001 to 0.0007 inch in thickness. Special splitting knives, sharp at both the edges towards the point, are used for this purpose. Good splitting blocks should have clear-cut bevelled edges and corners, as much free from objections and impurities as possible. Presence of air bubbles or air inclusions is not a defect in splitting blocks, as the bubbles or inclusions clear up on sheets being rifted into thinner films.

Indian ruby muscovite splittings are most suitable for the manufacture of best grade micanites for electrical purposes, and the specifications of purchase orders of the large buyers of splittings call for "Indian mica or its equivalent". Indian splittings are taken as the standard for finest grade of mica splittings in the international trade.

DIFFERENT PACKINGS OF SPLITTINGS

Indian splittings are manufactured in the following forms or packings :—

Description.	Trade abbreviations.
(a) Bookform or book-packed ..	B. F. or B. P. splittings.
(b) Pan-packed	P. P. splittings.
(c) Loose or loose-packed splittings including "dust" or "powder" loose splittings.	

PROCESS OF MANUFACTURE OF SPLITTINGS

Bookform splittings.—All the films, split out of an individual block or sheet of mica, are kept separately and packed together like a pack of cards, with mica dust sprinkled all over and between the laminæ, so that all the films made out of the particular block mica may remain distinctly separate and uniform in shape, size and finish; the films do not stick to each other in the "pack".

This class of splittings is the finest of all splittings and is in largest demand. In course of manufacture of *built-up* mica or micanites, bookform splittings can be applied very conveniently and they speed up the progress of work a good deal. Up to 1925-26, bookform splittings were not in large demand, as the large consumers of mica splittings, including the General Electric Company of Schenectady, Westinghouse Electric and Manufacturing Co. of East Pittsburg, Pa., etc., used circular pan-packed and loose splittings. Since then these large consumers have revised their methods and are using bookform splittings instead to such an extent that the price of pan splittings which formerly sold at very high rates came down near to the level of loose splittings of the corresponding grades.

MARKETABLE GRADES OF BOOKFORM SPLITTINGS

No. 4 Bookform splittings.	No. 5½ B. F. splittings.
" 4½ "	" 6-1st quality B. F. "
" 5-1st quality B. F. "	" 6-2nd " " "
" 5-2nd " " "	" " " " "

Of the above, No. 6 bookform splittings are in largest demand, which are also designated as No. 6 extra special dust book-packed and No. 6 special dust book-packed splittings.

Pan-packed (circular) splittings.—Splittings of different shapes of blocks (unlike that of bookform splittings) are split and packed together. In manufacturing these splittings the splitter requires as equipment, a blunt-edged but somewhat pointed splitting knife, a shallow circular (or square-shaped) tin pan (about 2 inches in depth and 6 inches in diameter), 3 or 4 sheets of paper and a sheet of tin or similar metal sheet. The splitter lays the splittings just as he splits over the bottom of the pan, keeping as even a thickness as possible, and when the desired thickness is built up a sheet of paper is put in position and the process is repeated. Finally, the tin sheet is placed on the top and the splitter presses down the whole lot with his palm. The contents of the tin pan are then taken out, which consist of several separate cakes of splittings each of about $\frac{1}{8}$ to $\frac{1}{4}$ inch in thickness. The splittings between two paper sheets get together firmly, on account of its natural adhesive property.

The advantage of this form of splittings is that, in the subsequent manufacture of the films into plates, the workmen can conveniently hold the small packings in the left hand and remove the films readily by the right and lay on the plate-making table. The value of pan-packed splittings at one time may be gauged from the fact that the well-known "Renotone" type of No. 5 extra special P. P. splittings sold at 5s. 6d. to 6s. per lb. c.i.f. New York.

Square-packed splittings.—Instead of circular pans sometimes square tin pans are used, in order to make square pan splittings, called for by certain buyers. The demand for this class, however, is rare nowadays. In price, gradings and finish, they are similar to the P. P. splittings.

MARKETABLE GRADES OF PAN SPLITTINGS

The following are the marketable grades of pan splittings. Formerly the grades in demand included up to No. 3 down to No. 6 (small) but now, apart from the diminution in the consumption of pan splittings generally, use of higher grades also has become scarce. A revival of demand of the pan splittings, however, is anticipated in some quarters.

Description.

- No. 3 P. P. splittings.
- „ 4 „ „
- „ 4 stained or spotted P. P. splittings.
- „ 4½ P. P. splittings.
- „ 5 extra special P. P. splittings.
(G. E. C.'s designation "Renotone").
- No. 5 special P. P. splittings.
(G. E. C.'s designation "Reneuour").
- No. 5 ordinary ("O" or "B") P. P. splittings.
- „ 5 stained or spotted P. P. splittings.
- „ 5½ P. P. splittings.
- „ 6 extra special P. P. splittings.
(G. E. C.'s designation "Renovamen").
- No. 6 special P. P. splittings.
- „ 6 ordinary ("A" or "B") P. P. splittings.
- „ 6 stained or spotted P. P. splittings.

In the absence of any specification as "stained", "green", "amber", etc., Indian splittings are generally taken to mean "ruby" clear splittings" (muscovite).

*G. E. C.'s specifications of requirements of splittings
(September 1925).*

- No. 5 Renotone.*—Each film must yield a rectangle or square of 4 inches including sizes up to the maximum of No. 5 grade and thickness of 1,400 films to an inch.
- No. 5 Reneours.*—Each film must yield a rectangle or square of 3 inches including sizes up to 4 square inches in area, thickness 1,100 films to an inch.
- No. 6 Renovamen.*—Each film must yield a rectangle or square of 1½ inches square up to maximum of No. 6 grade, thickness 1,400 films to an inch.
- No. 6 Reoxyder.*—Each film must yield a rectangle or square of 1 inch square to 1½ inches square, thickness 1,100 films to an inch.
- No. 6 Bookform.*—Same as above, each film dusted with mica powder, packed in compartments, preferably four by pasteboard or paper, so as to prevent shifting in transit.

Loose-packed splittings.—This is the easiest and cheapest class of splittings. The splittings, as split, are collected at random in baskets or pans and packed loose in cases for sale or shipment. Loose splittings including “dust or powder loose” are nowadays in very large demand. In view of the increasingly keen competition in the manufacture and marketing of cheap finished products, manufacturers are constantly looking for cheaper basic raw materials.

Demand for cheap quality loose splittings was most insistent in 1935 to 1937 and enormous dumps of low-grade mine and factory scrap have been to a large extent exhausted.

The marketable grades generally sought for in the loose quality are Nos. 5, 5½ and 6 in various descriptions of sub-qualities, between the standard grades, according to the variation in degrees of perfection, flawlessness and transparency. The marketable grades may be named as follows:—

- No. 5-1st quality loose.
- „ 5-2nd „ „
- „ 5-stained or spotted loose.
- „ 5½-1st quality loose.
- „ 5½-stained or spotted loose.
- „ 6 extra special loose.
- „ 6 special loose.

(Some designate it as "S" loose, meaning superior or soft loose according to the quality or finish of the splittings and sold sometimes in "1st" and "2nd" qualities.)

- No. 6 "A" loose or 1st quality loose splittings.
- „ 6 "B" loose or 2nd quality loose splittings.
- „ 6 "C" loose or 3rd quality loose splittings.
- „ 6 cheap loose splittings. (These are also sometimes sold as 1st quality cheap loose and 2nd quality cheap loose splittings.)
- „ 6 stained or spotted loose splittings.

Besides the above, there are several higher grade splittings, supplied in loose form, both clear and stained; demand for these splittings, however, is not common. Some of these are No. 3 loose, No. 4 loose and No. 4½ loose splittings.

Of the descriptions of sub-qualities, the basis of distinction is sometimes very slight, if not illusive, and supply of one "sub-quality" against a requisition for another is not quite infrequent.

Dust or powder loose splittings.—These splittings are made in the same manner as the loose splittings described above, with the only difference that mica dust or powder is sprinkled over the films as they are made, which prevents adhesion of the films with one another and the splitter has to be somewhat more careful in manufacturing these splittings than in case of the ordinary loose splittings. These splittings, however, fetch better prices than the loose types.



[By permission of the Director, G. S. I.
Fig. 12.—Manufacturing mica splittings; J. Podger's Mica
Factory at Kodarma.

MADRAS ROUND-CUT SPLITTINGS

In Nellore some miners and manufacturers make splittings from round-cut ruby and green mica blocks, which are locally known as "rounds". The splittings are called Madras ruby or Madras green round mica splittings and they can be had in book, pan or loose forms as required.

The Madras green splittings are very fine and soft in texture and are favoured by certain users on the continent.

HOME-SPLITTING SYSTEM

Splittings are made mostly by women and children in India, the United States and Canada; the women splitters in Bihar perform the job very skilfully and adroitly.

The "home-splitting system" is in vogue in India as also in the United States. The home-splitters take home a recorded quantity of splitting blocks on "piece work" basis, to be made into splittings at home, which are delivered back to the factory. Labour for this class of work is paid at fixed rates per seer or pound, with an allowance for process wastage. Generally cheaper classes of splittings are made by home-splitters.

SPLITTINGS IN THE UNITED STATES

Labour charges are very high in the U. S. A., and splittings made there prove very costly, compared with the price of the fine Indian splittings. The United States is the largest consumer of splittings and also the second largest producer of muscovite sheet mica and yet its production of splittings scarcely amounts to 5 per cent. of its own requirements.

As early as 1908-9 an attempt was made, perhaps for the first time, in the United States by the Asheville Mica Co. to manufacture mica splittings from domestic sheets. This is one of the pioneer producers of sheet and punch mica in the Union and have well-equipped power punches with suitable dies to punch discs, washers as also a variety of numerous odd-size patterns. For splittings they engaged first 10 to 12 young women at 9 to 12 cents per lb., each of whom could earn 75 cents to \$1.00 a day. The work proved profitable for a time but when the price of Indian splittings declined to about 5 cents per lb., domestic splittings from mined sheets proved too costly in competition with that of Indian supply of better prepared and finer quality of splittings. The cleavability of the domestic muscovite is not so perfect as that of Bengal ruby mica. Lower labour cost and traditionally expert craftsmanship in the art of fine splitting are important economic factors with which India holds monopoly in splittings to this day.

MICA SPLITTING MACHINE

A mechanism to split mica has been devised and patented in the United States by Louis T. Frederick (U. S. Patent No. 1666130) which has been described as follows :—

It consists of a revolving drum A into which the mica blocks coming from the mine are charged through the chute I. The blocks have previously been given a preliminary treatment consisting of bending alternately in opposite directions, to loosen the laminations. As the drum revolves the blocks tumble over each other and are acted upon by the baffles F, which action is enhanced by a blast of air that issues through the slot P in the centre pipe. This blast may be dispensed with if preferred. The slot P faces downward so that the air blast issuing from it strikes the edges of the slabs of mica as they rise under the action of the baffles of the rotating drum. The slabs or blocks requiring re-treatment fall into the receptacle M. A second current of air is blown into the drum through the duct J. The separated flakes are blown out of the upper end of the drum by this current into the hopper G. Mr. Frederick claims that the combined effect of the treatment received in the drum effects a very complete separation of the flakes and also that the flakes are extremely thin and of considerable size, for example, 1 by 1 to 1 inch to 1 by 2 inches.

MICA SPLITTINGS IN CANADA

The method of preparation of splittings in Canada somewhat differs from that of the United States or India in that the rough mica blocks or crystals are split into sheets of about 1/16 inch thick with the defects or broken parts removed. These sheets are then re-split into films of 1 to 2 mils thick by means of a splitting knife, its dull-edged blade being used for this purpose. The resultant mica films are called "thin split mica" or mica splittings.

One splitter is estimated to produce 10 to 12 pounds of 1 inch by 2 inches size of splittings in a day of 10 working hours and 7 lb. of 1 by 1 inch size of splittings. The smaller the size of mica blocks, the lesser is the quantity of the resultant outturn of splittings and the rate of wages for splittings of lower grade is therefore lower than that of the higher grade splittings.

MECHANISATION OF SPLITTING OPERATION

Several machines to split mica have been patented in the United States and Canada, which have not been successfully adopted widely in the industry as yet. The description of one

of such splitting devices in use in a factory at Valparaiso, Indiana, has been given as follows* :—

“Small books of mica are placed between two belts, running over a number of pulleys. The binding action gradually separates the films of mica in the book and the splittings are finally delivered into a trommel, which removes the dust as well as the small flakes. The splittings then drop in front of a suction-drum from which they are delivered and laid flat ready for application of a binder, for manufacture of mica boards.”

SPLITTINGS IN MADAGASCAR

Madagascar is developing a good splitting line and the United States is the most potential buyer of Madagascan phlogopite splittings.

Madagascan splittings are made largely by the two large mining interests, namely, “The Societe des Minerais de la Grande Ile” and “Societe Miniere et Forestiere de Madagascar”. These splittings are generally made and sold in Nos. 5 and 6 grades.

Madagascan splittings are made exclusively by women and children usually in their homes, as in India, on “piece work” basis and an ordinary cooking knife or a sharpened corset steel is used for this purpose.

Soft and medium quality blocks are made into splittings, the harder quality mica being selected for sale at good price for stove plates.

* U. S. Bur. Mines, Inf. Cir. 6205.

Chapter XI

GROUND MICA INDUSTRY

As the United States is the only country where waste or ground mica industry has developed by the utilisation of waste and scrap mica, this chapter will mostly contain details of the United States ground mica industry. India has enormous reserves of inferior or waste mica and micaceous rocks and minerals, but no useful channel for its economic utilisation has yet been found, although there are great prospects for the Indian waste to be used in the ground mica industry.

In the early stages of the mica industry in the United States, as it still prevails in India and elsewhere, rejected or defective mica used to be ignored or thrown away as mere waste, but nowadays not only the waste or rejected mica but also mica recovered from micaceous gneisses, schists, other rocks and kaolins, etc., are in very large demand in the United States for the purpose of grinding. Production of scrap mica has in fact been the mainstay of the U. S. mica industry, without which mica mining and manufacture could not have been remunerative.

It has been explained in the previous pages, what a great bulk of the *mine-run* of a mica mine or mica factory constitutes waste or scrap through the various stages of treatment from the mine to the ultimate works of its industrial employment. That 90 to 95 per cent. or still more of waste has got to be handled at heavy cost, just to recover 5 to 10 per cent. of the mica for industrial use, is the most surprising feature of the mica industry with the result that the small fractional commercial output has to be sold at the cost of the gross mine-run including labour expenses paid in the treatment of further wastes in factories and elsewhere. Countries like India, Canada and Madagascar can afford to mine mica even in such circumstances because a good percentage of large flawless sheet mica is generally available from the mica recovered, but mica mining proved to be a hopelessly losing profession in the United States, in spite of large muscovite mica deposits, owing to the fact that the proportion of sheet mica obtained from the *mine-run*, particularly sheets above No. 5 grade, is very small.

Proportion of sheet in U. S. A. mine-run very small.—A country like the United States, full of resources and initiative, cannot afford to let lie unused such huge deposits of a useful

mineral and her scientists and industrialists took to strenuous researches which have led to the development of a large ground-mica industry. These persistent efforts at research with mica and micaceous minerals, characteristic of the American pioneers, have opened up the potentiality of the mica waste and scrap to such an amazing extent that the large domestic production of true scrap and *reclaimed mica* does not adequately meet the ever-growing requirements of the industry and considerable quantities of mica waste, scrap and ground mica are being annually imported, even at a heavy import tariff, from other countries like South Africa, Canada, Soviet Russia and India.

Industrial research in the United States has thus converted a huge reserve of waste mineral into a potential wealth for the nation, forming in fact the basic asset for several lines of manufactures offering, at the same time, an additional revenue to the mica miners. Mica mines that could not be worked profitably for sheet production alone before, can as a result of this potential outlet for wastes and by-products be worked now on a profitable footing.

MICA, PECULIARLY DIFFICULT TO GRIND

Mica is a peculiarly difficult mineral to grind, owing to its excessive toughness and elasticity. Even the thinnest film is tough and elastic and so smooth that one easily slips over the other like a well-greased material. Mica, therefore, requires special grinding plants to pulverise it.

It is very difficult to secure detailed informations of the various processes of grinding mica which are generally shrouded in secrecy.

Mr. A. L. Hall*, however, has classified the general pulverising methods as follows :—

- (i) Disintegration by heating.
- (ii) Abrasion with mill stones or metal burrs.
- (iii) Banking at intense heat followed by pulverisation by a blast of steam. As mill stones require water to wash out the ground material and drying is difficult, they are not frequently used as a pulverising medium. The most modern method of baking and steam blast has not been widely used. Reliance has mainly been placed upon a mechanical grinding machine or pulveriser in the form of a metal cylinder lined with corrugated cast steel and containing a revolving shaft, to which are attached

* Eng. and Min. Journ., Vol. 122, No. 23, 1926—Mica Mining and Milling Methods, by Toner Antisell.

disintegrators or metal heaters. When the shaft is rotated at a high speed (3,000 r.p.m.) and pieces of mica are introduced into the cylinder a pulverised product is made which can either be drawn from the cylinder by an exhaust blower or removed by falling through a screen. The ground material is carefully screened on a set of vibrating screens. Separation by means of air current and gravity has also been used but how successful it has been is not known.

TARIFF PROTECTION TO THE DOMESTIC MICA MINING INDUSTRY IN U. S. A.

Recovery of mica from kaolin and micaceous minerals.— In order to make the development of domestic mica industry paying, in the face of uneconomic conditions attending mica mining, the Government of the United States enacted suitable measures of protection and placed a heavy tariff on importation of such cheap or waste mica which can be domestically produced. The duty specified on the lowest grade imported mica "*valued at not above 15 cents per lb.*" was fixed at 4 cents per lb. With the marvellous expansion of the ground mica industry so as to require imported stuff over and above the domestic production, the Government relaxed this high rate from 18th June, 1930, and permitted the import of "*waste and scrap valued at not more than 5 cents per lb.*", on a duty of 25 per cent. *ad valorem*. From this year import of waste continued regularly well till 1935, when another new far-reaching factor of importance developed in the technology of the U. S. mica industry by the successful invention of a process to recover mica, in commercially large scales, from kaolinised and semi-kaolinised rocks.

The recovery of mica from kaolin during recent years has encouraged wider activities in mica production from residual deposits and plants have been built in 1935 in Spruce Pine, New Dale and Mica Ville, N. C., for reclaiming mica from the kaolinised or semi-kaolinised pegmatites. Mica thus recovered competes with the dry-ground mica and is employed chiefly in the manufacture of roofing components.

Original credit for this important development lies with the James Ore Concentration Co. of Newark, N. J., who devised, for the first time in 1924, a method for commercial recovery of mica from the micaceous deposits, such as mica schist, quartz and kaolinised rocks, etc.*

* Mineral Industry, 1929 : W. M. Myers.

PROCESS OF RECOVERY OF KAOLINISED MICA

This may be described in brief as follows :—

The mica-bearing material is passed through a log washer, to remove the kaolin and then it is milled in a Hardinge ball mill with an abundance of water. This mill contains ribs by which the balls are cascaded in order to disintegrate completely the mica aggregates. The milled material is then concentrated on tables and although the difference in gravity between the mica and quartz is very small, a clean separation is possible. The last traces of quartz are removed by treating the mica concentrate in a pulsating classifier*.

Further details have been given at the end of Chapter V under "Reclamation of Mica".

MANUFACTURE OF GROUND MICA

Ordinarily grinding means crushing and friction but in the case of mica grinding must include shredding and tearing as well. It should also aim against impairing in the least the properties of mica in course of treatment and grinding. Intense heating facilitates the grinding operation but it detrimentally affects its properties and commercial usefulness. Wet-ground mica generally retains more of these properties than the dry-ground product.

THE PROCESSES OF GRINDING OF MICA : DRY AND WET

Mica is ground by two processes, known as *dry grinding* and *wet grinding*. Wet-ground mica is the finer of the two and is sold as such at nearly twice or more of the price of the dry-ground product.

DRY-GRINDING PROCESS

This is comparatively a simple process and is generally done by disintegrators. For this purpose, in the United States, *Raymond pulverisers*, *Kek grinders*, *Buhr* or *Ball mills*, *Emery mills* or *Hammer mills* are installed. *Marcey rod mills* are also reported to be more successfully employed for this purpose. Case integrators in close circuit with an air separator is the latest improvement in dry grinding of mica.

METHOD OF GRINDING IN TUBE MILLS

Tube mills were the rudimentary units of mica milling formerly used to reduce mica to powder. This consisted of a

* By courtesy of William Brand & Co., N. Y.

punched iron cylinder carrying a charge of steel slugs. Fine mica passed through the holes and was bolted to various sizes, the oversize being returned to the mill. The beaters of the tube mill are surrounded by screens of desired mesh and as fast as the mica is sufficiently pulverised, it passes through the openings. The pulverised product is then bolted to various sizes. High speed disintegrators or hammer mills were adopted giving better results in replacement of the tube mills.

Improved hammer mills or Case disintegrator types, fitted with screens of any desired mesh or with an air-separator device fitted to them, are giving very good results. These screen pulverisers are considered as more efficient for dry grinding than any other special type of disintegrators formerly used and are already growing popular. Table feed is more convenient and of great facility to avoid the frequent clogging with mica sheets.

The scrap is fed to the mill, where it is broken up. These are automatic arrangements to conduct the broken or ground mica to a series of vibrating screens of different meshes. The product is then screened and packed up in separate meshes. The oversizes that lie over the screens and conveyed back to the crusher are re-ground. The disintegrators may also be accompanied with a cage mill consisting of two cages, one inside the other and rotating in opposite directions. The discharge of such mills is also classified by bolting. The oversize from the bolting machines is usually sold for decorative purposes, such as "snow" for Christmas trees or for shop windows, etc.*

Mr. Bowles also describes a grinding plant in Georgia, employing a process by which mica is hauled in wagons to bins, from which it is shovelled to a *Sturtevant Coffee-mill Crusher*. The product of the crusher is conveyed by belt to a *Jeffry No. 3 Time Pulveriser Hammer Mill* and carried by screw conveyor and elevator to home-made screens 5 by 10 feet on a 30-degree slope. The sizes produced are 60 to 80 mesh, 80 to 120, 120 to 200 and minus 200. The greatest demand is for the 60 to 80 mesh as a dressing for roofing paper. The capacity of the plant reported is 5 tons in 24 hours.

The *Kek* grinder is also in use in Canada in which the mica is shredded between two horizontal steel discs, carrying rows of studs or teeth, the upper plate rotating at high speed and the lower plate remaining stationary, the fines are discharged through a side opening and pass to bolting trommels, the oversize being returned to the grinding†.

* O. Bowles : U. S. Bureau of Mines, Rep. of Inv. Serial No. 2357 (1922).

† H. S. Spence : Canadian Bureau of Mines, Mines Branch Report 701, 1929, p. 117.

WET-GRINDING PROCESS

The grinding process has been described as follows :—

If the scrap is dirty, it is to be washed, before grinding, in a trommel type of washer, removing the adhering dirt, mud and sand, etc., and making it grit-free and then it is dumped on a floor by a dewatering elevator. The cleaned mica is pulverised in 8 wet-grinding machines. They are of the non-continuous type each handling a charge of about 1,000 pounds, which requires 24 to 30 hours for grinding. Each grinder works in a steel tank, 4 feet deep and 10 feet in diameter. The bottom and sides are lined with wooden blocks placed on end. A vertical shaft with a 3-arm spider operates three 30-inch wooden rollers built up on planks. The vertical shaft rotates 10 to 12 revolutions per minute. An automatic plow attached to an arm throws the charge from the circumference towards the centre. The finished charge has the consistency of mush, it will not flow but may be squeezed through the fingers. The mush is washed along a trough where it settles and is conveyed to a settling tank. When partly settled, the water decanted from this tank carries with it rubbish, grease and other impurities. The settled mica is dried over steam coils, disintegrated and passed to a 30-mesh silk bolter. What passes through is again bolted through 140-mesh silk and the finished product conveyed to bins or bags. It is claimed that by bolting it in two stages there is less damage to the silk than where it is sized on the 140-mesh only. The product is used in the wall paper and rubber trades*.

Another process† is as follows :—

The grinding mechanism consists of tubs fitted with impellers for stirring the charge. These tubs are upright cylinders, constructed of wooden blocks, with the end-grain exposed to resist abrasion. The impeller is a wooden disc that fits loosely within the cylinder. The cylinder is fitted with a clean scrap of mica and enough water is added to permit free motion of the charge. The impeller is then pressed down on the masses and started revolving. The friction of the disc churns the entire mass so that the mica is constantly being split and abraded by the mutual impact and friction of one part on another. The friction is so great that the water actually boils. Grinding is slow, 8 hours being commonly required to grind a batch of 300 to 400 pounds.

Edge runner mills, constructed of wood, of larger capacity, are worked in several places, where the pans vary in size up to 10 feet in diameter and 36 inches in depth, the wooden bottom being made with end-grain blocks. Four wooden rollers approximately 30 inches in diameter with 24-inch faces revolve round

* U. S. Bur. Mines, Inf. Cir. 2357, pp. 32-33.

† U. S. Bur. Mines, Inf. Cir. 6205, 1929, p. 18.

a central shaft. These rollers are so arranged that they can be raised and lowered, depending upon the height of the charge in the mill. Washed mica scrap is placed in the mills, water is added and the rollers are lowered so that they are in contact with the charge. The rollers revolve at low speed and churn the mass until grinding is completed. The wet-ground mica is sluiced from the grinding mill into the settling tanks, the supernatant water from one tank often being let to another, in which the finished mica is recovered. From the settling tanks, the wet mica is shovelled out and dried on steam tables, after which it is generally screened on 160-mesh. Oversize material is returned for further grinding, the undersize being packed for disposal or shipment. Improved methods now include the replacement of the impeller by wooden rollers of the chaser types and replacement of wooden tubs by large circular steel tanks.

Wet-ground mica should have a high metallic lustre, should feel slippery and be free from grit and also mix freely and smoothly with liquid vehicles.

GROUND MICA SOLD IN TWO GRADES

Ground mica is sold in two forms. The coarser or inferior grade (prepared dry) is consumed in manufacturing roofing compositions as well as coating stuff on tar-roofing to prevent sticking when rolled.

The finer or purer grade of ground mica (prepared wet) is taken up in the manufacture of wall paper, paints, ornamental tiles, concrete, etc. An admixture of mica powder and aluminium powder is reported to make an excellent rust-preventive paint.

PROSPECTS OF MICA GRINDING IN INDIA

The following is the extract from the U. S. Tariff Commission Report on the grinding of mica*.

“Although the process of wet grinding could not be undertaken by wholly inexperienced operators with the expectation of immediate success, it is not a highly complicated process. Moreover, it does not require very much capital. Therefore countries like India, with ample supplies of desirable scrap at hand, low wage rates and very cheap containers (gunny sacks), could conceivably become headquarters for the ground mica supply of the world, both dry and wet ground. It is probable that, if ground mica were much cheaper than it is at present, it would find an expanding market, but at the expense of some competing commodities such as talc.”

* Report No. 130 : Second Series on the Mica Industry, 1938, p. 120.

**ROOFING COMPOSITIONS ALSO KNOWN AS
"PATENTED ROOFING"**

Dry-ground mica of cheap quality (of meshes 6 to 15, 20, 24 and 25, etc.) is used in the manufacture of rolled roofing and asphalt shingles to coat its underside, in order to prevent the sticking between the adjacent finished surfaces. Mica suits the purpose very well on account of its flaky nature which prevents its absorption by the freshly made goods; its additional advantage is that it remains unaffected by the acid in the asphalt or by weathering.

Finely ground mica is a chief constituent of many plastic wall finishes, rendering them particularly receptive to textural effects. Formerly talc powder was used for the purpose of rolled roofing, etc., but ground mica has proved of greater economic advantage owing to its higher covering capacity and the flat shape of the thin particles and as such it is fast replacing the talc.

Even a layer of raw mica waste of about 9 inches thick may cause a reduction in temperature of about 15°C. under a roof.

COVERING CAPACITY OF GROUND MICA

About 0.60 to 0.75 pound of ground mica is required to cover a surface area of 108 square feet. 60-mesh powder serves the purpose and its price ranges between \$20.00 to \$30.00 per ton in New York (which fluctuates greatly from time to time).

Between 1930 to 1934, approximately 5,000 tons of ground mica at an average has been annually consumed, ranging from a minimum of 3,592 tons in 1931 to a maximum of 6,995 tons in 1934. The figures have marvellously improved in 1935 and 1936 during which 14,403 short tons and 20,279 short tons respectively have been consumed in roofing trade alone. Roofing trade takes up more than 75 per cent. of the annual production of ground mica in the United States, which in 1935 and 1936 have come up to 78 per cent.

WALL PAPER TRADE : DECORATIVE PURPOSE

The finest grade of white wet-ground mica (ground to about 160-mesh and higher) is used in the manufacture of wall paper, demand for which, for the purpose of decoration, is steadily increasing. Between 1930 to 1934 the average annual consumption was about 2,000 short tons but in 1935, 1936 and 1937 the annual figures of consumption have come up to 2,051, 2,869 and 2,623 short tons respectively. Wall paper consumption generally depends on the condition of the building trade which went down to the worst depressed level in 1930 and as such the figure diminished to an unusual limit of 970 short tons, but the building trade in the United States has greatly recovered since 1935 as will appear from the high rise in

consumption of ground mica for the purpose of wall paper manufacture.

RUBBER TRADE

For the rubber industry, particularly for auto-tires, both dry- and wet-ground mica, generally of 100, 160 to 200-mesh powder, is usually employed. Mica forms an excellent filler for rubber and it competes well with talc, silica, asbestos and other cheaper fillers. Since 1935, it has been possible for ground mica to compete with these rivals economically as a result of the process of recovery of mica from schists and kaolins.

Mica powder is sprinkled between the casing and inner tube of the tires, to prevent friction and sticking. In the manufacture of rubber tires, ground mica is used to dust the tires before being placed in the moulds and for vulcanising or packing before shipment.

Consumption of ground mica for this purpose, however, has decreased very considerably in recent years. Between 1926 and 1931 the average annual consumption was about 1,300 short tons, which between 1932 and 1936 came down to something over 750 short tons, being mainly due to depression in rubber trade. The figure has, however, recovered to 1,413 tons in 1937.

PAINT INDUSTRY

A good quantity of ground mica is nowadays employed in the manufacture of special paints. It is extensively used in painting the water bags used in vulcanising automobile tires as it prevents sticking and gives the goods an excellent finish*.

Lately the figures of consumption of ground mica in the manufacture of paints are becoming very significant and in 1935 and 1936 about 1,307 and 1,011 short tons have respectively been consumed. These figures in the official reports have been till now included in the heading "*Miscellaneous*", but from 1936 it is shown separately in view of its increasing importance.

MISCELLANEOUS APPLICATIONS OF GROUND MICA

This includes the following amongst others :—

- Moulded insulation†.
- Surfacing asphalt singles.
- Christmas tree snow.
- Lubricants.
- Annealing, concrete, steel foundry facing, etc.
- Pipeline enamelling.
- Plastic specialities, etc.

* U. S. Bureau of Mines Information Circular No. 6288 (April 1935).

† Moulded electric insulation has been developed to high efficiency by the General Electric Co., of Schenectady, N. Y.

TABLE VI.

Production and consumption of ground mica in the United States. (In short tons.)

	Domestic production (2) -	IMPORTED		TOTAL GROUND CONSUMED				CONSUMPTION OF GROUND IN DIFFERENT INDUSTRIES										
		waste	ground	Tons	\$	Dry	Wet	Roofing		Wall Paper		Rubber		Paint		Miscellaneous		
		Tons	Tons			Tons	Tons	Tons	Per cent.	Tons	Per cent.	Tons	Per cent.	Tons	Per cent.	Tons	Per cent.	
1920	3,258
21	5,723	..	67
22	6,641	..	157
23	8,054	..	934	4,931	373,620	2,830	2,101
24	4,709	..	671	5,460	433,110	2,592	2,867
25	9,695	..	475	4,923	381,620	2,526	2,402
26	7,043	..	70	4,866	304,660	2,375	2,490	608	12	1,260	26	1,655	34	(1)	..	1,342	28	
27	6,280	1,294	4	5,793	423,479	2,593	3,199	1,293	22	1,884	33	1,588	27	..	..	1,028	18
28	7,760	1,748	2	6,189	453,609	2,871	3,312	1,294	21	1,614	26	1,933	31	..	..	1,348	22
29	6,253	(b)	..	4,516	390,361	1,814	2,697	603	13	1,614	36	1,316	29	..	..	983	22
30	6,732	1,839	..	7,531	352,258	5,956	1,575	4,826	64	970	13	506	7	..	..	1,229	16
31	6,621	2,065	..	7,807	436,436	5,362	1,444	3,592	46	2,665	34	1,029	13	..	..	521	7
32	7,040	1,360	55	7,705	310,840	5,253	2,452	4,383	57	1,752	23	668	9	558	7	343	4	
33	8,751	1,618	268	9,831	398,681	6,439	3,392	5,756	58	2,340	24	963	10	..	..	772	8
34	7,719	3,505	159	9,547	403,330	6,824	2,723	6,595	69	1,778	19	858	9	..	..	316	3
35	18,852	2,993	..	18,323	542,973	15,178	3,145	14,403	..	2,051	11	768	4	..	..	1,101	4
36	20,955	3,893	66	25,585	674,807	20,800	4,785	20,279	79	2,869	11	516	2	1,307	5	614	..	
37	25,196	6,723	41	27,245	..	21,150	6,095	21,636	79	2,623	10	1,413	5	1,011	4	562	2	

(1) Included in miscellaneous.

(2) Not separately shown.

PART V

UTILISATION OF MICA AND MICA PRODUCTS

Chapter XII

BUILT-UP MICA OR MICANITE

The following may be of some interest with reference to the origin of "Micanite", as developed in the Works of the Edison Manufacturing Co., Schenectady, N. Y., U. S. A., in the year 1888. It was written by Mr. Arthur H. S. Dyer* together with Mr. C. W. Jefferson, who were the inventors of the material that is now known throughout the world as "micanite".

"I was placed in charge of the Mica Department under C. W. Jefferson in the early part of the year 1888. Mica at that period was only used in the construction of commutators, and it was only after the idea of moulding what we called "built-up mica" that this material was used in manufacturing armatures, field coils, transformers, etc. The knowledge of mica was very limited at the period mentioned, and the idea of moulding this material was thought impossible in sheet form.

For commutator segments, bush, and ring insulation only cut mica was used.

The process at the period mentioned consisted in splitting, gauging, pasting the laminæ together, baking and pressing, and again gauging.

The waste in splitting the larger sizes of cut mica, say 3 by 5 inches and 5 by 8 inches, was considerable, as only complete laminæ were used. I found that this waste, which contained quite large laminæ, was swept up with the floor sweepings and consigned to the scrap heap.

After being in the department a few weeks the idea came to me to sort out the larger pieces of waste mica, and a considerable quantity was stored in barrels, when an order sent to the Sydenham Mica Company in Canada for cut amber mica could not be executed owing to the source of supply having failed. It is at this period that the commencement in the manufacture of micanite begins. The scrap that had been saved was built up exactly as micanite is now

* Received through the courtesy of Major W. J. Anderson of the Associated Insulation Products, Ltd., London.

made in 1935, with the exception that the plates were 10 by 12 inches to commence with and gradually increased in size.

The first use made of this new product was moulding commutator sleeves, thereby doing away with the wasteful method of placing strips of built-up mica under each commutator bar. These strips were *very* narrow for commutators having, say, 105 segments. The moulded product proved so successful that we were not only making commutator insulation, but armature, field coil, rheostat and transformer insulation from mica waste costing at that time two pence per pound. We very soon exhausted the supply of what was classed as mica cuttings from all the American mica merchants. This opened up the supply from India of what was known as No. 5 block mica, and later, through the efforts of the Mica Insulator Company, this grade of mica was prepared in India at very much lower prices than we could produce in America.

It is of interest to note that the small department of 35 employees I found when taking charge increased to some 270 in a few months. The development of electric traction greatly increased the demand for mica, especially in armature and field windings. The first traction motor armature to be insulated with moulded mica and shields was the No. 6 S. C. motor (smooth body). Later came the Nos. 14 and 16 S. C. motors. These motors were the first to have slotted armature cores, which were insulated complete both slot and end shields with moulded mica. The slots in these motors were insulated with four-mould mica strips.

It is interesting to note that one car on the Schenectady Strut Railway, equipped with two No. 14 S. C. motors, failed through over loading of car, both armatures being burnt out. Upon stripping, the moulded mica insulation on the core was found perfect, and was used for a second re-wind.

Following the above types of traction motors came the W. P. 30 and W. P. 50. The armatures of these motors were the first to have moulded mica troughs; these with the moulded mica end shields made an armature that would stand up to over loads.

In 1889 it was my great privilege to be sent to the Edison Laboratory to confer with Mr. Thomas A. Edison upon the question of mica supply and to illustrate to him as to what we were doing in our Mica Department at Schenectady.

In 1891 I applied for a patent on built-up mica through Messrs. Munn and Co., of Washington, which patent was

eventually combined with those of C. W. Jefferson upon the formation of the Mica Insulator Company, which Company I joined in 1894”.

In the chapter on mica splittings, I have described in detail how the idea of the built-up mica was originally conceived in America by that great mica specialist Mr. C. W. Jefferson and how the Mica Insulator Co., of New York, came in as pioneers of micanite manufacture in collaboration with Mr. Jefferson. This gentleman designed the first process to build up the smaller flakes of mica, till then treated as waste, into large mica plates to suit any size and thickness to precision. The first hand-made micanite was placed on the market by the Mica Insulator Co., of New York, in 1894.

Built-up mica is said to have been introduced in England in 1895, two years after its original invention, by its use on the 1,000 Kw. Ferranti Alternator at the Deptford Station. Danger of the high voltage from the bare copper of the armature sparking across to the field was overcome by placing micanite caps over the poles. The caps about $\frac{1}{8}$ inch thick can easily stand up to 25,000 volts.

The built-up mica or micanite has been found to be as good as natural mica or superior to it in certain respects, particularly in its convenient adaptability for shaping to suit any specific purpose. Besides, it is free from the polarity of the natural mica sheets and possesses a stronger cohesion between the plates with lower tendency for absorption of water, than the natural sheets. Built-up mica has another advantage in that it can be conveniently sawn, cut or bent, leaving out clean edges after cutting.

The built-up mica plates can be conveniently milled to uniform thickness and, apart from the fact of cheaper prices, they can be made into any desired size or shape including tubes of circular, triangular, rectangular or complex cross section, having multiple compartments and with proper binders may be hot or cold-moulded into any required shape.

The splittings or films, with which the built-up mica is to be made, should be the thinnest possible, not over 0.001 inch and generally between 0.001 and 0.0001 inch, and the Indian ruby muscovite mica, particularly that of Bihar (*known internationally as Bengal ruby mica*), is considered universally as the finest electrical mica in the world, from both economic and di-electric points of view.

Amber mica splittings (phlogopite) are not good insulators but the use of these splittings is preferred to muscovite in certain lines of built-up mica manufactures, including commutator segments, on account of the greater heat-resistance and comparative hardness, though rather dearer in price usually than the Indian muscovite mica splittings.

POINTS OF IMPORTANCE IN BUILT-UP MICA MANUFACTURE

In selecting splittings for the manufacture of built-up mica or micanites, the undernoted points should be constantly kept in view :—

Electrical

1. Di-electric strength.
2. Di-electric power loss.

Physical

3. Slippage (*i.e.*, swelling or puffing) :
Nothing should slip or ooze out under pressure or high temperatures and cause alteration in thickness. *This is of great importance in tight rigid construction.*
4. Transverse strength.
5. Density.

Chemical

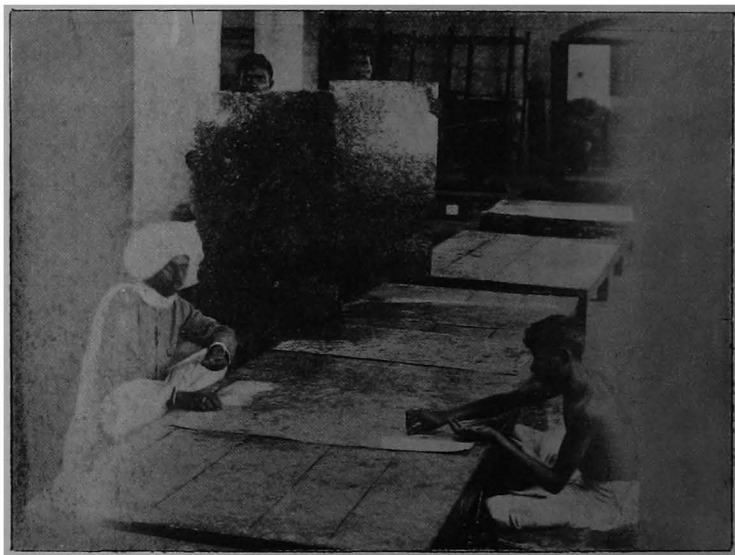
6. Carbonisation :
The binder content of the micanite must have the least tendency to carbonise under high temperatures or influence of heat.
7. Corrosion :
The micanite should be non-corrosive against copper. The binder content, if and when decomposed at high temperatures, should not be either corrosive or conductive (specially in commutator insulation).
8. Thermal :
Heat resistivity.

PROCESS OF MANUFACTURE OF MICANITES

Built-up mica plates or micanites are made by laying on a table (without paper) or on a clean thin sheet of paper an overlapping layer of mica splittings, as thin as possible but not usually thicker than 0.001 inch, in such a manner that it leaves no space between. These splittings are then brushed over with a strong insulating binder (shellac varnish in case of hard micanite and oil copal, in the absence of more efficient special preparations). Another overlapping layer of mica splittings is then placed on the varnished surfaces, while the latter is still wet, in such a manner that the joints in the lower layers are covered up by the whole pieces and the process is repeated until a plate of the desired thickness is attained. In order to drive off the volatile solvents used in the preparation of varnish, the freshly made micanite plates are transferred to a steam-heated table or a hydraulic press and the operation of pressing down under heat

is continued for a specific period, which depends on the purpose for which the finished material will be ultimately used. The boards are thus baked under pressure and machined into the required dimensions and thicknesses.

The pressure employed is generally 1,000 lb. per square inch (or 70 to 80 k.g. per cm.²) and temperature as high up to 37° F. which varies according to the type of the binder used and it is continued for 20 to 30 minutes.



[By permission of the Director, G. S. I.

Fig. 13.—Manufacture of micanite in India, F. F. Chrestien & Co's
Domchanch Mica Factory.

MECHANISATION OF THE MANUAL OPERATION OF LAYING THE FILMS

Great advances have been made in mechanising the processes of manufacture of built-up mica and the improvements made from time to time by different manufacturers are often kept as close secrets. Splittings are now mechanically showered down special towers constructed for the purpose so that the films may be automatically made up into layers by means of suction devices. The cementing varnishes are also applied by immersing the mass of films in a varnish tank or reservoir or each of the layers is varnished quickly and efficiently by a special dripping mechanism.

Multiple platen hydraulic presses are employed for mechanical baking and drying, as and where necessary, the platens of which are steam-heated or water-cooled according to requirements.

The quality of the mica plates or boards varies according to the degree of the temperature and pressure as well as the quality of the binder applied in course of the processes of manufacture. If a hard sheet is to be made, the micanite sheets are to be placed on a hydraulic press for a just sufficient time, in order to soften and compress the material, and while this is being subjected to pressure it is cooled by circulating water through the plates in the press. The percentage of bond in the finished



[By courtesy of Major W. I. Anderson of the Associated Insulation Products, Ltd., Walthamstow, London.

Fig. 14.—Sorting of mica splittings by English girls, Walthamstow Works, London.

micanite plates usually varies from about 10 per cent. in the moulding micanites to about 1 per cent. in the commutator segment micanites.

The varnish or binder used in the process is almost entirely pressed out of the plates during this process in case of the compressed micanites so that the finished product may not contain more than 1 to 2 per cent. of the binder. *When heated the built-up mica can be bent into any desired shape or form which is not possible with the natural sheet mica.*

The invention of micanite and its industrial utilisation was indeed a very significant development of far-reaching economic importance in the advancement of electrical engineering, but for which the steady progress of the industry would have been seriously crippled particularly because of the insufficiency and high price of the large-size flawless natural sheet mica. By building up or reconstructing the smaller mica sheets about 85 per cent. of the mines output is now utilised.

Mica splittings are thus used to build up mica plates principally in three finished forms, namely, (i) *sheet micanite*, (ii) *hot-moulding micanite* and (iii) *cold-moulding micanite*. Sheet micanite is used generally for flat insulation work, such as insulating the segments in commutators and heating apparatus, etc. Hot-moulding sheets are used for moulding bushings, washers, commutator V-rings, channels and corner cells, etc. Cold-moulding sheets are used, without being heated, for binding around sharp corners as are encountered in forming slot insulation coil wrappers, coil sheaths, etc.

COMMUTATOR SEGMENT INSULATION

Built-up mica was first developed for insulation between the segments of commutators. Formerly natural sheet mica was used for this purpose. Built-up sheets serve the purpose better and in some respects have overcome the limitations and disadvantages of the natural stuff.

In building up the component layers of mica splittings, attention should be directed to make the resultant plate very hard, uniform in thickness and heat-resisting with minimum of cement or binding component in it, so that while in use at moderately high temperatures the heat may not carbonise the binder. For this purpose, the sheets are treated on a hydraulic press in as fresh a condition as possible under a pressure of about 1,200 pounds per square inch, for a sufficient length of time. These presses can be heated and cooled so that, in addition to squeezing out the superfluous binder under pressure, the application of heat causes the volatile ingredient like alcohol to evaporate, while the remnant of the binder, usually with a good deal of shellac in it that remains, sufficient to insure firm conglutination, turns solid. After the sheet is subjected to pressure for the necessary length of time and evaporation is complete, the press is cooled down and the sheet taken out as finished.

The components of the binder, if and when disintegrated under high temperatures, must not prove corrosive on copper or become conductive nor should it display a detrimental effect when lead is soldered to the commutator bars at high temperatures. The plate should not ooze or bulge when heated nor shrink with age.

If proper and flawless splittings as well as suitable binders are applied on Indian mica, the built-up sheet should be hard enough to give a clear sound on being struck*.

Glyptal† is considered as the best known synthetic binder for this purpose, the manufacture of which has been restricted by registered patent to the General Electric Co. of Schenectady, Westinghouse and the Micanite and Insulators Co., Ltd., of Walthamstow, England. Micanite built up with glyptal as binder is marketed sometimes in the trade name of "glyptanite".

The Micanite Insulator Co. recommends the use of Indian mica plates for "flush" commutators and amber mica plates for "undercut" commutators. Westinghouse also use amber mica plates for insulating commutators that are not undercut as, being extremely soft, it prevents sparking and it wears evenly with the copper bars of the commutators. They recommend muscovite (white) mica plates for use on undercut commutators.

For efficient application in the collectors, reversing-pole machines, the thickness must be very accurate in order to ensure perfectly symmetric and equal division of the segments. This requires the grinding or milling of sheets, which process is to be continued or repeated until every part of the surface shows its visible effect. Repeated milling would smoothen the rough surfaces. The number of times of grinding or milling that might be necessary is to be determined on the basis of evenness or unevenness of the sheet so turned out. The wastage entailed in the process is an important consideration, which should not go beyond 10 to 12½ per cent. at the most and it depends on the expert workmanship of the hands employed in laying out the flakes for the specified size and thickness of the plates to manufacture.

The plates are sometimes coated on either or both sides with a thin tissue paper to prevent any subsequent roughening or exfoliation of the surfaces due to careless handling of the finished products.

Accuracy and uniformity of thickness, minimum binder content and freedom from slippage are the three essentials of commutator micanites.

Sizes.—The plates are made by different makers in different dimensions, of which the usual ones are 18 by 36 inches or 23½ by 35½ inches (*i.e.*, 595‡ by 900 mm.). The width should not ordinarily exceed 24 inches but sometimes it is made in 18 inches or other widths, as the milling of wider sheets would

* Lecture by Prof. H. Schering before the Electro-technical Society and Technical High School of Berlin.

† A synthetic bond or glycerine phthalic anhydride resin invented in the Research Laboratory of General Electric Co., Schenectady, N. Y.

‡ One inch = 25.4 mm. (millimetres).

require machines of very large size, entailing heavy costs and working expenses. The approximate weight per sheet varies according to the thickness, quality of binder or material, dimension of sheets, etc. One sheet 42 by 22½ inches (*i.e.*, 1,070 by 570 mm.), 0.040 inch or 1 mm. thick, roughly weighs about 3.3 lb. Amber sheet is a little heavier (about 5 per cent.) than the Indian mica commutator plates.

Thickness.—The thickness ranges usually between 0.0625 inch (1/16 inch) to 0.040 inch with an allowance of plus or minus 0.0005 inch, *i.e.*, a plate designed at 0.030 inch thick generally measures between 0.0295 and 0.0305 inch in thickness.

Puncture voltage.—The puncture voltage of these sheets ranges between 700 to 1,000 volts per mil*. Indian mica commutator plates manufactured as above should not contain more than 2 per cent. of organic constituents.

Test of the plates is carried on by saponification, extraction or more rapidly and just as accurately by incineration.

Uses.—This kind of insulation is applied particularly in such flat insulation work which is not ordinarily subjected to high temperatures, but it must not contain foreign matter. This can be tested with the aid of *x*-rays which will detect the existence of foreign inclusions.

MOULDING INSULATION (OR CONE PLATES)

The micanite for moulding purposes should be sufficiently softened at 100°C. (or 212°F.) so as to be readily moulded into any desired shape without the risk of flaking, cracking or breaking which will be retained on cooling.

The average puncture voltage per 0.001 inch should range between 900 volts on the thinner sizes and 800 volts on the thicker sheets. For ordinary purposes, such as washers, discs, troughs, etc., these sheets can be rolled into tapes, bands, rings, etc. It should not be used for commutator segment insulation and care should be taken not to use it for insulation between copper bars of commutators. Moulding micanite contains a greater proportion of the binder components than that of the commutator plates which is usually about 10 to 12 per cent. and it is not required generally to resist very high temperatures. On cooling, the sheet regains rigidity, uniform pliability being an essential property of this class of micanites.

Manufacture of moulding mica plate is easier than that of the commutator plates, owing to its being allowed to retain a greater percentage of shellac or binding component, but it is for this reason difficult, if not impossible, to ensure accurate measurements, certain variation being inevitable. A greater allowance in

* Mil = 0.001 inch or one-thousandth of an inch.

variation therefore is to be permitted in case of moulding micanite than that of the commutator plates. The milling of the moulding micanite somewhat damages the structure and lowers the puncture resistance of the plates.

The moulding plate is cut to the required shapes and sizes by means of stamping machines, hand-cutters or strong scissors instead of saws, as the latter cause fraying out. The smaller the radius of the size to be punched the greater is the chance of such fraying out of the laminations even in cutting by hand-cutters or scissors.



[By courtesy of Major W. I. Anderson of the Associated Insulation Products, Ltd., Walthamstow, London.

Fig. 15.—Micanite Ring Department, Walthamstow Works, London.

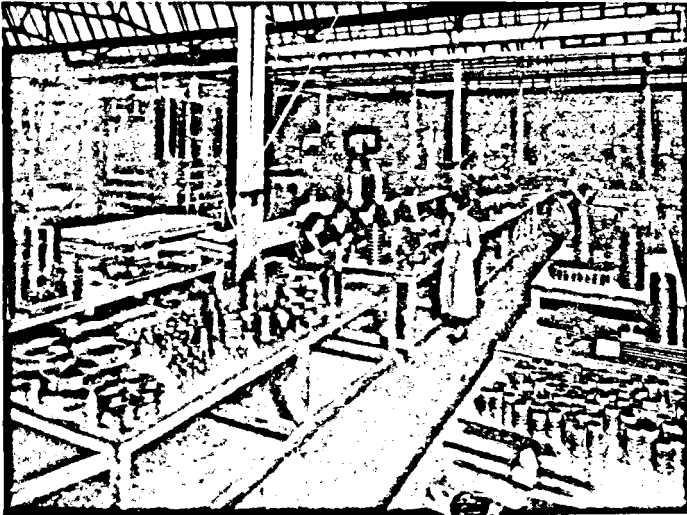
Sizes.—The sizes usually preferred are 18 by 36 inches, 23 by 40 inches, 24 by 36 inches, 20 by 40 inches, etc. Continental sizes are usually 1,070 by 570 mm. (*i.e.*, 42 by 22½ inches), 1,000 by 580 mm. (*i.e.*, 23½ by 35½ inches), etc. Special sizes such as 18 by 36 inches, etc., are also supplied on order.

Thicknesses.—The thickness of moulding plates usually range between 0.125 inch ($\frac{1}{8}$ inch) and 0.056 inch (1.4 mm.) with variation of 0.005. Special thickness is also supplied to order.

Weight.—Approximate weight of a sheet 20 by 40 inches in size and 1/32 inch thick is about two lb. and the average

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Thicknesses.—The thickness of moulding plates usually range between 0.125 inch ($\frac{1}{8}$ inch) and 0.056 inch (1.4 mm.) with variation of 0.005. Special thickness is also supplied to order.

Weight.—Approximate weight of a sheet 20 by 40 inches in size and 1/32 inch thick is about two lb. and the average

breakdown strength of such sheet is about 1,010 volts per mil. A sheet 1,070 by 570 mm. and 0.040 inch thick (*i.e.*, 1 mm. thick) weighs about 2.86 lb.

Uses.—Moulding micanite is extensively used for moulding cones, bushings, commutators, V-rings, channels, troughs, spools, corner cells, armature slots, etc., as also to wrap transformer partitions, field coils, round, square or rectangular tubings and cones, etc.

FLEXIBLE MICANITE INSULATION

This class of micanite is made with non-drying varnish and can be formed or bent into any desired shapes without applying heat, the sheets being sufficiently flexible in the cold state. Flexible micanite therefore need not be heated like the moulding plate or *mica folium*, while lining the curved surfaces or channels. It should, however, have a good di-electric strength and stand a high puncture resistance test.

Unless protected by tape or similar means, it is not recommended for application where it might be subjected to frictional wear.

Sizes.—The sizes usually preferred are 24 by 36 inches and 40 by 40 inches. German sizes include 42 by 22½ inches (1,070 by 570 mm.). 36 by 36 inches and 40 by 40 inches (1,000 by 1,000 mm.) are extensively marketed in the United States.

Thicknesses.—The usual thicknesses range between 0.056 and 0.005 inch.

A sheet 40 by 40 by 0.010 inch thick weighs approximately about 2½ lb.

Uses.—This class of micanite is used in insulating armature, slots, transformers, coils, magnet and commutator cores, field coils as well as for forming collars, channels and rings, etc.

When used in transformers, it should not be affected by swelling (or disintegration) at 150°F. to 250°F. It is applied without heating for binding around sharp corners as are encountered in forming slot insulation, coil wrappers and coil sheaths. Unless protected by tape, etc., it is not advisable for application where there is a chance of frictional wear.

HEATER MICANITE INSULATION

For electrical heating a reliable and thoroughly efficient insulating medium is required, which should efficiently resist high puncture voltage and all possible tensions (usually up to 440 volts) that are of practical test in cold stage as well as at high temperatures, not exceeding 1,200°F. and possess high di-electric strength. These insulations should be as thin as possible

so that the heat issuing from the heating appliances is conducted with the least loss to the iron or metal body from which it is to radiate outward. The organic cement should not exceed 1.5 per cent.

The heater plate, made of Indian muscovite splittings, is admirably suitable in the heating appliances for operating temperatures up to 1,000°F. (i.e., 800°C.), whereas the amber heater plate remains unaffected at temperatures even up to 1,800°F. Heater plates should contain the smallest percentage of binding components and should be able to withstand intense heat, as is usually to be met in flat irons and similar units. It should also stand a high electric puncture test. Puncture voltage of this class of plates is about 900 to 1,000 volts and, in exceptionally superior plates, it goes even up to 1,500 volts.

The commutator, heater and moulding micanites that are usually imported into India and sold as high di-electrics are generally cheap stuff, very seldom fulfilling the real thermal, di-electric and puncture resistance required of them. Most of the importers or dealers of these materials, except in case of manufacturers themselves, know little of the technical properties or requirements of the stuff they sell or deal in.

The heater plate is made in both flat and moulded forms for use in heating elements and in several grades to meet the different testing voltages and commercial requirements.

Originally natural mica was used for flat iron and heater appliances but the large increasing demand for a great variety of large or strip-size ("petaree" or long strips with narrow widths) sheets called for a suitable and efficient substitute to suit all purposes and tests at economic costs. Heater micanite meets these requirements. Of course certain manufacturers still regularly use natural sheets in good quantities when available at permissible prices.

Sizes.—The sizes in which they are usually available are 18 by 36 inches, 23 by 40 inches, 23½ by 35½ inches (595 by 900 mm.), etc. Natural sheets are efficient at 0.005 to 0.008 inch for the covers and 0.008 to 0.012 inch for the supports of flat iron heating elements, whereas the built-up heater micanite should be used at greater thicknesses (not usually under 0.010 inch) in order to ensure firmness. The disadvantage of heater mica plate as compared with natural mica lies also in the fact that some of the organic binder constituents evaporate gradually. *These materials should always be stored in a perfectly dry place.* Heater micanite plate is not recommended to be milled, as it may damage the massive structure of the plate and puncture strength. The slightest displacement that might take place inside the heater plate, subsequent to the satisfactory

initial test, may cause fine chinks or minute holes, affording a passage for an electric discharge*.

Muscovite mica is used for such heater plates which are not subjected to temperatures over 1,000°F. Phlogopite, which easily stands up to 1,500°F. temperature, is used for special units involving a high heat.

Thicknesses.—They usually range between 0.010 to 0.020 inch. The sheets most in demand are 0.010 to 0.030 inch thick. The average breakdown strength is 250 volts per mil.

COIL INSULATION (MICA FOLIUM)

This consists of one or more layers of mica splittings, built on a thick shellac-coated base such as thin paper, etc. Thin but strong *kraft paper* is usually preferred for this purpose. It was for the first time introduced by Mr. Haefely of Zurich (the firm Emile Haefely of Switzerland). For the thinnest product, a thin silk-base is used with a single layer of carefully laid mica films. For thickness of 5 mils and above, condenser paper or kraft paper of 0.0015 inch (1½ mils) is used, with one or more layers of mica films. It is made in rolls. The average thickness of mica folium is 4 to 5 mils.

Mica folium can be wound and pressed without any seam round clearly wound coils and concentrated bar windings, cylinders and mica tubes, which used to be bought ready made, and can be manufactured in the same way on the spot without any loss of time. It lends itself very easily to be manufactured into large tubes and cylinders on heated mandrels. Best results of the use of mica folium is obtained at a working pressure of 250°F. It has high di-electric and mechanical strength and is made in standard rolls.

Sizes and thicknesses.—The sizes and thicknesses current in the market include rolls of 1,050 mm. (about 41½ inches) and 0.20 mm. (about 0.008 inch) thick.

Uses.—Mica folium is used in winding tubes, cylinders and insulating bars under pressure and heat.

MICANITE PAPER

Flexible micanite is sometimes coated with thin tissue paper or Japanese paper on both the sides. Thus coated, it is styled as micanite paper or paper micanite. Such paper backing prevents exfoliation and insures compactness against easy disintegration. The two layers of thin paper should not exceed 0.001 inch in thickness. Generally one, two or several layers of very thin carefully selected mica splittings are covered up with the two layers of papers on the two sides.

* Mica and Mica Products by Richard Schroeder.

Sizes and thicknesses.—The common sizes include 36 by 36 inches and 40 by 40 inches (1,000 by 1,000 mm.) in thicknesses of 0-005, 0-007, 0-010 inch, etc. It is also supplied in various special sizes as required. The breakdown strength is about 475 to 500 volts per mil.

Uses.—Mica paper is preferred for use in armature slots, commutator cores, magnets, etc. Mica paper is also made into tapes in lengths up to 30 feet.

MICA CLOTH OR MICA LINEN*

Similar to micanite paper, one, two or several layers of carefully selected mica splittings are bound between a fine quality of linen, cloth, silk, muslin or sometimes paper is used on one side with linen, silk or cloth on the other.

Sizes and thicknesses.—The usual sizes include 36 by 36 inches and 40 by 40 inches (1,000 by 1,000 mm.), in thicknesses of 0-008, 0-011, 0-015, 0-020 inch, etc. A sheet 36 by 36 inches by 0-008 inch thick weighs approximately $\frac{1}{2}$ lb. The average breakdown strength is about 450 volts per mil.

Uses.—Mica cloth and mica paper are used in the insulation of commutator cores, transformers, field coils, armature slots, cores and field magnets.

COMPOSITE MICA PAPER

This is made of fish paper on one side and tissue paper on the other, enclosing two overlapping layers of Indian mica splittings between.

This kind of micanite paper is used where a material stronger than rope paper or press board is required as a base for the mica films. It is suitable for use in low voltage work, requiring mechanical strength and moderate temperatures.

ROPE PAPER AND MICA

This is just the same as fish paper and mica, only with the substitution of rope paper in place of tissue paper. It is used in moderate temperatures and voltages and useful for armature and transformer insulation. It is particularly suitable to insulate hot-pressed coils.

A kind of Japanese paper and mica is also marketed by certain manufacturers, which is recommended as specially suitable for small coil wrappers, curved washers and spacing strips.

MICA PAPER AND PRESSPAHN

Presspahn of 0-2 mm. on one side, paper on the other and mica in the middle, 0-3 to 0-5 mm. thick, makes mica paper

* Use of mica cloth or linen is waning nowadays.

and presspahn. It is considered stronger than ordinary flexible micanite. It is practically flexible micanite covered with presspahn.

MICA ASBESTOS

This is generally made of a layer of mica splittings of 0.2 mm. on one side and a layer of asbestos of at least 0.5 mm. thick on the other. For thicker sheets, the asbestos is reinforced.

Mica asbestos is available in several sizes including 1,000 by 500 mm., 0.7 mm. and above in thickness.

It is used in the mounting of electrical heating apparatus and the insulation of windings of flat copper pole pieces for motors and alternators of high power and temperatures.

ART MICA PLATE

Certain insulation makers manufacture and market this class of plates. It is a grade of compressed sheet mica product made of the best grade of Indian mica splittings carefully selected and cleaned for the purpose. Combined with pure shellac compound, the mica is baked into sheet and the resultant product displays an attractive appearance.

The plate is usually supplied in the size of 18 by 36 inches and about 0.020 inch thick and other different specifications are made and supplied to order.

A considerable demand has developed in recent times for art mica plate, also called special art micas, for use in electric lamp shades, chimneys (specially Torchiere chimneys), panels and cylinders. It is preferred for the beautiful colouring of the shade plate when lighted as well as for its pleasing appearance and mellow quality of the transmitted light (as claimed in the maker's catalogue).

Muscovite mica on account of its higher transparency is generally used in the manufacture of art mica plate and various colours from white to dark reddish brown, etc., may be obtained by using pale dark or similar binders.

Art mica is being used in the United States in increasing quantities. It is also used for ornamental purposes as decorative medium and various other decorations. It forms a moulded covering for the body of lighting fixtures in many places.

MICA TAPES

This class of material is made of a layer of thin carefully selected mica splittings overlapped and bound between two layers of thin strong insulating paper on both sides.

Tape is used generally where sheet material cannot be conveniently applied such as for wrapping and winding coil, sharp bends, large, small or closed coils, armature as also strap and bar-wound armatures, etc., where they are subjected to higher

temperatures, which the ordinary insulated fabric and cotton cannot stand. Mica tape is specially used when higher temperatures are involved. The tapes are of various makes with different bases, some of which are described below.

MICA PAPER TAPE

(i) Paper on one side, mica on the other, 0.08 to 0.10 mm. thick, with a layer of varnish on mica.

(ii) Paper on both sides, mica in the middle, 0.1 to 0.5 mm. thick.

MICA SILK TAPE

Silk on one side, mica on the other, 0.10 mm. thick.

MICA PAPER SILK

Silk on one side, paper on the other and mica in the middle; thickness 0.15 to 0.50 mm.

MICA LINEN TAPE

Linen on one side and mica on the other, with a layer of varnish on the mica. Thickness usual about 0.25 mm.

Tapes are marketed in rolls of $\frac{3}{4}$, $\frac{1}{2}$ inch, etc., in widths and in lengths of 50 or 100 linear feet. Thickness ranges between 0.005 to 0.007 or more and the puncture voltage is about 750 volts per mil.

They are wrapped carefully so as to retain the flexibility and packed in airtight metallic containers. These tapes, when left or stocked insecurely and exposed to air, tend to lose their flexibility. The materials therefore have got to be securely packed and delivered.

MICA TUBES

Mica tubes are made in circular, square, rectangular or other required shapes.

Circular (round) tubes.—These tubes are made with moulding mica plate by winding the plate around circular cores in as many layers as required to retain the desired wall thickness after which they are baked. The protruding ends of the mica splittings thereafter are trimmed off. These tubes should give a high and clear sound on being knocked against an iron object or against the cemented floor. The tighter the winding is done, the clearer will be the sound of the knocks.

Non-circular tubes.—Non-circular tubes are also made in iron moulds. The material is wound round an iron wedge, consisting of two longitudinal halves, until the desired thickness of the wall is obtained, after which the whole thing is placed in the mould, the wedges being pushed against each other so as to

obtain the desired inside thickness. The mould is then baked and when it has cooled down, the tube is withdrawn and the wedges are pushed out. The tubes made in this way are somewhat more resistant to heat, but owing to the existence of a seam in most of the tubes so made the process is not in general favour nowadays. It is desirable to prepare the tubes by pressing seamless tubes into the desired shape and then baking them down by which the risk of seam may be ruled out.

Uses.—Mica tubes of round, square, oval, hexagonal or other special shapes and specified sizes are used in large quantities for insulation. Large tube for induction coil, specially treated tubes or bushings for apparatus, immersed in oil special heat-proof bushings, rolled without cement for spark plugs, etc., are also made by various built-up mica manufacturers.

MICA TUBING WITH MICA FOLIUM

Very hard seamless mica tube may also be made by winding the mica folium round an iron wedge or bar. The winding can be done by hand or machine.

Tubes thus manufactured under proper pressure and special conditions stand a test with 24,000 volts without any risk of puncture and in short-time test it stands even up to 40,000 volts per mil.

Sizes and thicknesses.—These are too numerous to mention here.

INSULATION BINDER

This is a very important factor in the manufacture of built-up mica, and on the quality of the binder used depends a good deal of the efficiency of the built-up mica made. There are special classes of varnishes* to be used for different kinds of micanites, *i.e.*, flexible, hard-moulding or commutator plates, etc.

Glyptal, a binder originally developed by General Electric Co., is said to be the best of all the available binders.

For Indian conditions of climate, research should be undertaken to invent suitable varnishes, as the varnishes of European origin or the micanite of European make, wear off or disintegrate within a short time of stocking in the Indian climate.

DIFFERENCE BETWEEN GLYPTAL AND SHELLAC FOR USE IN BUILT-UP MICA MANUFACTURE

Mr. Spence has given the following results of the tests made to determine the relative efficiency of shellac-pasted and

* The usual binding agents are shellac varnish and a phthalic anhydride and glycerine compound (an alkyl resin) dissolved in alcohol. The latter is recommended by some people to impart a higher dielectric strength and translucency permitting no slippage.

glyptal-pasted mica plate, the values for glyptal-pasted material being expressed as 100* :—

	Glyptal-pasted.	Shellac-pasted.
Di-electric strength ..	100 to 160	100
Relativity ..	200	100
Surface resistivity ..	400	100
Di-electric power loss ..	66	100

Physical properties :—

Density ..	107	100
Compressibility ..	slight	slight
Slippage ..	none	mica may slip
Transverse strength ..	150 to 200	100
Translucency ..	considerable	slight
Resistance to abrasion ..	100	100

Chemical properties :—

Carbonizing tendency ..	slight	marked
Products of decomposition ..	non-conducting	conducting
Products of decomposition ..	do not attack copper	attack copper
Effect of mineral oils ..	none	none
Effect of moisture ..	very slight	slight
Effect of heat ..	slight	marked

There are certain other mica binders containing neither shellac nor alkyl resins, such as certain copals, East Indian manilla and New Zealand kauri dissolved in oil. Glimalac and Sticolene are English varnishes†.

* Mica by H. S. Spence, p. 104.

† U. S. Tariff Commission Report No. 130, Second Series. The Mica Industry by Howard F. Wierum, 1938.

Chapter XIII

TESTING AND SPECIFICATIONS OF MICA AND MICANITES

1. **Mica an efficient insulator for high voltage work.**—Mica to suit this class of work should have high di-electric strength and be free of all defects and flaws in each individual sheet. It is not always possible in making purchases to test properly every individual sheet with the help of a portable testing instrument. The buyers therefore, while placing an order or contract, have to lay down certain commercial specifications against such common flaws which generally prove detrimental to the mica for its use as an efficient insulator.

SPECIFICATIONS FOR ELECTRIC INSULATION*

- (i) Most compact and tough, but not hard.
- (ii) Not sensitive to heat, must resist high temperatures, chemically stable.
- (iii) Equally thick all over and absolutely level in its surface.
- (iv) Absolutely proof against water or oil.
- (v) Great resistance to electricity; specific insulation resistance very high.
- (vi) Must be equally hard and evenly wearing as copper.

Muscovite mica free from stains and bubbles proves to be an ideal insulator for use in electric condensers, as it shows exceedingly low power loss. The ability to withstand high temperatures and corona discharge and the fact that it is not affected by oil or water, adds greatly to its importance as an electric insulator.

2. **Mica for magneto condensers.**—Mica for use in the magneto condensers should also possess high insulating property but the di-electric strength need not be so high as 20,000 volts per mil, which limit is usually prescribed for high-class electrical work. A lower electrical resistance is permissible for magneto condensers. The films are subjected to rigid x -ray inspection to detect flaws and inclusions.

* Insulation of Electric Machine by H. Turner and H. Hubort.

Thin mica films are used in very large quantities in condensers for magnetos and wireless apparatuses and a high quality is called for this purpose. It must have clean edges; be of clear ruby or greenish to colourless; easily splittable into smooth thin sheets, one-thousandth of an inch or thinner; free from cracks, pin holes or any kind of holes, weak spots, stains or wrinkles, rulings, waves, air bubbles or knots of any form. Sizes usually required are not above $1\frac{1}{2}$ by 2 inches or 2 by 3 inches (*i.e.*, not above No. 5 of Bengal grading). Indian muscovite ruby quality is generally specified for condenser purposes.

3. Mica for radio* and wireless outfits.—The finest quality of electrical mica, preferably Indian ruby muscovite, is required for condensers, spark plugs, radio and wireless outfits, etc., but where low voltage currents are employed less perfect mica sheets containing some impurities may be allowed. The United States Navy Department calls for a di-electric strength of not less than 25,000 volts per mil or, say, for each $1/54$ -inch mica sheets. In fact the highest quality mica, absolutely flawless, is required for radio and wireless purposes. In recent years, the great steady development of the radio, wireless and aeronautical industries has stimulated an enormous demand for high-class condenser films of small sizes. The usual specifications for this requirement stipulated by buyers are “*for high-class electrical work*”. Thin films of clear muscovite used in the manufacture of high-grade, small capacity condensers, such as are used in radio apparatus, are not replaceable. The maintenance of the radio industry, therefore, hinges in part upon the ample supplies of suitable mica for making these condensers†.

4. Stove mica.—Mica for this line of manufacture should be transparent, hard, rigid and of high resistance to heat. It is specified in the trade as *clear first quality* and *clear second quality* capable of withstanding temperatures between 800° to 900°F.

Stove mica No. 1 must be free from cracks and stains, but it may contain air bubbles; stove No. 2 may be spotted or stained to a limited extent. High-grade stove mica sometimes fetches even a more remunerative price than that of electrical mica, because of the larger and special sizes often sought for. For iron toasters, stove windows and fronts, specially hard and rigid mica is suitable. Mica for electric heater equipment should be tested before application to fulfil the specified heat resistance,

* Radio films mostly used range in thickness between 0.008 to 0.015 inch with tolerance of ± 0.001 inch in the holes and 0.005 inch on the outer dimensions.

† U. S. Bureau of Mines Inf. Cir. 6822, 1935.

as some phlogopite bloats when heated because of incipient hydration*.

The general sizes called for are narrow strips, good lengths of which are usually difficult to obtain in quantities. Such selected mica, of course, has to be paid a fancy price.

5. Commutator segment mica.—This class of mica should possess high di-electric strength, capable of withstanding charges of high-voltage electrical currents, at the same time soft enough to wear down evenly with the copper segments. Phlogopite or Canadian amber mica is particularly suitable for this purpose.

Testing of this mica is carried out by passing the condenser film through a high-frequency, low-potential spark gap.

6. Diaphragm mica.—Mica for this purpose must be very high class, extremely hard and rigid, absolutely clear, highly resonant, transparent, free from all kinds of flaws, cracks, inclusions, stains, air bubbles, rulings, etc., in any degree and most of all it should be easily splittable into perfectly flat sheets. Such mica sheet should be so hard that it would give a clear almost metallic sound when let fall on a cemented floor or similar solid substance. Diaphragm mica therefore commands a high price and supplies have seldom been sufficient to meet the demands for this quality. An attempt was therefore made to find substitutes and Germany succeeded in introducing a metallic diaphragm which is cheap and has consequently replaced mica, although the latter is admittedly considered superior in efficiency to the metallic diaphragm.

Lepidolite or lithia mica is best suited for diaphragm purposes, but this type of mica is rarely available in sheets of required sizes and the Indian muscovite clear sheet is used as the next best. Only a small quantity of sheet lepidolite is obtained from Western Australia, and this is utilised by the manufacturers of phonograph and sound-making or sound-detecting devices.

7. Micalite or chimney mica † (for spark plug and chimney manufacture).—Flexibility is the most important property required in this class of mica and the following specifications are usually prescribed by the buyers :—

The mica should be flexible enough so that each sheet of about 0.001 inch thick is capable of being bent into a cylinder of one-fourth of an inch ($\frac{1}{4}$ inch) in diameter without the least tendency of cracking or, alternatively, each sheet of 0.010 inch

* H. S. Spence, 'Mica' in 'Industrial Minerals and Rocks'. Amer. Inst. Min. Eng., 1937.

† Mica is used nowadays in making covers to enclose the electrodes of Neon light signs. Mica sleeves are also made to surround the electrode and keep it off from the contact of the glass.

thick should be capable of being bent at ease to form a cylinder 3 inches in diameter, without the least tendency to crack.

8. Mica (small blocks) for the manufacture of splittings.— This mica should be easily splittable into very thin flat films or laminæ, 0.001 to 0.0001 inch or thinner, containing such minimum permissible flaws, impurities or air bubbles that may not be the cause of any defect in the working of electrical inventions in which they may be used.

Splitting mica should be a good di-electric, bevelled towards the edges (*i.e.*, sickle or knife cut) and not straight cut, of perfect cleavage at the basal direction and flexible to a good extent. "Cross-grain" is a serious defect for splitting mica and must always be carefully eliminated except perhaps in the case of the cheapest loose splittings, where a limited proportion of cross-grained sheets is sometimes allowed.

GOVERNMENT SPECIFICATIONS FOR PURCHASE OF MICA AND MICANITES*

Form 1.—*Uncut mica* (muscovite unless phlogopite is specifically called for).

Grade A-1	..	..	36 to 48	square inches.
" 1	..	..	24 to 36	" "
" 2	..	..	14 to 24	" "
" 3	..	..	10 to 14	" "
" 4	..	..	6 to 10	" "
" 5	..	..	3 to 6	" "

Class 1	..	<i>Clear.</i>
" 2	..	<i>Slightly stained.</i>
" 3	..	<i>Stained.</i>

DETAILED SPECIFICATIONS FOR UN CUT MICA

Uncut mica shall be of the best muscovite mica (unless otherwise specified). When phlogopite is specified, it shall be suitable for commutator repairs. The mica shall be flat with laminæ of equal thickness throughout, of easy cleavage and free from cracks, waviness, inclusions, pin holes, ridges, striations, iron oxide and other defects, and shall have di-electric strength of not less than 1,500 volts per mil of thickness.

The *uncut mica* shall be furnished in sheets of random thickness. No sheet should be less than 0.007 inch or more than 0.030 inch. Each sheet should be closely knife-trimmed, without notches, and of such general shape as to permit a rectangle

* U. S. Navy Specifications 17M5C, 1st December, 1920.

of the size specified in the following table to be cut from the sheet with a wastage not exceeding 40 per cent. of the original weight :—

Table of limiting dimensions

Grade.	Length (inches).		Width (inches).		Area sq. in.
	Min.	Max.	Min.	Max.	
A-1 ..	4	6	6	9	36
1 ..	3	4.9	4.9	8	24
2 ..	2	3.74	2.74	7	14
3 ..	2	3.16	3.16	5	10
4 ..	1.5	2.45	2.45	4	6
5 ..	1	1.73	1.73	3	3

The grade of *uncut mica* shall be determined by the largest rectangle piece of sound mica, conforming to the above table, which can be cut from the sheet.

TEST ON NATURAL SHEET MICA

Di-electric test on sheets.—*Uncut mica* shall have the di-electric test conducted on at least 10 sheets selected for each lot for inspection. In case of failure of any sheet, a sufficient number of additional sheets shall be selected and tested to assure that at least 95 per cent. of the lot will meet the specification requirement.

Test for iron oxide.—This test shall be conducted on such sheets as may be selected as being liable to contain this impurity. The sheet shall be laid upon a flat metal plate, connected to one terminal of the high-tension circuit of an ordinary ignition spark coil. A lead from the other terminal of the coil shall be passed over and in contact with the surface of the mica. Acute sparking occurring at one or more points will prove that the piece is defective for the purpose.

Test for cleavability.—This shall be tested by splitting two or more samples to a uniform thickness of not more than 0.0015 inch. The area of each splitting shall not be less than that specified by the grade required by the contact. In case of failure, a sufficient number of additional pieces shall be selected and tested to assure in the inspection that at least 90 per cent. of the material will pass this test.

Form 2.—*Cut mica* (muscovite unless phlogopite specifically mentioned).

Detailed specifications for cut mica.—Cut mica shall be furnished in sheets of random thickness, no sheet to be less than 0.007 inch nor more than 0.030 inch in thickness. It shall be cut exactly to the specified dimensions, rectangular in shape with

sharp corners and clean true edges. There shall be no imperfections which are liable to cause breaking of the edges. It shall also conform to the requirements for *uncut mica* contained in paragraph 2 of these specifications.

Test.—Just the same as *uncut mica* (as above), with the exception that at least 80 per cent. of the sections resulting from the test for cleavability shall have an area equal to the original piece.

Form 3.—*Pressed mica plate* (built-up mica or micanite sheets).

Grade A	..	Commutator segment plate.
„ B	..	Hot-moulded plate.
„ C	..	Cold-moulded flexible plate.

DETAILED SPECIFICATIONS FOR SHEET MICANITE OR BUILT-UP MICA SHEET

The *pressed mica plate* shall be composed of mica splittings built up into plates of standard dimensions by the use of a binding material. The standard dimensions of a plate shall be 18 by 36 inches, a plus or minus tolerance of $\frac{1}{8}$ inch being allowed on either dimension. The surface of the finished plate shall be perfectly smooth and shall show no excess of binder or cement.

Mica splittings for built-up mica.*—Mica splittings of which *pressed mica plates* of all grades are composed shall have an average area of not less than 2 square inches and shall be split evenly, without splitting or cracking, to a minimum thickness of 0.0008 inch. The maximum thickness shall not exceed 0.001 inch for plates up to 0.015 inch in thickness; for heavier plates the maximum thickness of the laminæ shall not exceed 0.002 inch.

BINDING MATERIAL FOR MICANITE MANUFACTURE

The *binding material* for all pressed mica plate shall be high-grade insulator, free from waxy substance, rosin or other foreign material. The binding material shall be applied uniformly throughout and shall be the minimum required to make a firm plate; but in no case shall it exceed 5 per cent. of the weight of the completed grade A plate, 15 per cent. of the grade B plate and 20 per cent. of the grade C plate.

DI-ELECTRIC STRENGTH OF MICA PLATES

The di-electric strength of all grades of pressed mica plates shall be sufficient to withstand the momentary application of 800 volts per mil of thickness between flat metal plates or 900 volts per mil of thickness between pointed or spherical

* For "NEMA" specifications of mica splittings see Appendix.

electrodes and the continuous application of 500 volts per mil of thickness for 60 seconds.

**DETAILED SPECIFICATIONS FOR GRADE A MICA PLATE
(COMMUTATOR SEGMENT PLATE)**

Amber mica plate.—It should be composed of phlogopite mica suitable for use in commutators, unless muscovite similar to Indian, Brazilian or American mica is specifically called for.

Thickness.—The maximum or minimum thickness of any sheet of grade A shall not vary more than 0.005 inch from its average thickness; the average thickness of an individual plate shall not be more than 0.001 inch above or 0.0015 inch below the thickness specified. For plate which is too thin to be milled (*i.e.*, all thicknesses under 0.020 inch) the allowable variation will be increased 0.0005 inch. The grade A plate shall be of uniform density throughout and contain no high spots which have received unusual pressure or low spots or pockets filled with cement. The specific weight shall be not less than 0.090 pound per cubic inch and shall average 0.093 pound (approximately 1½ ounces) per cubic inch. When compressed under 2,500 pounds per square inch at a temperature of 260°C. (500°F.) for two hours, it shall not diminish in thickness by more than 5 per cent. The mica films shall not show more than a very slight trace of cement oozing out under this test. At a temperature of 150°C. (302°F.) for two hours and a pressure of 2,000 pounds per square inch, there shall be no splitting nor oozing whatsoever.

**DETAILED SPECIFICATIONS FOR GRADE B MICA PLATE
(MOULDING MICA PLATE)**

Muscovite mica plate.—This should be composed of mica known as muscovite similar to Indian, Brazilian or American micas, suitable for moulding purposes. This grade of plate shall soften sufficiently at a temperature of 125°C. to be readily moulded into ordinary moulded form without chipping, cracking or breaking.

The thickness of any sheet of grade B plate shall not vary more than 0.001 inch above or below its average thickness. The average thickness of each plate shall not vary more than 0.0025 inch above or below the specified thickness.

**DETAILED SPECIFICATIONS FOR GRADE C MICA PLATE
(FLEXIBLE OR COLD-MOULDING MICANITE)**

This should meet all the requirements of grade B plate except the variation in thickness but shall have greater flexibility, meeting the requirements as to moulding (as above) at a

temperature of 15°C. or lower. The surface of the grade C plate shall not be tacky. Variation for this grade will be allowed as follows :—

	Inch.	Under inch.	Over inch.
Thickness	0.010 and under	0.002	0.003
”	0.011 to 0.025	0.003	0.004
”	0.026 and over	0.004	0.007

DI-ELECTRIC TESTING OF MICA PLATES

This should be carried on by using a brass plate 12 inches square for the lower electrode and a copper or brass block approximately $2\frac{1}{4}$ by $2\frac{1}{4}$ by $\frac{3}{8}$ inches thick for the upper electrode. The upper electrode shall be so moved as to subject the entire area covered by the lower plate to the test and the plate so moved that at least two portions of it are subjected to the test.

Where pointed or rounded electrodes are used, they shall be held directly opposite each other in contact with the plate and the plate or electrodes so moved that the line of contact of the electrodes with the plates shall be at least 9 feet long and shall include all portions of the plate. By either method of test, the test of 60-second duration shall be made on two parts of the plate.

PRESSURE TEST ON COMMUTATOR MICANITE (GRADE A PLATE)

This is to be done on samples from one or more plates selected at random. Where two or more thicknesses of plate are concerned, samples may be combined or two or more tests conducted at the examiner's discretion.

Enough samples should be cut to 3 by $1\frac{1}{2}$ inches to form a block $\frac{3}{4}$ -inch thick, which shall be held in the testing clamps. The testing clamps shall be of metal and of sufficient rigidity to withstand the required pressure without distortion or affecting the accuracy of the required measurements and of such form as will permit inspection of the mica edges without removal from the clamps and shall be held together by two through bolts of not less than $\frac{3}{4}$ -inch diameter, with nuts bearing on cut steel washers or equally good bearing surfaces. Threads should be sharp, clean and free from oil and the nuts shall turn freely. After placing samples in the clamps, the nuts shall be tightened by the application of a pressure of approximately 60 pounds applied at a radius of 12 inches and the thickness of the mica block accurately measured. The clamp and block shall then be placed in an oven at 150°C. for two hours, removed and the nuts immediately tightened to the former pressure, after which, without removal from the clamp, the mica shall be inspected for slipping and oozing.

Immediately following this test the clamp shall be placed in an oven at 260°C. for two hours, removed and the nuts immediately tightened, with a pressure of approximately 75 pounds at 12-inch radius. The thickness of the mica block shall be measured to determine the amount of reduction in thickness. After cooling to approximately atmospheric temperature, the mica shall be removed and examined for oozing and slipping.

COMMERCIAL SPECIFICATIONS FOR MICA SPLITTINGS*

GRADE A—INDIAN MICA SPLITTINGS NO. 5

General.—The material purchased on this specification shall be Indian mica splittings suitable for use in the manufacture of mica tape. These splittings shall be evenly split, with clean cut edges and free from thick edges or corners.

Physical.—The thickness for 10 films shall be maximum 0.008 and minimum 0.007 inch.

Size.—The splittings shall be of sufficient size to cover a rectangle of maximum $5\frac{1}{2}$ square inches and minimum 3 square inches in area (*i.e.*, No. 5 full size Bengal grading).

Composition.—The splittings shall be clear films of sound muscovite ruby mica, free from all spots or stains.

Packings.—The splittings shall be packed with powder, in book form, loose-packed or pan-packed as specified on order.

The splittings shall be packed in good strong boxes, not exceeding 125 lb. in net weight. The boxes shall be lined with strong paper or other material to prevent splinters from the case from becoming mixed with the splittings. The boxes must be so packed as to prevent movement of the films and consequent injury to their edges. All boxes of splittings shall be marked, showing the net weight, the kind of splittings and the name of the purveyor.

GRADES B AND C—INDIAN MICA SPLITTINGS (NO. 6 LARGE)

General.—The material purchased on the specifications shall be Indian mica splittings suitable for use in the manufacture of mica paper, mica cloth, etc.

"B" quality.—The splittings shall be evenly split with clean cut edges and free thick edges or corners.

"C" quality.—The splittings shall be evenly split with clean cut edges (edges may be slightly uneven) and free from thick edges or corners.

Physical.—The *thickness* for 10 films shall be maximum 0.009 inch and minimum 0.007 inch.

* Specifications of a large American consumer of splittings, dated 1st January, 1930.

"NEMA" standards and specifications are given in the Appendix.

Size.—The splittings shall be of sufficient size to cover a rectangle of maximum $2\frac{1}{2}$ square inches in area and minimum of $1\frac{1}{2}$ square inches in area (No. 6 full-size Bengal grading).

Composition.—The splittings shall be clear films of sound muscovite ruby mica, free from all spots or stains.

Packing "B" quality.—The splittings shall be packed in book form, loose-packed or pan-packed as specified on order.

"C" quality.—The splittings shall be loose-packed, with or without power as specified on order. Other packing details as stated under grade A.

GRADE D—INDIAN MICA SPLITTINGS (NO. 6 SMALL)

General.—The material purchased on the specifications shall be Indian mica splittings suitable for use in the manufacture of flexible mica plates, lamp shade plates, moulding plates or heater plates. The mica splittings shall be evenly split with clean cut edges free from thick edges or corners.

Physical.—The *thickness* for 10 films shall be maximum 0-009 inch and minimum 0-007 inch.

Size.—Not less than 60 per cent. of the splittings shall be of sufficient size to cover a rectangle of maximum $1\frac{3}{8}$ square inches in area and minimum of 1 square inch in area. The balance of the splittings shall be of sufficient size to pass over a $\frac{3}{4}$ -mesh screen (equivalent to No. 6-B loose-packed of Indian grading).

Composition.—The splittings shall be clear films of sound muscovite ruby mica, free from all spots or stains.

Packing.—Loose-packed, with or without powder as specified on order, rest as above.

GRADE E—INDIAN MICA SPLITTINGS (NO. 6 SMALL, LOOSE)

General.—The splittings shall be Indian mica splittings, suitable for use in the manufacture of moulding and segment plates and evenly split with clear cut edges (may be slightly uneven) and free from thick edges or corners.

Physical.—The *thickness* for 10 films shall be maximum 0-009 inch and minimum 0-007 inch.

Size.—Not less than 50 per cent. of the splittings shall be of sufficient size to cover a rectangle of maximum $1\frac{3}{8}$ square inches and minimum of 1 square inch in area. Balance may be sufficient to pass over a $\frac{1}{2}$ -inch mesh screen (equivalent to No. 6-C loose-packed of Indian grading).

Composition.—The splittings shall be clear films of sound muscovite ruby mica, not more than 5 per cent. slightly earth-stained and withered mica, free from any mineral stains.

Packing.—Loose-packed, the rest as for other grades described above.

GRADE F—INDIAN MICA SPLITTINGS

General.—As above, for manufacture of moulding plates; edges may be slightly uneven.

Physical.—The *thickness* of 10 films together should be maximum 0·009 inch and minimum 0·007 inch.

Size.—The splittings shall be sufficient to cover a rectangle of minimum of $\frac{3}{4}$ square inch in area and sufficient to pass over a $\frac{1}{2}$ -inch mesh screen (equivalent to No. 6 cheap loose of Indian grading).

Composition.—The splittings shall be clear films of sound muscovite ruby mica splittings, not more than $7\frac{1}{2}$ per cent. slightly earth-stained and withered mica, free from any mineral stains.

Packing.—Loose-packed, the rest as for other grades of loose-packed splittings described above.

STANDARD SPECIFICATION OF A LARGE BRITISH USER OF MICA SPLITTINGS*

Mica lamination.—The quality and the treatment of raw mica shall be such as to ensure for the laminations, the properties herein specified.

General description.—The material desired is that class of naturally occurring silicates known commercially as mica in the form of laminations of grade A or grade B as specified.

Requirements : Grade A.—Shall be that quality commercially known as *first quality clear ruby mica* and shall be composed of flat laminations, free from holes, stains, spots, crosses, splits, gaseous inclusions and built-up or cemented pieces.

Grade B.—Shall be that quality known commercially as *stained mica* and shall be composed of flat laminations free from holes, built-up or cemented pieces, crosses and electrically conducted spots and reasonably free from splits, gaseous inclusions and opaque spots.

The laminations shall be clearly cut and truly rectangular and should be reasonably free from shattered and opened up edges.

Dimensions.—The required dimensions of the mica shall be specified in the purchase order or on a drawing which shall accompany and form part of the purchase order.

Tolerance.—Where no special limits are stated on the purchase order, a commercial tolerance shall be allowed on the

* London, 1926.

thickness, length and width in accordance with the table given below :—

	Tolerance.
Thickness up to and including 0.004 inch ..	0.0005 inch.
" from 0.004 to 0.010 inch inclusive ..	0.001 "
" " 0.010 to 0.100 inch ..	10 per cent.
" " 0.100 inch upwards ..	5 " "

Length and width.—

Up to and including 2 inches ..	1 per cent.
Over 2 inches ..	0.032 per cent.

Di-electric strength.*—When measured between smooth plates under a pressure of approximately one-half of one pound per square inch, the grade "A" mica shall withstand an alternating potential of at least 1,000 volts per mil of thickness and grade "B" mica shall withstand an alternating potential of at least 500 volts per mil of thickness at approximately 50 cycles per second for a period of 1 minute. The capacity of the source of alternating current shall not be less than one kilowatt.

Packing.—The mica laminations shall be packed between sheets of cardboard or other suitable material in wooden boxes so that they shall be adequately protected from injury and loss during transit.

Laminations up to and including 0.005 inch in thickness shall be packed in bundles of not more than 500.

SPECIFICATIONS OF GROUND MICA†

Specifications of two roofing concerns, as called for in purchasing ground mica, are given below :—

Specification No. 1.	per cent.	Specification No. 2.	per cent.
Over 20 mesh not more than	4	Over 20 mesh not more than	1
" 20 to 28 mesh from	15 to 25	20 to 40 mesh not over	45
" 28 to 35 " "	15 to 30	40 to 60 " "	30
" 35 to 65 " "	20 to 40	60 to 80 " "	4
65 to 100 mesh not over	25	80 to 100 " "	6
Through 100 mesh. not over	10	Through 100 mesh not over	14

*The word "di-electric" denotes a material possessing di-electric strength and the ability to momentarily store electro-static energy by induction instead of by conduction. The highest efficiency of mica in radio condensers is due to its lost power factor and uniformly high di-electric constant.

† Mica Mining and Milling Methods, Eng. and Min. Journal, Vol. 122, No. 23, 4th December, 1926.

Chapter XIV

ASSOCIATES, INCLUSIONS AND SUBSTITUTES OF MICA

All micas, in spite of their high power of resistance against weathering, suffer alteration by hydration, by chemical attack under natural conditions or by the introduction of mineral precipitates. Recurrent fluctuations of temperatures and exposure to the action of certain substances all combine to cause the disintegration or decomposition of the mica by reducing it to a pulverulent flaky condition. Although muscovite is the most stable of all the different types of micas, it is also altered and is sometimes changed to a secondary mica, *sericite*. Crystals of mica which have been exposed in *dumps* or other debris for a considerable time become "puffy" owing to their laminae becoming loose and separate from one another, largely due to the influence of fluctuating temperatures and weathering action. Moisture containing sulphuric acid and humid acids affects the thin laminations, causing loss of lustre and colour, and rendering the mica ultimately opaque and weak.

Many of the modifications or alteration products of the micas have special names, a few of which are described below.

Sericite.—Sericite is the commonest variety of altered muscovite and is found sometimes as an aggregate of microscopic anhedral crystals and in various other modes of occurrence. It is commonly found associated with quartz, *e.g.*, sericite-quartz schists, but it is difficult to separate it from the associated minerals. The name of sericite is derived from the Greek words which refer to its fine silky lustre and an unctuous feel. It is also known to be an alteration product of feldspar, kyanite and other aluminium silicates, and is almost invariably of secondary origin.

Sericite is ground in hammer mills like mica. It is easier to break than mica because it occurs in small crystalline aggregates and in scales unlike the larger sheet muscovite. Pulverised sericite schist is used in America in manufacturing axle grease, roofing compositions, foundry facing, rubber products, etc. Sericite is more readily absorbed by rubber than ordinary ground mica because its scaly particles are smaller. It is also used for surfaces where a black tint is desired. Appreciable quantities of sericite are shipped to Winnipeg to be crushed and used for stucco-painting and other purposes.

Fuchsite or chrome mica.—Muscovite and feldspar sometimes alter into fuchsite by parting with a proportion of their potash content and taking up chromium in replacement. Chromium-bearing mica schists occur on a commercial scale in some southern areas of the United States as well as in eastern Manitoba in Canada*.

Vermiculite.—Vermiculite is an alteration product of phlogopite and biotite micas, chiefly due to the oxidation of the iron components or change in their water content as derived by hydration. It is sometimes regarded as hydrated biotite, due to its having undergone alteration by hydrothermal agencies. The following represents a typical analysis of the material †:—

SiO	Fe ₂ O ₃ & Al ₂ O ₃	CaO	MgO	Na ₂ O & K ₂ O	Loss.
42.8	26.2	1.9	24.6	3.8	0.7

This material has become useful for industrial purposes since 1925. It occurs in Colorado and Montana deposits bearing phlogopite characterised by high magnesium content. An occurrence of vermiculite has also been reported from the Tanganyika Territory.

In colour it varies from white to yellow, brown, bronze-like and green. The surface indication of the mineral is usually a slippery soil composed of mica-like flakes. The most important property of this material is its expansion, on heating, to about 20 times its original volume. It changes to a silvery or golden colour and suffers a reduction of specific gravity from 2.5 to 0.09 (or less). The heat-treated or prepared material is used for insulating purposes. Vermiculite is also considered suitable for plastering, wall paper board, roofing composition, cement, lubricant and "gold" paints, fire-proof and insulating packing in safes, cabinets, hollow spaces, incubators, bank-vaults, etc. One of the vermiculite type of minerals has been named as "jeffersite", which also shows remarkable exfoliation on heating and swells enormously due to the formation of steam between the layers. It is also marketed by some people as "zonolite" as a heat-insulating and sound-deadening material.

The average covering power of vermiculite, however, is less than that of mica. Vermiculite is also used for sound-proof panels.

Four plants exist in Canada for expansion (by heat processing) of the hydrated variety of mica (vermiculite), which on expansion when heated yields an exceedingly light product that finds application for heat and sound insulation ‡.

Steatite or talc and serpentine.—Phlogopite sometimes alters to steatite and serpentine. Some titanium minerals, rutile, is also

* It is preferred in stucco-painting.

† U.S. Bureau of Mines Inf. Cir. 6205.

‡ Journ. Canadian Inst. of Min. and Met., May 1938, No. 313, p. 262.

said to be produced by it. By hydration, mica loses at times its elasticity and transparency and also often loses some portion of its potash by taking up magnesia, lime or soda. These changes may be promoted by water which contains carbonates of these bases*.

ASSOCIATED ROCKS AND MINERALS

Mica schist.—It is a laminated metamorphic rock, consisting largely of mica, generally muscovite or biotite in small flakes, together with quartz and other minerals. In some cases they contain large quantities of garnet, staurolite, tourmaline, kyanite, etc. Mica schist has been used as a refractory material and is also ground for prepared roofing†. It is one of the commonest and most widely distributed metamorphic rocks.

Mica schist has been used in America in masonry construction. It is also chiselled into 4-inch blocks and used for facing. Considerable quantities of schists are used as a refractory in the iron and steel industry. The schists, after being broken, are trimmed into square blocks and sold, which are used largely in lining furnaces, Bessemer converters, cupolas, soaking pits, hot-metal mixers, etc. The mica content, on being highly heated, fuses and binds the whole mass itself.

Chlorite schist.—Chlorite is the name of a group of micaceous minerals usually green in colour and often called brittle micas. They resemble true mica to some extent in appearance and cleavage but are generally opaque and the cleavage plates are inelastic. Chlorite schists, which are rocks containing much of this mineral, are sometimes ground to make a low-grade ground mica used in prepared roofing. They are commercially worked on a large scale in America, *e.g.*, Spruce Pine, N. C., Cartersville, Ga., etc.

Feldspar.—It is the name given by mineralogists to a group of rock-forming minerals consisting of several anhydrous silicates of aluminium, containing the bases potash, soda or lime. Feldspars are of two kinds—(i) potash feldspar and (ii) lime-soda feldspar. They are found in rocks of igneous origin, solidified from molten masses. They are the most abundant constituents of the mica-bearing pegmatites, quartz being the next in abundance and frequency.

Feldspar is used chiefly as a *flux* in the manufacture of glass, pottery, enamelware, brick and tiles. The proportion of feldspar used in glass manufacture varies between 30 and 50 per cent. and various forms of opaque glass are made of it, which is in demand in hotels, restaurants, drug stores, etc., where a vitrified surface is desired. Tiles and wash bowls are usually made of

* Dana.

† Non-metallic Minerals by R. B. Ladoo.

cast iron and while hot are covered with an enamel containing a considerable proportion of feldspar. It also forms an important constituent of electrical and other classes of porcelain.

Exceptionally pure potash feldspar is used in the manufacture of artificial teeth*.

Potash feldspar is found in two forms, namely, (i) microcline and (ii) orthoclase. Microcline crystallises in the triclinic system while orthoclase crystallises in the monoclinic system. Soda feldspar is also found in nature in the form of albite (sp. gr. 2.624 and hardness 6 to 6.5) but the pure mineral is rare.

Apatite, $Ca(F, Cl)Ca_4(PO_4)_3$.—In colour apatite is sea-green, bluish green, violet, blue, white or colourless; occasionally yellow, grey, red and brown. It is almost an invariable associate of phlogopite in the pyroxenite dykes, being often more abundant than the mica. It is of two kinds, namely, (i) fluorapatite (P_2O_5 42.3, CaO 55.5 and F 3.8, total 101.6) and (ii) chlorapatite (P_2O_5 41.0, CaO 53.8 and Cl 6.8, total 101.6).

Apatite is soluble in hydrochloric acid and nitric acid. In rock sections it is always found fresh and appears to be one of the last minerals to undergo decomposition. Most perfect apatite crystals are usually found embedded in calcite. It is widespread in various kinds of rocks and generally abundant in association with metamorphosed limestones in regions of crystalline schists such as in Eastern Canada.

Schmidt has published the following as the mean of several analyses of the Canadian apatite :—

Phosphoric acid 39.733; fluorine 3.494; chlorine 0.257;
carbon dioxide 0.630; lime 47.933; calcium 3.823;
insoluble 1.658; total 97.528.

Tourmaline, $H_3Al_2(B.OH)_2Si_4O_{10}$.—It is a frequent associate of muscovite mica and is chemically a complex silicate of aluminium and boron with magnesium, iron or the alkalis prominently in its composition. Tourmalines from different localities differ in the proportion of constituent elements and may be classified as alkaline tourmaline, iron tourmaline and magnesium tourmaline. It resists decomposition by acids and is rarely found altered. No cleavage is discernible in it. Tourmaline is brownish or bluish black as also bluish green but rarely white or colourless. It occurs largely in crystalline schists, and in the more siliceous igneous rocks, particularly in pegmatites and in the vicinity of veins. It is met with in gneisses, mica-schist granites and similar rocks. Sometimes it replaces mica and feldspar in granite, being due to the action of emanations from solidifying granite.

* U. S. Bureau of Mines Cir. 6381, October 1930.

Tantalite and columbite.—These are found in some of the pegmatites, columbite usually predominating. They are tantalate and columbate, respectively, of iron and manganese and pass from the one into the other by insensible gradation in composition. The specific gravity also changes correspondingly from 7.3 (tantalite) to 5.3 (columbite). The specific gravity of columbite of the Gaya district, found at *Abraki Pahar* within the Singur zamindari, is 5.28 to 5.52*. Other occurrences are in Kodarma in Hazaribagh district and in Nellore district.

Beryl.—A beryllium-aluminium silicate is a common associate of mica in Nellore, Kodarma, Ajmer-Merwara, Jaipur and Kishengarh†. It contains 11 to 13.5 per cent. of BeO. Nellore and Kodarma areas are capable of producing 3 to 5 tons of beryl annually as a by-product of mica mining. In recent years a few hundred tons of beryl have been shipped from Rajputana mainly to Germany. In some cases beryl contains portions which are clean enough to be cut as a precious stone (*aquamarine*).

Other minerals found in the mica pegmatites of India are :—

Samarskite.—Complex niobate and tantalate of cerium, yttrium, iron and uranium, found in Nellore.

Xenotime.—Yttrium phosphate, found in Bihar.

Triplite.—Phosphate of iron and manganese, found in Bihar.

Pitchblende and uranium ochre.—Uranium-bearing minerals, found in Bihar.

SUBSTITUTES‡ OF MICA

Pertinex.—It is a compressed paper product, developed in Germany during the mica shortage in 1914–18, when Germany was cut off from the sources of mica production including German East Africa. It is used for high tension condensers and resists heat approximately up to 200°C. It is also claimed by the makers to possess high puncture voltage resistance, *viz.*, 25,000 volts per millimetre, and not to be affected in hot oils and its tensile strength is also reported at 1,000 Kg. per sq. c.m. (*i.e.*, 14,200 lb. per square inch). This high tension resistance of *pertinex* is, however, disputed in certain quarters.

Other varieties on the market with similar properties have been developed by other manufacturers and marketed under various trade names given below :—

Turbonite (German).

Dellite (Swiss).

* Imp. Inst. Bull. on Tantalum and Niobium, 1930.

† It is a common constituent of the wolfram mines in Burma and pegmatites near Bangalore—Imp. Inst. Bull. on Beryllium and Beryl, 1931.

‡ None of the substitutes has successfully replaced natural mica with its unique combination of properties.

Micarta.—It is an artificial tan-coloured hard homogeneous mica product developed by Westinghouse Electric Co., and intended to take the place of hard fibre, glass, porcelain, hard rubber, built-up mica plates, raw hides, moulded compounds, etc., for use in commutators, bushings, brushware, insulators, conduits for wiring, spools for spark plugs of magnet windings, wireless coil separators*. *Micarta* can be easily sawn, mill turned and threaded. Thin sheets also can be readily punched. It is marketed in two grades. The bakelite *micarta* is claimed to be infusible and resistant to heat to a point at which carbonisation of some of the ingredients takes place and is insoluble in nearly all ordinary solvents such as alcohol, benzene, turpentine and weak acids as also alkaline solutions. The makers recommend it to be very suitable for the following applications :—

- Aeroplane fire walls.
- Cabin lining.
- Wing covering pulleys.
- Angles, bushings, brush-holders.
- Book covers, brackets.
- Cord terminals, cleets, cable joints.
- Channels, cores, counter tops.
- Door panels, embossed washers.
- Fan blades, entrance bushing, friction discs.
- Furniture veneers, industrial and automatic gears
- Caskets, handles, hospital table tops.
- Insulators, ignition coil boxes.
- Miner's hats, diver's helmets, mandrels.
- Rail joint insulation, radio panels and parts.
- Serving trays, switch boards, switch bases.
- Transformer spacers, telephone apparatus.
- Trainline jumper insulation, valve washer veneering, etc.

MYCALEX

Mycalex is a moulded compound consisting mainly of mica, which is bonded with glass. It is the invention of P. B. Crossley, and is covered by British Patent No. 152780.

One of the original objects of this invention was to utilise waste mica scrap and dust, and the product is certainly a material having an extraordinary set of characteristics, its electrical properties approaching those of mica, and its mechanical properties approximating to those of a metal.

The materials are prepared in a fine state of division, and intimately associated by careful mixing. A cold pressing operation is adopted for performing blanks, and these, after being dried, are raised to a temperature of approximately 700°C. in an

* U. S. Mineral Resources, 1916.

electrical furnace and then pressed finally in an electrically heated mould.

Metal inserts can be moulded into Mycalex mouldings, thus adding to the convenience, economy and strength of the designs, but it must be recognised that, owing to the fact that in its present state of development Mycalex is never really very plastic, only relatively simple designs of mouldings and inserts can be economically dealt with.

Although the cost of raw materials used in the manufacture of Mycalex is low, the manipulating technique is a little delicate and somewhat expensive, and this means that the cost of the finished articles must not be compared with that of cheap quick-pressed moulded plastics which are not in the same class as Mycalex as regards their characteristics.

ELECTRICAL CHARACTERISTICS OF MYCALEX

The permittivity and power-factor values of Mycalex, measured at 100 cycles, are approximately 8.5 and 0.002 respectively. The electric strength (minute value) in air at 25°C., and for a thickness of 200 mils, is 345 volts per mil, and a similar test made under oil at 90°C. gave a figure of 320 volts per mil.

ARTIFICIAL PRODUCTION OF MICA

Micas of several types have been artificially produced in the laboratory by the fusion of various silicates having the constituents of micas with fluorides of sodium, aluminium, magnesium and fluosilicate of potassium in different combinations. Attempts to produce mica artificially have failed but it has been found in microlites in fused rhyolite form (Iceland) and it occurs as a crystallisation product in some stages. The presence of hydrogen and fluorine in micas indicates that these elements are essential in the formation of mica from the solutions from which they are to be crystallised*.

Artificial production of mica in sheets of commercial size has not been possible so far, because apparently the natural geological conditions under which it forms are not reproducible in the laboratory. Hence such a product may be left out of consideration.

Attempt has recently been made in the Russian Laboratories, by the slow cooling of a silicate melt, fused in a graphite crucible where crystals of small size, claimed to be those of phlogopite, have been obtained but the crystals do not seem to possess the cleavage of natural mica and were no larger than 1/50th of a square inch†.

* Rocks and Minerals, by J. P. Iddings.

† The Mining Journal, dated 7th August, 1937.

PRODUCTION OF SYNTHETIC MICA

Development of a synthetic mica in the shape of inorganic films is just reported*, which is expected to be a suitable substitute for natural mica in certain applications. In view of their low cost of manufacture and their properties of resistance to acids, alkalis and oils and ability to withstand red heat without loss of strength, these films may find useful applications in many fields. Dr. E. A. Hauser is the inventor and the Massachusetts Institute of Technology, where the research was carried on, announced the discovery before the Tariff Commission in June 1938. The commercial exploitation of the process has been secured for the Research Corporation of America. If this synthetic mica proves a commercial success, it will bring in a revolution in the technology of mica and mica products.

* U. S. Tariff Commission Report No. 130, Second Series, 1938.

Other associates of mica include the following :—

Rutile (TiO_2) or Tetanium Dioxide.—This occurs in igneous, metamorphic and sedimentary rocks generally as an alteration-product of mica, usually parallel to the cleavage and other directions of the percussion figures of micas. It does not dissolve in acids and resembles cassiterite and zircon, readily distinguishable, however, from its greater and double refraction.

Ilmenite ($Fe. TiO_2$) or ($Fe. Te$), O_2 .—It occurs in gneiss, mica schist and amphiboles and is commonly a constituent of the igneous rocks. Mode of its occurrence is similar to that of magnetite and hæmatite, frequently developing into inclusions in the feldspars and pyroxenites in the basic rocks and is not soluble in acids.

Chapter XV

THE ELECTRICAL USES OF MICA*

INTRODUCTION

The phenomenal growth of the electrical industry can be attributed to a very large extent to the use of mica as insulator between the different conducting members of electric machines. Mica is a bad conductor of electricity, hence forms an excellent insulator. It is a comparatively light mineral, elastic in nature, and easily deformable within a certain range. Excepting metals and some organic materials no substance has yet been discovered which has this particular property of deformability to the extent as is found in mica. It can be split into exceedingly fine flakes, such that their thickness could be of the order of a micron†. It is further a bad conductor of heat and can stand fairly high temperature without altering its properties. It is practically unaffected by acids and alkalis. Organic solvents have no action on it but at the same time it easily bonds with different plastic materials. In fact when all these different qualities are found to be combined in one material, it is no wonder that it would find extensive application in the different branches of electrical industry.

In the literature there is no definite mention regarding its first use by the electrician but as early as the middle of the last century, Gramme used mica separators in the commutators of his machine. Paccinotti also used mica in his first machine. The development of Direct Current machinery, both for the generation of power as well as for its utilisation as motors, can be attributed to the use of mica in building up their commutator segments.

The use of mica in condensers is at least ninety years old. Faraday published a paper on the specific inductive capacity of mica in the form of a sheet as early as 1832. Along with its high specific inductive capacity it has a wonderfully high dielectric strength. The puncture voltage for a thin sheet of mica for 1 mm. thickness has been found by different investigators to be varying from 50,000 to 350,000 volts according to the condition and origin of the mica from different sources. It is this property which has been taken advantage of in the gigantic development of electrical power and the high voltage technique to its present stage. As has just been remarked, taking everything into consideration there is even not a remote chance of securing any material

* Written by Prof. P. N. Ghosh, M.A., Ph.D., Sc.D., F.Inst.P., Head of the Department of Applied Physics, University College of Science, Calcutta.

† 1 micron = 1/1000 millimetre.

approaching mica in the properties mentioned above and which could form a substitute for it. It is well known that electrical insulators for medium and high voltage work have to satisfy the following criteria :—

- (1) non-porosity,
- (2) rigidity,
- (3) uniformity in thickness,
- (4) moisture resistivity,
- (5) heat resistivity,
- (6) oil resistivity, and
- (7) high di-electric strength.

Various materials such as pressboards, fibre and leatheroid are being used in the electrical industry for certain class of work but they have never been able to replace mica.

Let us consider a few examples. When one considers small size D. C. motors one finds several hundred millions of them are in daily use throughout the different civilised regions of the world and one should not forget that in each and every one of them mica pieces have been used as separators for their commutator segments and unfailingly they are performing their duties imposed upon them even under worst possible conditions. In bigger types of machines, as rotary converters, motor converters, commutator motors, etc., micanite or bonded mica takes the place of raw mica. It is used as lining for the slots of our biggest turbo-generators, as partition plates between the coils of big sized transformers. Mica due to its heat resisting power and elastic properties holds its own against any other material known to the electrical designer.

In electrical heaters, for water boiling purposes or as small heating irons in modern households supplied with electric power, thin mica sheets are the bases on which the resistance wires are disposed and the same sheets act also for insulation purposes from the metal containers. The number of such domestic appliances can be counted to be several millions and the extended use of electrical energy for household purposes naturally would extend the scope of its applications.

One can easily understand the utility of mica in radio technique. Though paper condensers are used in considerable quantities in radio reception sets, yet mica condensers of small dimensions have got a much wider scope for dependability and several hundred thousand millions of such condensers are in daily use all over the world*.

* Each motor and each generator in an automobile or truck uses from 24 to 30 mica segment insulating pieces in its commutator, which means an annual consumption of, perhaps, 250 million of these small segments for automobile use alone.—U. S. Tariff Commission Report No. 130, Second Series, 1938, p. 16.

Another interesting use due to its flexibility combined with insulating property is found in some of the better class of sparking plugs of aero-engines as well as automobiles, where the material in question has to serve under very rigorous conditions.

Mica also acts as supports for heating filaments of high power electric lamps. For lamps of power consumption above 100 watts it has been found that suitable mica discs are necessary to support the leads to the intensely hot glowing tungsten filaments. The growth of the valves in radio technique similarly requires mica sheets for the purpose of supporting the grids and the present development of the short wave generators would not have been possible but for this wonderful material for mounting the different elements of the valves.

THE ELECTRICAL PROPERTIES OF MICA

The physical characteristics of mica have been dealt with in previous sections and here the electrical characteristics will only be considered.

1. **The di-electric strength*.**—When one considers different varieties of mica one finds that the electric strength of muscovite is superior to that of phlogopite and the following figure gives the average values for various thicknesses obtained on

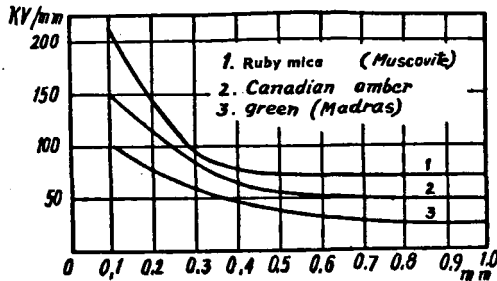


Fig. 16. Showing di-electric strength of different types of mica.

50 cycle A. C. voltage with one inch diameter disc electrodes under transformer oil at normal temperature under gradually increasing applied voltage (Fig. 16). The electrical strength of mica is

* Although spun and fibred glass has attracted the attention of electric insulation experts, mica remains far superior to it yet.—H. N. Mathes of the General Electric Co. (G. E. Review, May 1938, Vol. 41, No. 5, p. 219) states :—

In contrast to mica flakes the fibre-glass structure is porous and electrically can be considered only a physical spacer unless filled with an insulating varnish or compound. Treated fibre-glass has the desirable characteristics of good di-electric strength and low di-electric constant with good resistance to moisture, but does not possess the voltage breakdown strength of mica tape, particularly after aging, at high temperature.

apparently higher in air than in oil because of the difference in the di-electric constants of oil and mica. The di-electric constant of transformer oil is about 2.2, whereas that of micas varies from 5 to 9 and the stress at the edges of the electrodes is much higher than in the central portions when the testing device is immersed in oil.

Electric strength (instantaneous puncture)*
 Temperature 20°C. to 25°C.; 1 inch disc electrodes.
 Muscovite mica (Bengal ruby type in natural form)

Thickness in mils.	Electrical strength in volts per mil.	
	In air.	In oil.
10	1,960	1,740
20	1,480	1,360
30	1,300	1,160
40	1,200	1,060
50	1,160	1,000

Grünewald† removed the air between the electrode and the specimen in testing mica by means of aniline oil having a di-electric constant practically of the same magnitude as that of mica and thereby avoided concentration of stress at the edges of the electrodes. He found that the thickness voltage curves were linear and the different varieties of mica have characteristic electrical strength hitherto not so clearly brought out by ordinary tests under transformer oil.

Though the early work of Wilson was fairly exhaustive for thickness of the order of 10 mils and above, the recent works of Bogorodizky and Schwaiger on thinner laminæ disclosed much higher values for thin sections. For thicknesses near about 2 mils according to the latest investigations of perfectly clear samples of Bengal ruby mica the electric strength has been found to be near about 2,800 volts per mil, for phlogopite the value is lower, namely, near about 2,300 volts per mil for the same thickness. The green Madras mica has been found to be the weakest and the value has been roughly below 2,000 volts per mil.

2. **The di-electric constant**‡.—The di-electric constant of the different micas varies between very wide limits from 5 to 9.3 in different varieties and samples—the value for muscovite mica

* Wilson—Electrician, 54, p. 356, 1904.

† E. T. Z., Oct. 9, 1924.

‡ It has been defined as the ratio of the stored energy in the di-electric field (mica being in the di-electric field under discussion) to what would exist in the same space if air were used in place of the di-electric.—L. E. Barringer, Chief Engineer, G. E. C.: U. S. Tariff Commission Report No. 130, 1938, p. 22.

has been given by Stager* as 9.3 for the best samples, whereas the ordinary air-stained varieties free from water stains as well as inclusions from ferrous materials the value is near about 7, and the smallest values are found for the green micas of Madagascar.

3. **Volume resistivity and temperature variation.**—The volume resistivity of mica has been the subject of a large number of investigations, but the latest work is that of Bogorodizky† who found that for various samples from the different varieties there is a very wide limit of values, namely $(1-200) 10^{15}$. In this

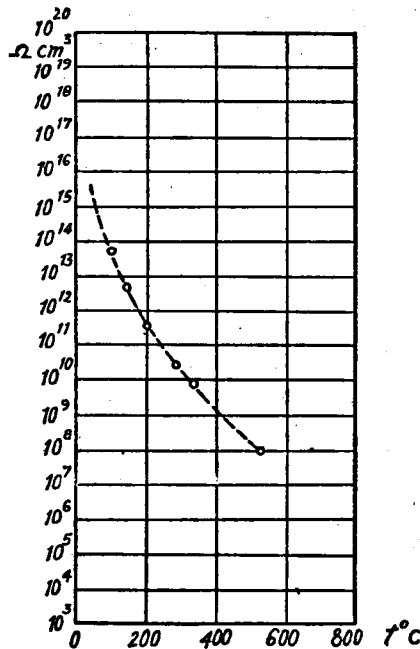


Fig. 17. Volume resistivity of muscovite mica.

case also the highest value has been found to be for the muscovite micas. The temperature variation of this specific resistance is very interesting since it practically follows a linear law between 0°C. to 100°C. (Fig. 17) and then it undergoes a slow but gradual diminution in its value. Between the range 550°C. to 900°C.

* *Electrotechnische Isoliermaterialien*, Stuttgart, 1931.

† *Arch. Electrotechn.*, 28, 644, 1934.

muscovite loses the water of crystallisation and ceases to be an insulator. For amber mica the value is however higher. For different samples it has been found that the resistances vary between very wide limits and the insulating property is lost between a temperature of 750°C. to 900°C.

4. **Power factor.**—The power factor or the di-electric loss ($\tan \delta$) has been the subject of very large number of investigations and the systematic work of Symons Walker* is usually accepted. Rohde† and Grundke‡ worked out the power loss for different cycles. The following table shows the values :—

	$\tan \delta$.
50—800 Hz	2.8
10 ⁶ Hz	1.7
5·10 ⁷ Hz	1.6
5·10 ⁸ Hz	≈ 2.0

It is thus noticed that the power loss for micas happens to be lowest near about a frequency of ten million oscillations. For phlogopite the values are higher.

A SUMMARY OF THE CHARACTERISTIC PROPERTIES OF MICA

Sp. gravity ..	2.65 to 3.2	
Hardness (Moh. scale) ..	2 to 3	
Calcination temp. ..	550°C. to 900°C.	
Shearing strength in Kg./mm. ..	23.5 to 26.5	}
	10 to 13	
		Muscovite (World Power 11,32,1929)
		Amber (World Power 11,32,1929)
Elasticity modulus in Kg./mm. ..	16,000 to 21,000	
Sp. heat (bet. 20°C. to 100°C.) ..	0.208	
Heat conductivity ..	0.0008 to 0.00014	
Linear coef. of expansion ..	30 to 10	
Sp. resistivity at 20°C. ..	(1-200) 10 ¹¹	
Di-electric strength in KV per mm. ..	50 to 350	
Di-electric constant ..	5 to 9.3	
Di-electric loss 10 Hz ..	2 (muscovite ruby)	
Loss of weight up to 900°C. ..	4.2 per cent.	
Max. temperature of use ..	500°C. for muscovite	
	900°C. to 1,000°C. for phlogopite	

Use of mica.—The uses to which virgin mica is put are restricted by the rarity and expense of sheets of any appreciable size. Built-up mica products are always used where large jobs have to be insulated—the mica being first laminated and then rebuilt into layers so that the flakes overlap. Suitable adhesives

* J. I. E. E., 48, 674, 1912.

† E. T. Z., 54, 581, 1933.

‡ E. T. Z., 55, 1214, 1934.

and sometimes fibrous backing are used so as to construct continuous sheets.

Virgin mica is used for small commutator segments, as di-electric materials of condensers, as formers for heating elements of different types, as supports of filaments of high power lamps, as supports and separators of grids of valves for radio purposes, as thermal and electrical insulators of sparking plugs, as well as for miscellaneous small punched parts and washers of electrical instruments, as frames for mounting non-inductive resistance elements and also for a variety of purposes where high resistivity, flexibility and thermal resistivity are required.

Mica for small commutator segments.—Pure mica is commonly used for separators of segments in small commutators such as those designed for fractional horse power—D. C. motors, car lighting and starting sets, house lighting generators, etc. Though pure mica separators can be obtained up to 16 or 18 inches long, it is more economical in practice to restrict the length up to 4 inches.

In the case of commutators with flush mica segments, the latter must be as soft or softer than the commutator copper otherwise uneven wear will result in service due to high mica and bad sparking will be the consequence. Flush segments are still employed with hard brushes on small machines without commutating poles. For flush segments amber mica is the best—but it is expensive and soft green micas have successfully been used by some manufacturers.

Almost any kind of sound mica which can be perfectly split may be used for undercut segments, the undercutting being commonly $1/16$ inch in depth. The depth and width are generally proportioned according to the dimensions of the brushes to avoid chattering. The material is supplied as rectangular separators or cut to the same shape as copper bars. The quality of mica should so far as possible be perfectly clear or where price is of some consideration air spotted varieties have been used with success. Amongst the builders of large and important machines it is the common practice to undercut the commutators even where soft grades are used. For unfailing service regardless of the extra cost this procedure has been found from experience to be the most satisfactory; a good machine will run for several years without new undercutting and have been found in practice decidedly to give security of service in the long run.

In the case of flush commutator segments, uniformity of hardness of the micas is almost as important as the actual hardness—and this is often secured by laminating the segments, shuffling the laminæ and then arranging them together again and thus

minimising the coincidence of hard spots. In fact, the non-uniformity of hardness is one of the serious drawbacks to pure mica segments and built-up micanite segments are found to be better in this respect.

Built-up segments (as distinct from micanite ones) are made from individual relatively thick plates of mica having butted edges, joints being staggered in the various layers. Minimum amount of adhesive, usually shellac dissolved in spirits, is used for the purpose and these built-up segments are found to be generally satisfactory.

Apart from the question of hard spots pure mica segments are generally more sound from the mechanical standpoint than the built-up or micanite ones. In pure mica the splitted sheets could be brought down within a tolerance—1 mil (1/1000 of an inch).

Pure mica withstands the action of oil better than built-up mica or micanite. It is known to the designers that mica is certain to disintegrate owing to the destruction of adhesive cohesion if oil actually happens to penetrate between the laminæ. Trouble is therefore found to occur if oil gets on to the commutators and special attention is paid to the bearings, oil throwers, etc., on the machines. With the use of ball bearings and roller bearings, this difficulty has partially been overcome, but the packing grease used in these bearings becomes fluid under high running speed conditions and, unless properly cared for, gets access to undesirable parts. For the protection of the commutator segments special discs are mounted between these bearings and commutators to avoid the admission of these undesirable elements. In the case of built-up mica or micanite, it has been known that the introduction of oil loosens the mica pieces so that they rise up, specially in high speed machines or those with large commutators such as big motor-converter sets. This is rarely the case with pure mica which is found to be much more resisting to the introduction of oil.

MICA FOR CONDENSER INSULATION

Electrical condensers were first used on a commercial scale in connection with telegraph work and their early development was largely due to Varley, Latimer Clark and others. Muirhead & Co. in the eighties were constructing condensers with mica and tin foil laid with paraffin for telegraph use and in 1884 Prof. Glazebrook* was carrying out special tests for them. The mathematical theory of condensers has attracted the attention of such eminent men as Kelvin, Heaviside, Tyndall, Clerk Maxwell, J. J. Thomson, Oliver Lodge, Preece, Rosa, Fleming, Dewar, Steinmetz and others. Swinburne in 1890 found that mica and tin foil condensers grew very hot on A. C. circuits and he found

* *Phil. Mag.*, 18, 98, 1884.

that, though individual sheets could stand 8,000 volts on test they broke down on 2,000–3,000 volts when made up into condensers.

The grade of mica used for condenser insulation varies according to the service for which the condenser is designed. For D. C. and general testing and standardising purposes, mica of particularly high insulation qualities is chosen. For very high voltage condensers, mica of the highest electrical strength must be used and low loss mica has to be selected for high frequency work. Generally clear ruby or white muscovite free from stains and spots is used for high grade condenser work and no inclusions, solid or gaseous, are tolerated.

Since mica has the peculiar property of being able to be splitted up into thin foil, mica condensers are of the parallel plate type.

If "A" is the area of each plate, "D" is the plate spacing, and "N" the total number of plates, the general formula for the capacity of a condenser of this type may be written as

$$C = 0.885 \cdot \frac{A(N-1)K}{d}$$

where C is given in microfarads, and K is the di-electric constant. In practice it is found that the actual capacity of a parallel plate condenser is slightly in excess of the value calculated by the above formula. This effect is due to the fringing of the lines of force beyond the geometrical space between the plates.

The block ruby mica for condensers is usually available in the form of irregularly shaped pieces and this rough mica is first sorted into different grades, depending upon the size of the plates which can be cut from them. For condenser purposes, the mica undergoes a series of inspections and testings and is then split into sheets of definite thickness. Although many attempts have been made to construct machines which will effect this splitting automatically, very little success has been achieved. The splitting is usually carried out by hand using a short splitting knife. Every piece of mica used in the manufacture of condensers is carefully gauged for thickness with the help of a micrometer dial gauge which can detect a variation in thickness even of 1/10,000 of an inch or 1/1,000 millimetre. For puncture and other defects each plate is placed on a metal sheet and a disc electrode is moved over the surface and any defect is detected from the readings of a delicate galvanometer. For commercial purposes high resistance neon lamps are now used which show up the defect by the excitation of the lamps at commercial voltages. After the plates have been found to be satisfactory they are punched with the help of special hollow dies with cushion ejectors, under fly presses. The plates should be clear, uniform in thickness and with clean cut edges, so that when dropped on a hard

surface they emit a clear metallic ring. After the punching operation each plate is again tested so that it is free from cracks and weak spots.

For standard condensers, mica and copper foil electrodes are joined together with shellac varnish to maintain the condenser in a rigid condition. Clamping of condenser plates between sheets of insulating materials has been in common use for a number of years. But this type of clamping though, serving to hold the condenser together, is of little real value for the purpose of securing really intimate contact between the conductor and the di-electric which is essential for the purpose of reduction of electrical losses in the condenser. With such clamping devices, the edges of the plates come into intimate contact, but it leaves the central portion free and the tighter the clamping boards are drawn the actual clamping becomes less and less effective. Improved methods of clamping condensers were developed some years ago by W. Dubilier and later by the Dubilier Condenser Company and other Companies working under his patents.

When condensers have to be built to withstand considerable voltage little advantage is gained by increasing the thickness of the di-electric beyond a certain point and the only economical solution is to arrange the condenser in the form of a number of small units connected in series. W. H. Henry* by a series of experimental work showed the practical utility of such an arrangement. If the capacities of these small condenser sections are all equal the total voltage across the complete condenser will be subdivided into a number of equal parts in the required manner. If it is required to build a condenser and having a capacity of "C" microfarads and capable of withstanding "V" volts one has to experimentally determine the thickness of the sheet capable of safe working at a definite voltage. This safe voltage will depend to a very marked extent upon the nature of the voltage to be applied to the condenser. It is usually highest for D. C. values and as the frequency of A. C. potential is raised the value of V is reduced and it has been found that in the case of radio frequencies the maximum permissible voltage is nearly 1/10th of the D. C. values to avoid undue heating and other undesirable effects.

If "n" is the number of elementary units which must be joined in series in the condenser

$$n = V/v.$$

The nearest integral value of "n" must be taken to the value calculated from this equation. The capacity of each of these elementary condenser sections must be $c \times n$ microfarads.

Thus it is easy to see how the total bulk of the sheets in a condenser will vary with the voltage which is applied to a

* Radio Review, 2166, 1921.

condenser of given capacity. For a condenser of given capacity under the same conditions of frequency, etc., the total size of the condenser will be approximately proportional to the square of the voltage.

This does not apply if the frequency is changed at the same time, since the permissible voltage gradient in each di-electric sheet is a function of the frequency as well. Particularly in the case of condensers required for use in radio-frequency circuits, it is undesirable to adhere too closely to this relationship, since in such cases changes in voltage on the condenser are very frequently made by changing the frequency of the circuit and this further modifying factor may give rise, particularly with the shorter wave lengths, to a considerable departure from the above proportionality.

These separate condenser sections are commonly connected in series with some convenient insulating spacer between each section, as indicated at S in Fig. 18, where such spacers are shown separating the successive condenser sections M_1, M_2, M_3, M_4 , etc. In this diagram only five such elementary condensers are shown, but the number will depend upon the conditions of use of the condenser. Each of these elementary condenser sections is built up of alternating mica and metal-foil sheets, the sets of foil or

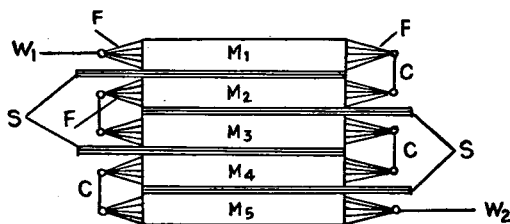


Fig. 18. Showing series of arrangements of condenser sections.

plates of opposite polarity being brought out at opposite ends of the mica sheets as at FF. The successive condenser sections are joined together usually by connectors soldered to the projecting ends of foil, so as to connect adjacent ends together, as shown at CC. The function of the insulating spacers is thus to separate adjacent connecting pieces from each other, since the voltage between such adjacent connections will be double the normal voltage applied to each section. The external connections to the complete condenser are made at W_1 and W_2 to the extreme end foils of the condenser stack. A long stack of series connected condenser sections is divided up into a number of groups.

In utilising a number of such condenser elements joined together in series, they may be held together into a continuous stack

by means of a clamp surrounding the whole stack and provided with a screw or similar means for applying pressure to the stack of sections. Such a clamp prevents relative movement of the parts of the condenser due to the electrostatic forces between the plates. It also tends to preserve constancy of capacity for the condenser under various climatic conditions, temperature changes, etc. The condenser stack, with its clamp of whatever form this may take, is usually inserted in some form of outer container, which may be either of insulating material or of metal, and provided with one or more suitably insulated terminals. In this arrangement, one terminal of the condenser is provided by the metal base on which the condenser stack is mounted, while the second terminal (usually the high potential one) is supported by a corrugated insulator mounted at the upper end of the condenser and connected to the upper end of the condenser stack. For such an arrangement, the clamp used for holding the condenser elements must either be constructed entirely of insulating material, or alternatively the condenser itself must be insulated from the clamp, if it is of metal. In either case, difficulties may be experienced through the energy losses which may occur in the insulating material of the clamp itself or used to insulate the condenser in the clamp, this disadvantage being most pronounced when the condenser is used in circuits of comparatively high frequencies.

A great step forward in the methods of constructing condensers, particularly those having a mica dielectric, was made in 1919, when the principle of the "central terminal" connection was evolved. By employing this principle it has become possible to dispense with all insulation material inside the condenser case, other than that actually forming the dielectric of the condenser sections, with a resulting great increase in the reliability and rigidity of such condensers.

In Fig. 19, one form whereby this result may be secured is illustrated. The condenser sections are in this case divided up into two groups CC, which are arranged on end and are clamped rigidly together between one face of the end of the box B and the clamping plate P, pressure being applied by means of the screw S passing through the opposite face of the metal box. The other connection to the condenser is made at the centre of the condenser stack, that is, at the junction between the two groups C and C, and this connection W is made to the insulated terminal T. Both ends of the condenser stack are thus of the same potential, and the two groups of condenser sections C and C forming this stack, are joined in parallel between the conductor W and the metal box. Since both ends of the condenser stack are at the same electrical potential, they may be held together by any form of metal clamp, provided that the clamp is spaced sufficiently apart from the condenser stack to prevent spark-over occurring between the clamp and the condenser sections near the

centre of the stack to which the greatest potential difference exists. This alternative arrangement (Fig. 20), which is also illustrated in the patent specification above referred to, is with slight modifications used to-day in many forms of mica-dielectric condenser. In Fig. 21, the same two groups of condenser sections are shown at C_1 and C_2 , and the common high potential terminal connection made between these two groups is led out to any convenient form of terminal insulator. The two extremities of the condenser stack are clamped rigidly together between the clamping plates P_1 and P_2 which are maintained under pressure by

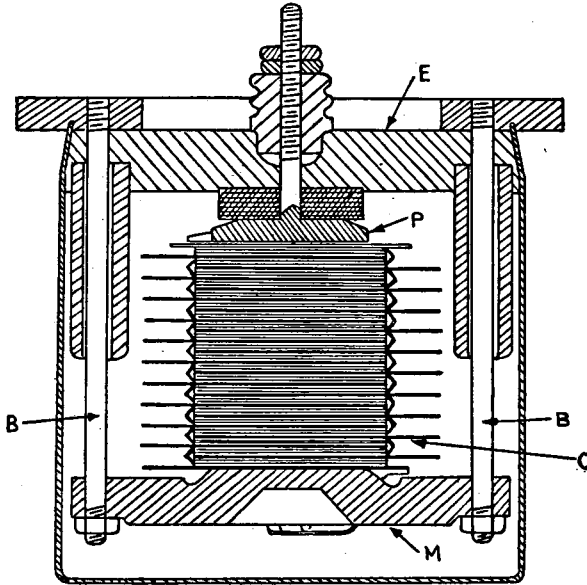


Fig. 19. Clamp with single insulated end for mica condenser.

means of the bolts BB and the end-plate P. A condenser unit constructed in this way forms a complete entity which is both electrically and mechanically rigid, and may be mounted inside a container of metal or any other material of any desired shape. The great importance of this construction is the absence of insulating material inside the condenser unit other than the condenser unit itself, so that the only auxiliary insulation becomes the terminal insulator on the condenser box.

When condensers are required of large size, suitable for use in large radio stations and for other purposes where they are called upon to operate at high voltages and frequently also to

carry large currents as well, the provision of a large number of independent metal clamps to contain the condenser elements would increase the difficulty of building such condensers. In such cases, a different type of construction, but one utilising the same principle, has been developed by the Dubilier Condenser Company

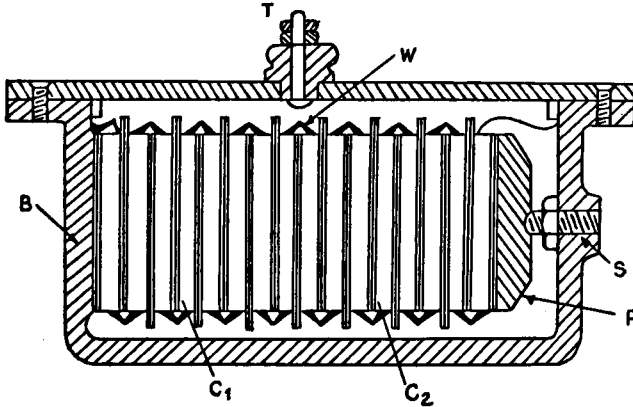


Fig. 20. Central terminal principle for condensers.

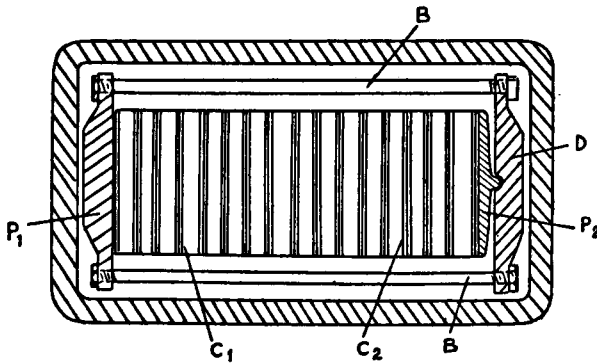


Fig. 21. Condenser clamp with central terminals.

and is known as the ring condenser construction. In Fig. 22, the essential features of this construction is illustrated. It consists of a metal ring which replaces the clamp for the condenser stack already described, and in this ring R are supported a number of stacks of condenser plates C_1, C_2, C_3 , etc., which may

be regarded as forming the arms of spokes of a wheel of which the ring R forms the rim. In Fig. 22, six such condenser arms are illustrated, each arm or stack being clamped between the ring R and a metal centre-piece B, to which is attached a tube or other conductor T, forming the high-potential terminal of the condenser ring. The six condenser arms or stacks thus serve, by the pressure exerted upon them, to hold the central block B in position, and to insulate the high-potential conductor at the same time. By supporting a number of such rings on metal brackets inside a tank, condensers of almost any size can be built up without the necessity for any internal insulation inside the tank other than the condenser dielectric, unless it is necessary that both terminals of the condenser should be insulated from the tank. Greater rigidity of construction is obtainable when one terminal can be connected

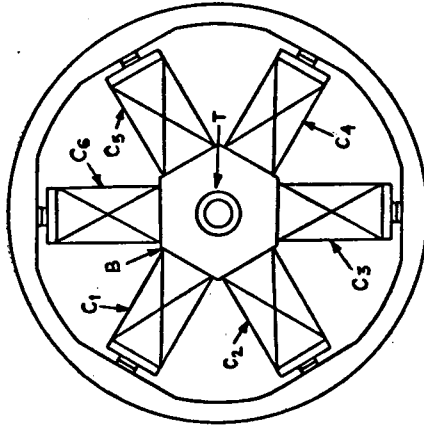


Fig. 22. Ring condenser insulation.

to the tank. A tank may contain a pile of six such rings arranged on top of each other and provided with a single terminal at the upper end, insulated by a special porcelain insulator. The high-potential terminal conductor runs right through from the top of the porcelain insulator through the centre of each of the six rings, thus connecting them all in parallel.

As a general rule, all the insulation arrangements which were developed primarily for spark transmitters proved unsatisfactory when continuous wave working is introduced, just as the earlier types of condenser construction gave excessive heating under the same conditions. As a matter of fact, condenser terminals which would stand up to as much as 40,000 volts, produced from a spark-radio transmitter, because hot and soon broke down when

subjected to only 6,000 volts of undamped radio-frequency energy. In the development of insulators to operate at high voltages, whether ordinary low-frequency alternating voltages, or radio-frequency voltages produced by a spark-radio transmitter, the tendency of design was merely to increase the physical dimensions of the insulator more or less in proportion to the increase in operating voltage. Such a method, however, is unsatisfactory for operation with C. W. radio-frequency voltages, primarily on account of the large bulk of material which is subjected to severe electrical stress. Mere increase in the surface creepage distance of an insulator is of no value with C. W. voltages, if the bulk of the insulation material is subjected to concentrated electrical fields in its interior. The breakdown of such insulation is due almost entirely to excessive heating, rather than to sparking over its surface. This same energy loss in the insulating material is

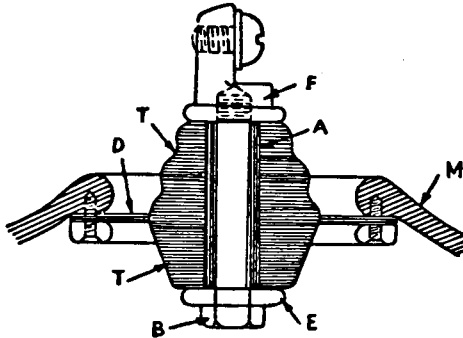


Fig. 23. Mica bushing.

likewise the cause of the failure of bakelite lids fitted to condenser boxes when used with continuous wave voltages, the excessive heating set up in the material usually producing blistering of its surface, in spite of comparatively large distances separating the terminal from the metal condenser case. It is on this account that metal heads for condenser boxes are usually more satisfactory with radio-frequency potentials, provided that a suitably shaped insulator is used. A marked advance in this direction was made in 1921 by the introduction of an *insulator constructed entirely of mica*.

The essential features of this insulator are illustrated in Fig. 23. In it the metal terminal bolt B, which it is desired to insulate from the metal lid M of the condenser box, is passed through an opening in that lid which is closed by a disc of mica washers D, which support the terminal bolt B in their centre. A layer of mica A is wrapped round the metal bolt, and on the

outside of this is arranged a pile of mica washers T, on both sides of the disc D. These washers are clamped together between the metal collars EF, which are compressed by the bolt B, so that all the washers are held tightly together and clamped on to the disc D. The edge of the hole in the metal lid M should be rounded so as to avoid excessive concentration of the electric field on any sharp edges. This type of terminal has proved a very useful one for operation at moderate radio-frequency voltages, but even with this arrangement there is a somewhat excessive concentration of the electric field on the laminae of the mica, and the direction of this field is in the planes of the laminae in which direction they are less suited to withstand the effects of such fields. In constructing these insulators, the outer surface of the mica washers was usually turned in a lathe and highly

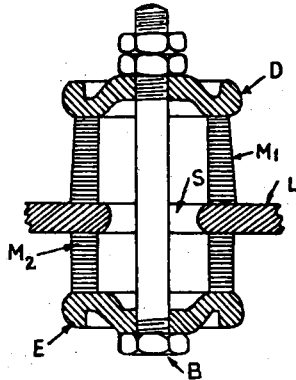


Fig. 24. Mica bushing special type.

polished, and the complete insulators were impregnated with wax to fill up any interstices between the mica laminae. Corrugation of the external surface of the mica in these insulators increased the resistance to surface flash-over.

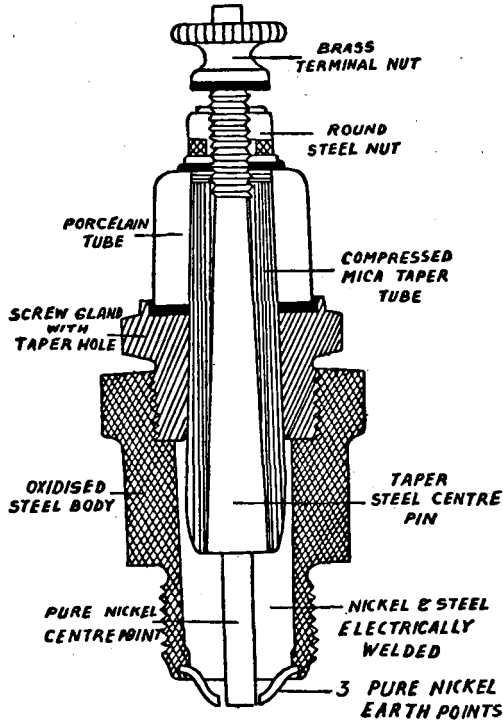
An improvement introduced by Coursey in 1923, using also mica as the insulating medium for the terminal conductor aimed at reducing the intensity of electric stress on the insulator, and at the same time disposing the direction of the electric field, so that it traversed the mica laminae as nearly as possible perpendicularly to their planes. At the same time, the point of greatest electrical stress in the space in the metal condenser lid through which the high-potential terminal conductor is passed, is filled with air insulation only. The general features of this insulator are set out in Fig. 24. In this drawing, the metal lid of the condenser box is indicated at L, and the terminal bolt B, intended

to provide the high-potential connection to the condenser inside the box, is passed through the open space S in the lid L. Attached to the terminal bolt are two metal clamping plates DE, which are held in position on the bolt B by screw-threaded nuts as indicated. Clamped between the plates D and E, and the lid L, are two piles of mica washers M_1 , M_2 , so that they provide a spacing for securing the terminal bolt B and the clamping plates D and E to the lid L, at the same time providing a good mechanical support for the terminal connections. The space S between the centre bolt B and the lid L is subjected to an electric field between the two metal parts, and the surfaces of these two metal parts are so rounded that this electric field is made as uniform as possible. The two plates D and E also act as electrostatic shields for the mica insulation M_1 , M_2 , and ensure that the electric field runs parallel to the surfaces of the solid insulating parts. With this arrangement, the electric field in the air space S surrounding the bolt B, and passing to the lid L, occupies air space only, and a practically uniform electric field passes from the discs D and E straight down to the lid L, through the mica, transversely to the planes of the laminae. These insulators have been found very useful on condensers operating on radio-frequency voltages, and in particular with undamped or continuous wave voltages, as the electrical losses in these insulators are much lower than in any that have previously been devised. The outer surface of the mica washers is turned up in a lathe to a high polish, so that dirt does not tend to stick on the surface, while at the same time the absence of corrugations on this surface prevents undue concentration of the electric field at such points which would tend to increase the dielectric losses. These insulators will operate for prolonged periods under radio-frequency stresses and remain quite cool, thus emphasizing the low figure to which the electrical losses have been reduced with this construction.

MICA FOR SPARKING PLUG INSULATION

Mica for sparking plug insulation has to withstand high voltages, high temperatures and a rapid rate of heating, and the structure of the built-up insulator has to be such as to avoid flaking and to resist mechanical shocks. Clear or slightly stained ruby muscovite is recommended for usual service, but where the highest temperatures have to be encountered, electrical and mechanical characteristics may have to give way slightly to the superior heat-resisting qualities of phlogopite (amber). Fig. 25 shows a section of a Lodge Sparking Plug insulated with mica, and reference to this will make the method of construction clear. In other constructions the insulator is made up of mica washers; mounted on the central stem which has first been wrapped with thin mica splittings (from $\frac{1}{2}$ to 1 mil thick). The mica washers near the middle of the insulator are larger than the others, and

thus form a shoulder that can be clamped between the gland nut and the shell body. These washers function purely mechanically, and are compressed into a compact gas and oil-tight hole by the tension of the central stem, which is constructed like a bolt with the clamping nut at the top. The wrapped insulation around the



No. 25. Lodge sparking plug.

stem takes care of the electrical stress. Mica insulation is used in some of the very best sparking plugs employed in the worst conditions of service, *e.g.*, in aeroplane and racing engines. It is not deteriorated by the engine combustion gases, and is less liable to mechanical fracture than porcelain or steatite. The insulation resistance of mica plugs is sustained at higher temperatures than in the case of porcelain or steatite plugs, and this is shown in Fig. 17, the curves of which indicate the variation of insulation resistance, at 500 volts, with temperature.

Tendency to blister and disintegrate is overcome by keeping the laminations under mechanical pressure, but even if a mica

flake should become detached and fall into the combustion chamber, it would do no damage. The access of oil and dirt between the laminae must, of course, be prevented, because these deposits would quickly carbonise and permit the ignition current to leak away to earth.

The relatively poor heat conductivity of mica necessitates the devotion of careful attention to the cooling of the electrodes of mica-insulated sparking plugs.

MICA FOR INSULATING WASHERS

Round or rectangular mica washers with circular or rectangular holes for general electrical purposes are produced in considerable quantities and in all sizes up to a maximum of 6 inches outside diameter and 2 inches thick. It is, however, naturally cheapest and most usual to make washers above, say, 2 inches diameter from micanite. Mica washers are ordinarily made from pure mica plates bonded together with shellac under pressure and heat. Washers in natural block mica are also produced up to about 0.05 inch thick, and for this purpose "twinned" micas, which do not readily split, are quite acceptable.

Summary of uses of micas

We summarise below recommendations as to the pure micas suitable for various purposes.

Summary of pure micas used for various purposes.

Use.	Kind of mica.
Small commutator segments :	
Undercut .. ..	.. Any high-grade mica.
Flush .. ..	.. Amber, silver amber, soft white.
Condensers .. ..	.. Ruby, spotted or amber (ruby for highest mechanical and electrical properties, and amber for highest heat resistance).
Sparking plugs .. ..	.. Ruby, clear or stained.
Washers, etc. .. ..	.. Green, spotted, etc.

For other uses of mica see pages 208-209.

Notes on the application of mica products for electrical purposes*

For many insulation purposes mica splittings are built up into a variety of composite forms, and, as pointed out in the previous pages, this is the natural result of the fact that pieces of commercial mica are too small in area to be used for insulating such things as long conductors, large commutators, bars, sliprings,

*This portion forms practically a part of Chapter XII.

etc. Pieces of mica up to 18 inches long, or even longer, can be obtained, but they are rare and too expensive to be used in ordinary engineering practice. The thinness of mica splittings, their flatness and flexibility are features that adapt the mineral to the ready formation of laminated sheets of insulation, in which the flakes are bonded together with suitable adhesives, the structure being built up with, or without, sheet fibrous backing.

Hard micanite plate.—This material is principally used for commutator segments, but it also finds application to field-pool insulation, insulating barriers, small terminal boards, etc.

Commutator segment micanite, used for insulating the bars of commutators too large to employ pure mica, is built up from muscovite (Indian) or phlogopite (Canadian or Madagascar amber) mica splittings. The former, which is cheaper, must not be left flush with the commutator surface, but the latter being softer need not be undercut. Spotted or stained mica may be used for most purposes; the size of splittings generally employed is No. 6 and the usual bond is high-grade shellac. The plates have to be heavily pressed in the course of manufacture, and the percentage of bond by weight is reduced to the absolute minimum. Three per cent. of bond may be regarded as the maximum permissible, and less than this is preferable, always, of course, providing that the bonding of the splittings is adequate to avoid individual flakes working loose in the various manufacturing processes and in service. Some concerns use segment micanite with an outer coating of thin paper, and this is an expedient to avoid flaking in the course of storage and handling sheets built with the minimum of bond.

Micanite commutator segments are commonly 0.02 to 0.04 inch thick, are produced to 0.002 inch limits of thickness, and 0.001 can be worked to if this accuracy is specially required. Regularity of wear is ensured by thoroughly mixing the splittings prior to manufacture, and thus uniformity of hardness is readily obtained with micanite, whereas pure mica segments require very careful selection, in order to approach the same condition.

The softening point should not be below 150°C. if "oozing" in service is to be avoided, and this feature is dependent on the characteristics and proportion of the bond present.

Hard micanite board for general purposes other than commutator segments is usually made with rather a high percentage of adhesive, say, 5 per cent., and this is the strongest of all the micanite products.

Moulding micanite.—Moulding micanite, although hard and rigid when cold, differs from segment micanite in that it contains sufficient adhesive (from 10 to 20 per cent.) to ensure that when warmed on a steam table at 100°C. to 120°C., it becomes soft and flexible, the splittings bending and slipping over each other, so that

various shapes can be moulded in hot moulds or the material may be wrapped around mandrels or conductors, rigidity ensuing on cooling.

Usually thin No. 5 or No. 6 muscovite mica splittings are employed for making moulding micanite, the sheets are not so thoroughly consolidated by pressing as in the case of segment micanite, and the amount of adhesive left, after the final moulding operation, is commonly of the order of 10 or 12 per cent. The micanite plates must also be thin, and in this connection it may be mentioned that moulding micanite is obtainable in thicknesses varying from 5 mils to $\frac{1}{4}$ inch.

The principal uses of moulding micanite are for commutator cones, large commutator "V" rings, slot liners, troughs, tubes and certain insulating wrappings.

Micafolium is really a composite moulding micanite. It was first developed for application on the Haefely wrapping machine, but the name is now applied generally to a wrapping material manufactured in continuous lengths, and consisting of a thin layer of flexible splittings pasted with shellac on a paper backing. Sufficient adhesive is provided to ensure ease of moulding into position under heat and pressure. The mica and paper are balanced so as to provide the highest possible proportion of the former, and it is general practice to use one to three layers of thin No. 5 muscovite mica splittings.

The use of micafolium.—Micafolium is extensively used for insulating conductors, coils, shafts, etc., and is always applied by a hot ironing process. The straight portions of conductors, coils, shafts, etc., are wrapped with micafolium on a hot table; they are then mounted in the wrapping machine and electrically heated "flappers" or irons rotate around the job and gradually iron the insulation into a compact and uniform coating, with a smooth and tough surface. Circular or rectangular sections are handled by this process, which yields very good results for high voltage jobs where the conditions do not require an insulation with a greater proportion of mica than 25 or 30 per cent. by volume.

Mica cambric and mica silk.—Laminated mica products for wrapping in the form of tape are used in considerable variety. We have already mentioned the permanently flexible mica and Japanese rice-paper tape, used for the insulation of stator coils in large high voltage machines; and mica tapes backed with cambric, long-cloth, gauze or silk are used where greater mechanical strength is required in the course of application, and a slightly lower mica content is permissible. Large (No. 4) thin splittings are often used with the silk-backed tapes, and the flexibility of this material is very favourable to the attainment of solid wrappings on bends.

Summary of common characteristics of mica products.

	Hard micanite. plate.	Moulding micanite.	Flexible micanite	Micafolium.
Size of splitting ..	No. 5 or No. 6	No. 5 or No. 6	No. 5	No. 5
Adhesive ..	Shellac or glyptal	Glyptal	Gums or bitumens	Shellac
Percentage of adhesive ..	3 to 5	10 to 20	7 to 10	7 to 10
Backing ..	..	..	Japanese rice paper, silk, etc.	Kraft paper.
Softening tempera- ture	150° to 170°C.	75° to 120°C.	Soft cold	75° to 120°C.
Moulding tempera- ture .. ..	..	120°C.	..	120°C.
Density ..	2.3	2.0	2.1	1.9
Electric strength (0.040 inch thick) average V/mil ..	870	800	920	680

Heat-resisting micanite.—The capacity of micanite to resist heat depends mainly on the character of the adhesive used, and for heating devices such as electric water-heaters, flat irons, etc., it was formerly the practice to use micanite bonded with inorganic binders such as sodium silicate. This binder is not altogether satisfactory, however, because when dehydrated in service its bonding qualities are practically negligible, and in the intervals of service it is unduly hygroscopic. Synthetic binders of the phenol-formaldehyde class do not, as a general rule, satisfactorily bond mica, and, in any case, no organic binders function for any length of time at temperatures of, say, 400°C. or 500°C. For these temperatures the really satisfactory operation of micanite can only be ensured by keeping the insulation under rigid mechanical compression. This is usually readily effected in heating devices, and it maintains the flakes in their proper position even after the bond has disappeared by oozing, evaporation or oxidation.

Of course, it is best, where the expense can be faced, to use virgin mica for heating apparatus insulation, and this is dealt with in the preceding chapter. The writer's experience is that, where micanite has to be used, it is best to use large sound splittings, the absolute minimum of bond, and heavy pressing in the course of manufacture.

Glyptal appears to be the best bond so far available, because it does not soften and ooze, but becomes leathery at high temperatures, and, furthermore, does not leave the sticky or carbonaceous evaporation residues common with natural gums. The percentage of bond in the finished micanite should preferably not be greater than 3 per cent.

THE PERCENTAGE OF MICA IN MICA PRODUCTS

The British Engineering Standards Association designates various classes of insulations by letter, and class B includes mica products, the useful lives of which, under the stresses of service, depend on the proportion of mica present. It is very important to know the percentage of mica by volume in mica products, but percentages by weight, incidentally yielding higher figures, and being more easily determined, have often in the past sufficed.

The percentage mica contents (by weight and by volume) of many samples of various materials have been accurately ascertained, and average results are as follows :—

*The percentage of mica by weight and by volume
in various mica products.*

	Percentage of mica.	
	By weight.	By volume.
Hard micanite plate (segment micanite)	96	70
Moulding micanite	86	72
Micafolium (sheet)	52	25
Micafolium (wrapped up)	49	29
Flexible mica tape	73	36
Flexible mica tape (wrapped up)	64	43

PART VI

MARKETING OF MICA

Chapter XVI

THE TECHNIQUE OF MICA MARKETING

Marketing of a merchantable material in modern times does not simply mean the linking up of the buying and selling interests but it includes the creation of market as well. The people, ignorant of the use and advantages of certain commodities, are enlightened about the benefits and comforts to be derived from their use and thus the circle of users and buyers of the materials is enlarged through numerous agencies of publicity. The American technique of marketing has been brought up almost to a degree of perfection, serving to increase the production and sales by influencing the habits and tastes of the people and thus constantly expanding the sphere of consumption of the innumerable products and by-products of the modern scientific development and civilisation.

India offers a vast field for domestic marketing of Indian mica production, but it requires intensive industrial research, wide publicity and a thoroughly efficient manufacturing and marketing organisation. Channels of utilisation of mica have hitherto been very few and limited in India and that too mostly for a fraction of her sheet production.

The marketing of mica is a peculiarly complicated job owing to its great variety of types, properties, behaviour and commercial specifications. The factors determining the commercial value of this mineral include the varying degrees of colour, transparency, flexibility, elasticity, di-electric strength, heat resistance, basal cleavage as well as flawlessness and freedom from commercial defects, physical imperfections and foreign inclusions. This great complexity of gradings and classification of mica is indicated by the fact that the unmanufactured but dressed block mica alone can be sorted into more than 100 grades and qualities. The salesmanship or marketing of mica therefore requires a thorough acquaintance and expert knowledge of the different aspects of mica including the following :—

- (1) The commercial specifications, uses and applications of mica.
- (2) The names, addresses and *relative references* or reliability of the dealers, buyers or actual consumers of mica and mica products with the specifications of their individual requirements, *viz.*, qualities, sizes, thickness, etc.

- (3) The sources of production and references about the producers.
- (4) The trend and forecast of the international demand and supply of mica including the latest development or improvements in the technique of mica production, manufacture, utilisation and marketing.
- (5) The economic aspects of the mica mining, manufacture and marketing.
- (6) The chances of development of mica products manufacturing industry and domestic marketing of mica.

Consumption of sheet mica (including films and splittings) in India is confined mostly to the railways and large electrical and iron and steel manufacturing concerns, etc. Purchases for government stores, state railways, etc., are made by the Indian Stores Department by tenders, but the method of purchase and inspection as in vogue now appears to be far from satisfactory. The purchasing officers or passing inspectors are not well acquainted with the properties, specifications, relative testing methods, etc., of mica and the dealers in large cities like Calcutta and Bombay, who manage to secure the contracts generally, know very little themselves about the essential properties of their own stuff. The sellers, taking advantage of the ignorance or connivance of the buyers or their representatives, often manage to pass through goods, really inferior to or other than the exact specifications. Amongst the Indian mica men there are very few who are conversant with the relative properties, industrial uses or the best available market for the merchandise they produce or handle. The real consumers of mica on the other hand, excepting a few large electrical manufacturers, are also not aware of the cheapest or reliable source of production of their particular requirements. Moreover the consumers prefer on principle to buy their requirements in exact specifications so that they may not have left on hand an excessive accumulation of waste or rejections. Mica consumers generally require one, two or several specified sizes of mica sheets and as such the trouble or function of dealing with any remnant stock or rejections is seldom welcome to them.

**MIDDLEMEN—PROMINENT IN DISTRIBUTION AND SERVE USEFUL
LINK IN THE TRADE**

For the above reason, the existence of a ring of dealers, or middlemen and manufacturers, serves an useful and indispensable link between the real producers and consumers of mica. These dealers are of two classes, namely, (i) those who simply buy and sell in the open market and (ii) those who buy mica in raw preparations, including *beema* or *undressed* in lump-lots, manufacture or work it up into finished forms and sell the

products to the electrical concerns and other buyers. In fact in America very little domestic mica passes directly from the miners or original producers to the actual users of mica, except in case of certain large electrical companies who own and work some of their own mines.

Mica brokers.—There is another class of intermediary interests in mica who carry on business as brokers in the large marketing centres of international mica trade, *viz.*, London, New York, Hamburg, Milan, etc. They keep themselves thoroughly acquainted with the exact nature of requirements and specifications of consumers in different industrial centres as well as with the domestic and foreign sources of production of such specified requirements. Brokers generally transact business on behalf of the buyers and sellers and seldom purchase or hold stocks on their own account. 2 to 2½ per cent. is the usual rate of brokerage and commission charged for the services rendered, exclusive of the incidentals. Some sellers consign goods in care of banks, to be sold by the brokers on agreed prices, the items of the consignment being usually subject to the broker's recommendation about the marketability and selling price limits in the prevailing market. Some of these brokers in London are well known* with a long-established reputation and they occasionally import mica for stock sale in the open market at a fair margin of profit.

The intermediary dealers and manufacturers in India, however, lack expert knowledge in which those in London or New York very efficiently specialise. The technique or value of publicity, so essential in modern business transactions, is almost unknown to them.

Warehouses or wharfingers in London.—There are reliable warehouse keepers whose charges are reasonable. Of these Smith's Warehouse, Savage Mann & Rowe Ltd., and World Transport Ltd. enjoy good reputation of reliability.

Large and small buyers or consumers.—Buyers like General Electric Co., Westinghouse, Jaroslaw's, Siemens, A. E. G., Sciama, Monti and Martini, Micanite and Insulators Co., Ltd., etc., have formed direct contact with the producers or suppliers at the sources of production and have their purchasing arrangements in London, but the small buyers or consumers have inevitably to purchase their needs from the brokers, dealers or intermediary manufacturers near at home. *Mere circularising blank offers and samples* by small mica dealers to all and sundry in the trade, most of whom are unreliable and often unscrupulous, does more harm than good to the commerce as a

* Hart Maylend & Co.
Hale & Son.
Keymer Son & Co., Ltd.

Startin & Co.
Chalmers & Guthrie, Ltd.

whole, besides unduly influencing the level of prices to uneconomic limits and causing deterioration of qualities and grading. It very often entangles innocent buyers and sellers into endless undesirable complications.

Terms of business.—The pound avoirdupois is the common unit of weight on which the price of sheet mica and splittings is based. The finished condenser films, radio sheets or diaphragm washers or disc mica are usually sold by the thousand. Waste, scrap or ground mica is sold in tons. In several countries, like France, Madagascar, U. S. S. R., etc., metric weights form the basis. The *maund* (equivalent to about 82 5/7 lb.) is the universal unit in India, except in case of foreign transactions in which mica is quoted "per pound" or "per cwt.". In mica there is sometimes just a slight or nominal difference between two sub-qualities or grades, which very often leads to a great deal of confusion and speculation.

Payment.—Spot cash or 30 days' time for payment at the most is the general custom in India. In New York and London the terms of payment consist of spot cash for imported stuff when purchased at warehouses and 30 days' net for domestic productions in America with 2 per cent. discount for payment in 10 days.

As regards foreign purchases, it is usual to open letters of credit for full value of invoice against complete set of shipping documents. This of course depends on the extent of reliability and market reputation of the suppliers and buyers. 30 to 90 days' D/P drafts or payment in full after inspection on arrival at destination are also prevalent in certain cases. Letter of credit for full value is usual for all Japanese purchases.

The New York manufacturers and buyers of mica enjoy the facility of leaving their purchased goods in bonded warehouses without being obliged to pay duty and are permitted to draw on the supply and pay duty according to their current needs.

Storage and clearance charges on imported mica are very low in New York and London, an idea of which may be gathered from the information given in Appendix II.

Packing.—Mica should be packed, as far as possible, in uniform weights or number of sheets, as the case may be. This facilitates checking or handling of mica for all concerned, from the original packing at the manufacturer's packing shed to the place of application in the user's workshop. Block mica is usually packed at 56, 100 or 112 lb. a case, larger sizes such as No. 2 and up being packed in lesser weights. Splittings and films are packed at 100, 112 or 125 lb. a case. Loose splittings are packed even at 150 lb. Bookform splittings are packed in compartments, in 1 to 5-lb. packets, so as to prevent the least damage to the films in course of transit or handling.

Certain dealers, however, wilfully prefer to follow the random weights, so that they may pack excessive or short weight of the net content of the cases, as their interests warrant. For instance, if an order is booked for certain number of cases at profitable prices, they pack excessive weights from 125 to 150 lb. even at random, or where possible they curtail the net contents in weight, keeping up the number of packages in order, if the price of the engagement appears to be less remunerative or unfavourable in the prevailing market or for shortage of stocks.

Marking.—Each case should be stencilled outside with its gross, tare and net weights, with indicative marks of quality and grading of the contents or brands. Some buyers or sellers put code words to evade detection of contents or sources by outsiders and rivals in trade.

Mica manufacturing and marketing centres.—In India, as already stated, Calcutta, Kodarma, Giridih and Nellore are the principal mica manufacturing and marketing centres, Calcutta being the largest centre of export. Other important centres are :—

In the United Kingdom : London.

In the United States : The large industrial cities, east of the Mississippi river, *viz.*, New York, Chicago, Schenectady, Cleveland, Pittsburg and Boston, are the chief centres of consumption. Chief domestic marketing centres are Asheville and Spruce Pine in North Carolina and Keene in New Hampshire. Chief markets for imported mica are New York City, Boston and Chicago.

In Brazil : Rio de Janeiro.

In Argentina : Buenos Aires.

In South Africa : Johannesburg and Cape Town.

In Madagascar : Fort Dauphin; Paris is the principal distributing centre of Madagascar mica.

In Rhodesia : Darwin is the chief distributing centre.

In Canada : Ottawa, Hull and Kingston are the three important distributing centres with large city shops.

Of the above, Calcutta and London are practically the principal world markets for mica, the former as sales centre in the country of origin and the latter as the world centre of distribution of Indian and African mica.

London's importance in the international mica trade.—London was, for a long time, the world's only centre of marketing mica from different producing countries, distributing approximately 75 to 80 per cent. of the world's total production, excluding the domestic output of U. S. A. Up to the outbreak of the Great War (1914), mica used to be consigned to London from most of the producing countries, *viz.*, India, Africa, Madagascar, Canada, Brazil, Argentina, etc., and sold at monthly or periodical auction sales, which the buyers or their representatives from all

the consuming countries attended. Bids were offered for the available supply after inspection. As an open market free from custom restrictions, London offered excellent international marketing facilities and reshipments of surplus or unsaleable stocks could be readily made to the American and Continental ports at little extra cost.

This importance of London, however, declined* with the termination of the Great War, and direct contact commenced to be established between U. S. A., the largest world consumer, and the principal producing countries, *viz.*, India, Madagascar, Canada, South Africa, etc. *Of London's annual imports of mica, 75 to 80 per cent. represent mica from India; approximately 1,000 tons are used for domestic consumption and the balance goes out as re-exports to the American and continental ports.*

Output sales.—In certain producing areas, *viz.*, Bihar and Madras in India and North Carolina in U. S. A., some producers prefer to sell their output in *entire lots*, without any remnant left over on hand. These lots generally unassorted (often graded but mixed quality lots) are bought by dealers or manufacturers at lump and very attractive prices.

PRICE OF MICA

The price of mica depends on several factors of which quality such as the varying degrees of clearness, flawlessness and freedom from commercial defects, etc., and size or dimension of the usable sheets obtainable from each individual piece are of prime importance. The other factors, which are also sometimes of vital significance, include the following :—

- (i) Over-production or over-stocking.
- (ii) Shortage or scarcity.
- (iii) Excess or paucity of demand.
- (iv) Indiscriminate price-cutting.

Mica is chiefly consumed by the electrical and building industries and the demand of mica as such, in peace years, depends on the conditions of prosperity or slump in these trades.

A study of the approximate levels of prices, prevailing in India, the United States and London, would give a fair idea of the trend of fluctuation of prices in the international mica trade. The prices given in the appendix, except those of the United States as published by the Bureau of Mines, are based on the author's personal experience in the trade and are

* In a letter, H/Lv., dated 9th February, 1931, Messrs. Jaroslaw's wrote to the author as follows :—

"The most characteristic change as regards the marketing of mica after the war is the fact that the London market is no longer of that importance as before the war. India exports more and more direct to the largest consumers of mica like America and Germany."

approximate. In the absence of a statutory standardisation of the preparation and classification of mica, it is often impossible to judge* the price of a particular grade or quality "as specified", without examining its representative sample, as two miners' or sellers' standards seldom correspond. According to the individual methods of preparation and grading, the price of a particular lot greatly differs from that of the other, though bearing an identical designation. Prices of thoroughly reliable miners or sellers are always higher than those of the usual market averages. Moreover the price of a particular grade or quality sometimes abnormally fluctuates even over or below the next superior one, due to its scarcity or surplus availability in the market, or sometimes even a large order or prospective enquiry for a particular classification from abroad pumps up the price in the local market.

Prices of cut electrical mica sheets, as sold in America and elsewhere, are specially high and the sizes are too many to mention here. The "per lb." New York or Boston price varies from \$3.00 to \$4.00 for 1 by 3 inches sheets to \$40.00 to \$45.00 for 8 by 10 inches sheets, if not still more.

* See pp. 103—104.

Chapter XVII

THE INTERNATIONAL MICA TRADE : WORLD DEMAND AND SUPPLY OF MICA*

In a nation's full growth and development in this age of electricity, maintenance of regular and adequate supply of mica has become a problem of great national concern. The United States, as the most advanced country in electrical science and development, is the largest consumer of mica in the world, Germany following next in order of importance; Great Britain, Japan, France and Italy are also moving ahead in the matter of electrification on a national scale and in the manufacture of electrical machinery and accessories†. Indeed to gauge a nation's advance in electrical science and industry, consumption of mica truly serves as a good index. The prospect of increasingly larger consumption of mica is better than that of other similar materials, owing to the wider use of electricity all over the world including the programme of farm and home electrification on a mass scale that is being sponsored in many advanced countries. Besides, in times of war, mica derives additional strategic importance. The great improvement in the demand of mica in 1936 and 1937 was world-wide, on account of the general industrial recovery and heavy consumption in the manufacture of munition materials and armaments.

Mica in suitable quality, size and quantity for proper industrial application as sheets occurs only in certain countries, of which approximately 75 to 80 per cent. form the strategic assets of the British Commonwealth, India being responsible for almost the whole of it. Muscovite ruby being the most efficient electric insulator and India its largest producer in sheets, she has become the principal world factor of strategic significance in international mica trade, particularly for supply in war times. During the Great War, the ensuring of supply of mica to the allied nations was one of the important war activities of the British Ministry of Munitions.

* Published in the *Financial Times*, January 1939.

† The account so far received of the situation in U. S. S. R. is encouraging but details are lacking.

RESOURCES IN MICA OF THE DIFFERENT POWERS

Great Britain and Russia are practically the two countries possessing adequate reserves of sheet mica deposits. The United States, though the largest producer of muscovite in tonnage, depends on international supply of sheet mica especially from India. During the war period (1914-18) the production of mica in the United States remained practically constant, despite the intensified mining and prospecting activities and greatly increased prices*. Mr. Brooks Emeny† gives the following estimate of the apparent consumption and requirements of mica of the different great powers :—

(Average of 1925-29; in short tons.)

	Mine's pro- duction.	Imports.	Exports.	Apparent consump- tion.	Production as per cent. of ap- parent consump- tion.
U. S. (Sheet) ..	1,839	5,202	nil	7,041	26·12
(Scrap and ground)	16,552	5,260	3,557	18,354	90·73
Germany ..	nil	2,204	132	2,072	0·00
Great Britain ..	nil	3,651	31	3,620*	0·00
France ..	nil	2,300	921	1,380	0·00
Russia (1929-32)	3,541	60	137	3,464	102·22
Italy ..	nil	302	29	273	0·00
Japan ..	1,678	nil (?)	nil	1,678	100·00(?)

*The annual requirement of Great Britain is usually near about 1,000 tons and with an output of over 4,000 tons in India, stocks to tide over an emergency might possibly be accumulated.—Sir Thomas Holland's Mineral Sanctions, as an aid to International Security, 1935.

In the above estimate Japan is taken to be 100 per cent. self-sufficient, having not to depend on imports, but the statistics of imports into Japan, particularly in recent years (1935-38), will not bear it out. The annual world production of mica has increased from about 3,000 tons in 1905 to about 50,000 tons in 1937, the production of waste and scrap having surprisingly

* Industrial Minerals and Rocks, N. Y., p. 456.

† Strategy of Raw Materials, N. Y., 1935.

increased in the United States since 1935. No reliable accurate figures of production and disposal are separately available for scrap and sheets, except in case of the United States and Canada.

Sheet mica.—The world production of sheet mica has come up approximately to about 16,500 metric tons in 1937, India alone being responsible for about 15,000 tons, *i.e.*, about 92 per cent.

Production of sheets in the United States (excluding splittings) during the period of 10 years (1928–37) ranged between a peak of 1,018 short tons in 1929 (against the next highest record of 1,238 tons in 1910) valued at \$286,321 to a low of 169 short tons in 1932 valued at \$45,882, the annual average aggregating to about 570 short tons. Even in 1937, it has not exceeded 847 short tons against 659 tons in 1936. The United States imports annually to the tune of 400 short tons of sheet (block) mica, calculated for this 10-year period.

Splittings.—Domestic production of splittings in the United States scarcely exceeds 5 per cent. of its annual requirement and as such it may be estimated to be about 50 short tons. The average annual import* of splittings, based on 1928–37 period, comes to about 1,600 short tons with a peak of 3,966 short tons in 1937, which is an all-time record, and a low of 472 short tons in 1932. India has furnished about 1,000 to 1,500 short tons annually during this period, with 3,452 tons in 1937. The United States' consumption of splittings in 1937 has established an unparalleled record with 4,347,435 lb. against 3,518,058 lb. in 1936, of which about 85 per cent. represent Indian muscovite splittings†.

Scrap mica.—The consumption of scrap and reclaimed mica in the United States has enormously increased, as will appear from the data given in the table of the world production of mica. The output of the United States, Canada and South Africa in 1937 amounted approximately to about 25,000 tons. The figures of production in U. S. S. R., Great Britain (mica clay) and Japan may be conservatively estimated annually at 12,000 to 15,000 metric tons. Of the total production of about 40,000 tons in 1937, the United States alone has consumed over 32,000 tons, importing 6,723 tons from abroad in addition to the domestic production of 26,043 tons. Between 1926 to 1934, the annual consumption of scrap in the United States averaged at about

* The bulk of the splittings and films imported into the United States from the United Kingdom and the Continent, excluding France, consists mainly of muscovite mica of Indian origin.

† Mining Journal, London, 3rd September, 1938.

9,000 to 10,000 tons, but it has increased to an annual average of over 26,000 tons during 1935-37.

India has become an exporter of scrap mica recently, having shipped to the United States 1,612, 1,667, 2,708 and 4,718 short tons in 1934, 1935, 1936 and 1937 respectively.

THE STRATEGIC SITUATION OF THE GREAT POWERS IN RESPECT OF MICA RESOURCES

Great Britain.—She produces no mica herself but controls about 75 per cent. of the world's sheet mica output in her possessions including India, Canada, Union of South Africa, Tanganyika, Rhodesia and Ceylon. In the event of war, Britain will have ample supplies from India and other potential colonial reserves. Her annual domestic requirement is about 1,000 tons against an average annual production of 4,000 to 14,000 tons in India alone.

United States.—In sheet mica, the United States produces annually an average of 500 short tons against an annual apparent consumption of about 6,000 to 7,000 short tons. In case of an eventuality of a prolonged war and interruption of regular supply from India, the United States will have to find fresh sources of production or supply within the realm of her political influence. Mr. Brooks Emeny, on the authority of Mr. Horton of the U. S. Bureau of Mines, remarks that the United States can be self-sufficient by increased production and adequate supplies, but this appears to be an optimistic view. She would require large supplies of sheet mica from India, Canada and Madagascar besides the available supplies from the Central and South American countries.

Germany.—There is no production of sheet mica within the German territory, even taking the recent annexations of Austria and Czechoslovakian provinces. Lithia mica is produced in small quantities in these countries, which is of commercial worth just as a source of lithium content bearing no value as sheet mica.

France.—Apparent consumption is about 1,380 tons against which she gets about 250 to 300 tons from her colonial sources in Madagascar (average of 1930-34). Mr. Emeny, in his "Strategy of Raw Materials", writes that France can command, in case of emergency, up to 75 per cent. of her requirement by increased production in the colonies or potential production on the basis of known reserves.

Italy.—Entirely dependent on imports; occupation of Abyssinia provides Italy with a probable source of mica deposit, but its economic importance as a sheet mica reserve is yet unknown.

Italy will have to depend on imports of mica from foreign countries.

Russia.—Entirely self-sufficient; she is not expected to have a surplus of sheet for exports, unless of course the ever-expanding industrial activities in the country receive a set-back, resulting in diminution of domestic consumption of mica.

Japan.—Annual consumption in normal years is estimated at 1,700 tons and, except the production in Chosen (Korea), she has no other potential source in control so far known. Japan has therefore to depend on foreign imports. Though Mr. Emeny observes that Japan is normally self-sufficient, the author differs from this view. In view of the great expansion of her electrical industries and large manufacture of aerial armaments, Japan requires large foreign supply of sheet muscovite.

The following world estimate of production and consumption of *sheet mica*, including mica splittings, was given by Mr. Oliver Bowles* :—

(In short tons)

	Produced recently.	Date.	Normal consumption (1913)	Maximum exportable surplus.	Minimum necessary import.	Control of world production, per cent.
U. S. A. ..	500	**	2,500	..	2,000	11
British Empire ..	..	..	..	..	..	81
U. K. ..	nil	nil	1,000	..	1,000	..
India ..	3,000	***	..	3,000	..	..
Canada ..	500	1917	..	500	..	..
Central and South Africa ..	12½	1916	..	12½	..	..
Ceylon ..	20	1918	..	20	..	..
France ..	..	..	250	..	250	..
Italy ..	..	..	100	..	100	..
Brazil ..	125	1918	..	125	..	3
Argentina ..	75	1917	5	70	..	2
Guatemala ..	5	..	..	5	..	..
Norway ..	..	1917-18	..	..	..	..
Sweden ..	..	..	40	..	40	..
Germany ..	..	..	1,250	..	1,250	3(?)
Tanganyika ..	150	1913	..	150	..	..
World total	4,387½	..	5,150	..	..	100

** Average.

*** Pre-war average.

The above situation has very greatly changed in the post-war years, especially since 1935. Taking into account the productions of U. S. S. R. and England (mica clay), etc., the

* U. S. Bureau of Mines, Rep. Invest. Serial 2357, 1922, p. 8.

following represents the author's estimate of consumption of mica by the different countries :—

	Pre-war consumption*.	Consumption during the period of 1935-37 (metric tons).			
		Sheet mica.		Total mica, including waste.	
United States	48.6 %	4,000	22.2 %	22,000	44 %
United Kingdom	11.4 "	2,000	11.1 "	8,000(a)	16 "
Germany	22.9 "	2,000	11.1 "	2,500(b)	5 "
Russia	(?) "	3,500	19.4 "	3,500(c)	7 "
Japan	(?) "	2,000	11.1 "	2,500	5 "
France	2.9 "	1,500	8.0 "	1,750	3.5 "
Italy	1.4 "	1,000	5.6 "	1,000	2 "
India	11.4 "	400	2.2 "	500	1.0 "
Others	1.4 "	1,500	8.3 "	8,250	15.5 "
		17,900	100.0 "	50,000	100.0 "

* Estimate given by W. T. Schaller of the U. S. Bureau of Mines.

(a) Average consumption of mica clay in England taken at 6,000 tons annually.

(b) 500 tons taken as average annual production and consumption of lithia mica.

(c) Bulk of this production appears to be scrap mica, but no basis of a fair estimate is available.

India, the United States and the United Kingdom are the principal countries vitally interested in the international mica trade—the United States as the largest buyer, India as the largest producer and the United Kingdom as the biggest distributor or marketing centre of mica in the world. The United States alone practically takes up more than 50 to 65 per cent. of the world's exportable surplus production of mica over and above her domestic output. In the pre-war years, Canada and German East Africa (Tanganyika) were the third and fourth largest producers of mica, the United States and India scoring the first and second places between them. On the basis of tonnage production, *i.e.*, taking scrap and reclaimed mica into account, the United States stands first, but the position reverses between them if sheet is considered between the annual averages of 500 for the United States and 10,000 to 15,000 short tons for India. The relative importance of these two countries has continued to be the same even to date, but that of the other mica producing and consuming countries has changed considerably. In the matter of production, Madagascar has entered international trade since 1918 and she has already outstripped Canada in the supply of phlogopite mica, both sheet and splittings. Canada has practically slipped off from the foreground now, yielding place to this new rival, though a few years back she had the monopoly of the amber mica business. The Union of South Africa and Soviet

Russia are prospective formidable suppliers of the future, as it appears from the official reports of these two countries. The following is the order of importance of different countries as suppliers of mica :—

(For sheet mica only.)		(With waste and scrap.)
Pre-war.	Post-war.	Pre-war and post-war.
India.	India.	United States.
Canada.	Madagascar.	India.
United States.	United States.	Canada.
East Africa (Tanganyika).	Canada.	Union of South Africa.
Brazil.	Brazil.	Brazil.
Argentina.	Argentina.	Argentina.

The United States consumes all the domestic production herself and is besides the largest buyer in the international market. As producer and supplier, therefore, the United States is of no importance outside her own territory, but she exerts a great influence by regulating the extent of her requirements of mica from foreign countries. Russia has been omitted from the above list, as the details about the proportion of sheet and scrap out of the gross production, consumption and exports are not ascertainable. From a study of imports into the United States from Soviet Russia, we find the figure to represent almost entirely ground and scrap mica, the value of which is not of much significance. The following review appears in the *Mining Journal of London* (Part VII, dated 3rd September, 1938) :—

“Significant features of recent trend are much larger use of splittings, increased imports of scrap and a relative decline in the imports of sheet and of block mica that can be rifted into sheets. British India continues to supply about two-thirds of the imports of unmanufactured sheet mica and mica splittings and recently has begun also to supply substantial quantities of scrap for grinding in American mills. Madagascar ranks second having displaced Canada as the main source of supply of phlogopite splittings and likewise furnishing some muscovite. London is still an important mica market and a good deal of India mica, including manufacture, is shipped to the United States and some Madagascar mica is transhipped from France.”

Chapter XVIII

THE PRESENT AND FUTURE OUTLOOK OF THE INDIAN MICA INDUSTRY—A RETROSPECT

The Indian mica industry has hitherto entirely depended on foreign demand, there being no large outlet for the industrial employment of mica within the country. Domestic consumption has been officially computed at about 200 to 400 tons a year, which on an average annual production of 4,000 to 10,000 tons comes up to only 4 per cent.

STANDARDISED TRADING AND CO-OPERATIVE MARKETING.

The need for this has been discussed in pp. 103-104. So far as the factor of price is concerned, India loses annually a very large sum of money, owing to the absence of a proper organisation to deal with mica on a co-operative basis. Even in times of great world demand for the Indian quality of ruby muscovite mica, which has no rival to compete with, prices have not gone up as remuneratively as they should. In splittings, in which India enjoys a world monopoly, the price fetched in 1937 has proved on an average to be lower than that of the averages of 1929. If, in any instance, an improvement has been in evidence, the percentage of improvement is not comparable with the percentage of increase in the price of the United States domestic mica in the corresponding years which, in 1936-37, have exceeded the highest post-war rates of 1929 by over 50 to 75 per cent. That Indian mica should fetch such a low price in the face of an unprecedented demand is most deplorable and it is, in the author's opinion, due to the lack of a system of standardised trading and co-operative marketing, which alone can bring in the necessary remedy. Better standardised classification of mica by sizes and qualities tends always to stabilise the industry and this, coupled with the elimination of unfair competition through a scheme of central co-operative marketing organisation and control of production and supply according to the estimated demands, can ensure the stability of the industry as a whole. The following extracts are taken from the note on the marketing and utilisation of mica by Mr. G. V. Hobson* :—

“Some system of co-operative marketing by the producers, with local representatives in the larger consuming

* Bull. No. 40 of the Indian Industries and Labour, 1928, pp. 4-5.

countries, seems to the present writer to constitute the most feasible plan for the elimination of the wide margin between the producer's sale price and the consumer's purchase price. * * * The writer is aware that, so far as producers in India are concerned, a great change of heart would have to take place before such a scheme of co-operative marketing could be brought into being; the mutual distrust amongst the producers would have to give place to co-operative trust among all for the common good."

Mr. Hobson further observed, as a result of his personal investigations at the foreign marketing centres :—

"In the matter of delivery up to sample (in case of a large consuming American buyer), there is another undesirable practice detected by the firm mentioned. It being impossible to examine all mica before sending it to the workshop, it is customary to examine an off case here and there, as representative. One case was opened in which it was found that the mica of larger size than that ordered had been packed. This aroused suspicion and other cases of the consignment were therefore opened and some found to contain undersize mica. The shipper's explanation was that finding himself a little short of the required size of splittings, he had to use a certain proportion of undersized material and had included oversized mica to maintain the average. Examination of the total consignment, however, revealed the fact that the balance had not been evenly maintained but was much in favour of the shipper. Another instance illustrates the danger of employing, in western markets, business methods which are current in the East. An order for mica of a given size and quality was given and the Indian producer evidently felt that this was an indication that a slightly higher price could in fact have been squeezed out of the buyer in the first instance and he accordingly wrote and did not even cable to say that the price for the repeat order had to be a slightly higher figure. The company in question ignored such correspondence and placed the order elsewhere. The first exporter hearing of this again wrote to ask why he was not given a chance to see whether he could possibly fulfil the order at original price. These instances seem to show how certain producers spoil the markets by failure to maintain rigid adherence to the terms of their contract."

The following are the observations of certain foreign buyers on supplies by some Indian shippers :—

"We had decided to discontinue doing business with you. * * * If you permit us to make a comment, we must

say that there seems to be a lack of straight method of doing business so essential to succeed. * * * Remember to read or have read to you and explained to you all our instructions, every word of it. Do not use your imagination. Give us what we want *and not what you think is good for us.*"

"When we took a sample out of the cases at the dock, we were surprised, disgusted and angry. * * * Our experience with the Indian shippers has been so disgusting and exasperating that we have made up our mind to refuse to do business with any Indian shipper unless we could satisfy ourselves that the shipper is a high-class businessman both mentally and commercially. We do not feel like characterising your proceedings in this shipment because our words would have to be very severe, but we hope you understand the way we feel about it when we say that it has cost us money, time and efforts to arrange these shipments and then to find all at once that we may as well have written to the sea-gulls in the North Pole for all the good that our correspondence and our explanation, and the appeals we have made to you, could do, we assure you, has been of no avail."

The above affords the strongest urge for standardisation and enforcement of co-operative working plans in the mica industry by legislative enactments.

DOMESTIC UTILISATION OF MICA IN INDIA

To rid the Indian mica industry of its periodical stagnation or slump, extensive channels of utilisation of the country's mica resources have to be developed by persistent research and investigations of its potential possibilities. India should have an independent bureau of mines department modelled on similar bureaux in the United States and Canada, with a fully equipped research laboratory attached to it. The provinces of Madras and Bihar should work in close co-ordination so that the large mica reserves of these provinces may be exploited to the best advantage. Greater attention should be paid to increase domestic consumption of mica and develop national manufacturing industries, rather than only exporting the assets out of the country at low prices.

GOVERNMENT AND MICA INDUSTRY

In regard to the prospects of the mineral industry in India, mica in particular, I may quote the following observation of Sir Edwin Pascoe* :—

"India is unusually supplied with the munitions of war; she possesses most of the many constituent requisites in the

*Imperial Inst. Bull. No. 2, Vol. 29, 1931, on Mineral Wealth of India to its present and future development.

manufacture of all kinds of steel, petrol and coal as fuels for transport, oil for lubrication of vehicles and lead and nickel for bullets; saltpetre for gun powder; mica so much in request for the electrical parts of aeroplanes; tin for commissariat uses. The only important war materials she does not actually produce are sulphur and aluminium and these she potentially possesses in large quantities."

The mica content in its deposits is said to be more variable than that of any other known mineral and the element of uncertainty and speculation in it is a most important feature. The proportion of commercial sheet mica, out of the quantity handled in mining and preparation, forms only a small fraction (1/5,000 to 1/10,000 on the total rock-matter handled) and the proportion of large sheets is usually insignificant in quantity if not in value. Productive pegmatites may prove worthless in a few hours' working and immensely prospective "pockets" may carry no sheets worth exploiting at any moment of the operation. In metalliferous mining certain common indications or structural features may offer valuable, if not sure, guidance in prospecting or mining of the ore-bodies, *viz.*, gold, copper, lead, zinc, tin, etc., but in mica mining, chance or luck plays the supreme part. Successful exploitation of mica deposits, therefore, greatly depends on a high degree of technical skill and scientific management of the mines. Most of the mica miners in India either are unacquainted with or do not realise the great importance of the modern systems or suffer from chronic insufficiency of capital. Mining men should always be enterprising and resourceful with an enlightened outlook, but bulk of the Indian miners engaged in the mica line are generally fearful of the mining risks and long for "windfalls" without much effort or enterprise. This naturally results in unsystematic mining and a colossal economic loss to the country. An organised industry with a *co-operative marketing plan and standardisation* is the imperative need of the moment and this will not be possible in India without a firm official hand to control and consolidate all the divergent factors.

Some of the progressive countries are making tremendous advance in converting their mineral assets into national wealth. I take the liberty of quoting the following paragraph from the "Handbook for Prospectors" by M. W. von Bernewitz, to show how they are moving on :—

"In Australia direct aid is extended in the form of cash to be refunded and public treatment plants. During 1914, the States of Western Australia were assisting 2,000 men with supplies as food, tools, explosives, transportation and advice from visiting inspectors. In New Zealand, 400 men were given relief in the form of living wage."

The Government of India should seriously probe into the above problems and introduce suitable measures of legislation at

the earliest opportunity. If necessary the Government may also consider the amendment of the provisions of the existing Land Acquisition Act or Land Laws in mineral-industrial areas, in the light of the suggestion made on the subject of acquisition of lands for industrial purposes and in public interests, by Mr. Padshah in his learned dissenting minute to the Report of Indian Sugar Committee in 1920. In the opinion of Sir Thomas Holland*, the mining of certain minerals may be placed in the category of public utility services with or without the acquisition of mineral rights by the State. The Indian Industrial Commission received considerable evidence urging the advisability of state action in this direction but considered it impracticable then to propose more than acquisition of rights over minerals essential for national purposes.

The recommendations made in this handbook, for the stabilisation and advancement of the industry, may be briefly summarised as follows :—

- (i) Statutory standardisation of the methods of preparation, classification and marketing.
- (ii) Establishment of a co-operative marketing organisation or syndicate, similar to the Indian Sugar Syndicate.
- (iii) Establishment of a separate bureau of mines department with a research and experimental laboratory attached to it.
- (iv) Compulsory group management or ownership or large co-operative working organisations, commanding sufficient resources, working equipment and expert personnel for efficient production and marketing of mica and mica products.
- (v) Revision of the existing rules, laws and legislative provisions on the subject, particularly in respect of the (a) rents and royalties. The mining rules prevailing in the Union of South Africa would offer a helpful guidance. (b) Customs import and export classification of the different preparations of mica and mica products. (c) Rates of railway freight for different classes of mica and provision of economic means of transportation.

In the opinion of the author, a National Research and Development Corporation may take over the prospecting and exploitation of the mineral resources of the country in the best national interests, but it will be a long time yet to make such a scheme a practical proposition in India. Public utility and power services including power and mineral resources, transport, etc.,

* Proceedings of the Empire Min. and Met. Congress, 1928.

constitute vital factors of economic significance, in a comprehensive national planning.

In concluding this chapter, I would like to draw the attention of the authorities concerned to give the foregoing suggestions their careful consideration and take such effective steps as are deemed conducive to the conservation and economic utilisation of the mica resources of the country, in view of its providing a vital key* material for the development of the national electro-technical industries in general and its great international strategic importance in times of war.

** Sheet mica—more than a “key” commodity in United States.*

“Sheet mica is one of 23 commodities on the list of ‘Strategic’ materials, approved by the Army and Navy Munitions Board, U. S. A., 22nd March, 1938, and is the only non-metallic mineral on that list. To be thus classed as strategic, a material must be not only a ‘key’ commodity but one of which the domestic supply is (in U. S. A.) insufficient.”—U. S. Tariff Commission Report No. 130, 1938, Second Series, p. 1.

THE END.

APPENDIX I

CODE FOR MICA INDUSTRY IN THE UNITED STATES*.

A Code of Fair Competition for the mica industry was submitted and approved by the Administrator for the Industrial Recovery on 24th February, 1934. The Code consists of 10 articles, which are summarised as follows :—

Article I—states the purposes of the Act.

Article II—gives definitions and sets forth the following five divisions of the mica industry :—

- (a) The mining division.
- (b) The importing division.
- (c) The sheet-mica division.
- (d) The wet-ground mica division,
- (e) The dry-ground mica division, including grinders of shop or scrap mica, grinders of mica schist and those recovering mica from clay washing.

The manufacture of plate and other built-up mica is operating under the Code of Fair Competition for the electrical manufacturing industry.

Article III—deals with the working hours and comprises of six sections, summarised as follows :—

- (i) No employee shall work more than 40 hours a week nor more than 8 hours a day, provided however that for six weeks in any six-month period, an employee may work 48 hours a week.
- (ii) Outside salesman, executive or manager earning not less than \$35.00 a week is not restricted as to working hours. Emergency maintenance or repair works are limited to 48 hours per week.
- (iii) Engineers, firemen and cleaners may work 48 hours a week and not over 56 hours during any six weeks of any 6-month period.
- (iv) Watchmen may work 54 hours a week.
- (v) No employer shall permit any employee to work for a time which if totalled with working time expended with another employer in the industry would exceed the maximum allowed by the Code.
- (vi) No employee shall work more than 6 days in any seven-day period.

Article IV—this article specifies the minimum wages shown in the following table in the different divisions of the industry in two geographical sections, which embraces Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee and Virginia, and the

* Mica in 1934, U. S. Bureau of Mines Year Book.

Northern Section which includes all other states and territories of the United States :—

		Minimum hourly wages in the mica industry.	
		Southern section.	Northern section.
		\$	\$
1. Mining division	..	0·25	0·30
2. Importing division	..	0·30	0·35
3. Sheet-mica division	..	0·25	0·30
4. Wet-ground mica division—			
in grinding operations	..	0·30	0·35
in other operations	..	0·25	0·30
5. Dry-ground division—			
in grinding operations	..	0·275	0·325
in other operations	..	0·25	0·30

Article V—states that no person under 16 years of age shall be employed in the industry nor any person under 18 years of age in work which may be hazardous or dangerous to health.

Article VI—establishes a national code authority, consisting of the chairman of the division code authorities and not more than three other members appointed by the Administrator but without vote. It also defines the duties and powers of the code authority.

Article VII—establishes a divisional code authority of five members in each division of the industry and specifies how the members shall be elected and their duties and powers under the general supervision of the national code authority.

Article VIII—outlines a code of definite competitive practices and provides for the drafting of rules and regulations by the divisional code authority to make the code effective.

Article IX—provides for enforcement of the provisions of the code with the arbitration of the disputes within the industry.

Article X—guarantees that the employees have the right to organise and to bargain collectively through their representatives and that they shall not be required to join any company union. It also provides for cancellation or modification of the code by the president and allots one vote in the affairs of the mica industry to each corporation, partnership or individual who is a member of the code and provides that it becomes effective the second Monday after its approval by the president.

The writers of the chapters on mica in the *Minerals Year Book* observed on the effects of the code over the mica industry as follows :—

“It is difficult to predict the total economic effects of the code, but the short-time results will doubtless be increased wages, shorter hours and a probable increase in employment. Hearings on the code brought out that mica miners received 10 cents an hour and worked 50 to 60 hours a week, compared with the established 25 cents hourly wages and 40-hour week under the code.”

APPENDIX II.

APPROXIMATE CHARGES OF WAREHOUSING AND CLEARANCES IN
IMPORTANT FOREIGN CENTRES.*

(a) WAREHOUSE CHARGES ON MICA IN LONDON.

	1†	2†	3†
1. Landing (receiving ex steamer, London; landing and housing) ..	16s. per ton, min.; 5 tons per shipment.	1s. 1½d. per cwt.	15s. per ton.
2. Customs clearance ..	1s. 9d. per package.		
3. Weighing at landing or delivery.	2s. 6d. per ton.		
4. Port dues ..	1s. per ton.	1s. per ton.	1s. per ton.
5. Rent per week ..	9d. per ton.	11d. per ton.	9d. per ton.
6. Sampling (opening, nailing and closing).	1s. 6d.	1s. 10d. per case.	1s. 6d. per case.
Sampling while open ..	9d. per case	8d. per case.	
Sampling opening and delivery within city limits.	2s. 6d. per sample.		
7. Inspection ..		1s. 10d. to 2s. 6d.	1s.
Where contents removed from case and re-placed.			2s. 6d.
8. Port marking, etc., minimum 6d.	6d.	6d. per score of letters.	3d. per score of 20 letters less 10d.
9. Delivery to van ..		7d.	..
10. Warrant stamps, if warrants are issued.		3d. per warrant.	6d. per warrant.
11. Dock dues ..		none.	none.
12. Customs entry ..	5s.	"	5s. per consignment.
13. Cartage ..			none.
14. Fire ..		6" per cent.	5 per cent.

(b) STORING OF MICA IN NEW YORK.

Merchandise can be stored under bond, without the payment of duty, for three years, and then duty paid only on that part which is withdrawn and put into consumption.

The storage should be made in warehouses adjacent to the piers, to keep down delivery expenses and cheap rates of insurance should be tried for. The important storage companies are:—

- The New York Dock Co., Brooklyn, N. Y.
- The Bush Terminal Warehouse, Brooklyn, N. Y.
- The Ponch Terminal, Staten Island.

* Some of the rates shown are not current as they are subject to variation from time to time, but they would give an average idea of the nature of charges incurred.

† 1, 2 and 3 represent the rates of three different wharfingers.

(d) MICA SHIPMENT LOCAL CHARGES AT ANTWERP.

1. Reception from steamer on quay—Fcs. 11 plus 2½ per 1,000 kilos.
2. Cartage from steamer to railway station or to warehouse—Fcs. 42.50 plus 2½ per cent. per 1,000 kilos.
Cartage from warehouse to railway station—Fcs. 42.50 plus 2½ per cent. per 100 kilos.
3. Warehouse rent—Fcs. 5 per 1,000 kilos and per month or part of month.
4. Customs clearance—These expenses depend upon the importance of the consignment with a minimum of fcs. 10.0 per sending.
5. Postage and petties—Fcs. 5, fcs. 7.50 or fcs. 10.0 per sending.
6. Watching expenses eventually payable to the import steamer.

APPENDIX III.

CURRENCIES, WEIGHTS AND MEASURES IN DIFFERENT COUNTRIES.

English and Metric equivalents.

1 pound (avoirdupois)*	= 16 oz. or 453.6 grammes.	1 inch = 25.40 mm.	1 foot = 30.48 cm.
100 lb. = 45.36 kilos.		1 yard = 91.44 cm.	
112 lb. = 50.80 kilos.		1 mile = (1,760 yds.) = 1609.35 cm.	
1 long or English ton	= 2,240 lb.	1 sq. inch = 6.4516 sq. cm.	
	= 1,016 kilos.	1 sq. foot = 0.0929 sq. metre.	
1 short ton	= 2,000 lb.	1 sq. yard = 0.6361 sq. metre.	
	= 907.2 kilos.	1 stone = 14 lb. = 6.3503 kilos.	
1 metric ton	= 1,000 kilos.		
	= 2,204.6 lb.	1 millimetre = 0.03937 inch.	
	= 0.9842 gross ton.	1 centimetre = 0.3937 inch.	
	= 1.1023 short tons.	1 meter = 39.37 inches	
1 kilos = 2.2046 lb.		= 3.2808 feet.	
100 kilos = 220.46 lb.		1 kilometre = 0.62137 miles.	
1 maund (i.e., Bengal maund)	= 82½ lb.	= 1,093.6 yards.	
		1 sq. mm. = 0.00155 sq. inch.	
1 quintal = 100 kilos = about 225 lb.	or 2.6 mds.	1 sq. cm. = 0.155 sq. inch.	
		1 sq. meter = 10.7639 sq. ft.	
		= 1.196 sq. yds.	

Inch.	mm.	mm.	Inch.
0.006	= 0.15	0.01	= 0.0003937
0.008	= 0.20	0.04	= 0.0015748
0.010	= 0.25	0.1	= 0.003937
0.015/16	= 0.40	0.5	= 0.0019685
0.020	= 0.50	4	= 0.15
0.024	= 0.60	25	= 1
0.028	= 0.70		
0.032	= 0.80		
0.036	= 0.90	550	= 39½
0.040	= 1.00	570	= 22½
0.056	= 1.40	1000	= 39½
0.060	= 1.50	1030	= 40½
0.080	= 2.00	1070	= 42
0.120	= 3.00		

* 1 pound troy (for gold, silver, jewellery, etc.) is equal to 12 oz. or 373.242 grammes.

CURRENCIES

Approximate equivalent based on exchange Re. 1 = 1s. 6d. sterling.

Country.	Coin.	Approximate.
United States	.. Dollar	= 4s. 1½d.
Argentina	.. } Argentine	= 19s. 10d.
	.. } Peso	= 4s.
Brazil	.. Milreis	= 2s. 3d.
Bolivia	.. Boliviano	= 2s.
Germany	.. Reich Mark	= 11½d. to 1s.
France and Suisse	.. Franc	= 9½d.
Italy	.. Lira	= 9½d.
Norway, Sweden and Denmark	.. Kroner	= 1s. 1½d.
Netherlands	.. Fulden (florin)	= 1s. 8d.
Belgium	.. Franc	= 9½d.
Austria	.. Kronen	= 10d.
Russia	.. Rouble	= 2s. 1½d.
Spain	.. Paseta	= 1s. 9½d.
Portugal	.. Escudo	= 4s.
Madagascar	.. ..	French currency
Rumania	.. Leu	= 9½d.
Japan	.. Yen	= 1s. 0¾d.

APPENDIX IV.

TARIFFS ON MICA.

United Kingdom.—Mica not mentioned in the tariff; presumably free.

Canada.—Mica is not specifically included in the Canadian Customs Tariff but comes under general item No. 711. See p. 146.

Belgium.—Mica crude in sheets, plates or rough mica—free. Mica in leaves, sheets or cut,

for electrical machinery—5 per cent. *ad valorem*.

for stores, shades, fans, etc., and sheets for machinery other than electrical—5½ per cent. *ad valorem*.

others—17½ per cent.

Great Britain.—Mica is free.

Germany.—(i) Raw mica, raw plates or discs—free. (ii) Artificially coloured or ornamented cut sheets of mica—10 marks on every 100 kilos. Uncoloured or undecorated cut sheets—2½ marks per 100 kilos.

Czechoslovakia.—Ores free, mica plates (glimmer and mikanit platten)—21 Czech crowns (for most favoured nations) per 100 kilos. Manufactures of mica (glimmer-und mikanit warin)—

(i) Combined with "ordinary" materials—512.5 Czech crowns with 3 per cent. tax.

(ii) Combined with "fine" materials—1,080.0 Czech crowns plus 13 per cent. tax.

Sweden.—Mica crude—free. Manufacture of mica free.

Holland.—Mica not mentioned in the Tariff; presumably free.

Denmark.—Duty of 3 per cent. *ad valorem*.

Madagascar.—3 per cent. export duty on a valuation fixed by government.

Netherlands.—Mica blocks and splittings admitted free. Micanites—3 per cent.

Italy.—In lump, powder or scales—free. For imports of mica or scale, no duty. Mica in plates unworked or merely cut—free. Surtax 2.50 per cent. *ad valorem*.

Switzerland.—Mica raw or in squares, not cut out—per quintal, 30 cents. In squares or sheets, cut out or in frames combined or not with tissues, metals, etc.—5 francs. Not pierced or otherwise worked, per 100 kilos—8 francs. Worked, per 100 kilos—30 francs. Wares of mica not otherwise specified, even combined with paper.

Australia.—Crude mica in slab—20 per cent. *ad valorem*. Mica and manufactures thereof—30 per cent. *ad valorem* plus a primage duty of 2½ per cent. *ad valorem*. Mica not mentioned in the tariff; presumably free as "other earths and mineral substances, not specifically mentioned, crude, burnt, ground or washed" (Item No. 110B).

New Zealand.—Mica from British countries free and from foreign countries—25 per cent. *ad valorem* plus 9/40ths surtax. No export tax.

Spain.—Mica schist or works even with parts made of other materials: *First* tariff, 80 pasetas per 100 kilos. *Second* tariff, 20 pasetas gold per 100 kilos. *Second* tariff is always applied.

United States.—Dealt with on p. 146.

France.—Import duty on sheets or plates of mica, articles of mica, micanite or compressed mica, micaceous paper or cloth even mixed with other material.

Mica in regular morsels, standard size, shape or of specific forms weighing up to 5 grammes per unit—48 per cent. *ad valorem*. Others per 100 kilos—800 francs* net weight†.

Japan.—Mica and manufactures thereof, not otherwise provided for—

- (a) In slab or powder—free.
- (b) (i) In sheets, uncoloured or unornamented—free.
- (ii) Others—*ad valorem* 25 per cent.
- (c) Sheets glued together or mica glued on tissue paper, etc.—100 kin ‡ 38.10.
- (d) Others—*ad valorem* 20 per cent.

India.—No export duty on any mica sent out of India.

* 1,000 grammes equal to 1 kilogram or 2.2046223 lb.

† Mica from Madagascar free from duty.

‡ Kin equal to 160 momme, equivalent to 1.32277 lb. avoird., or 1.60754 lb. troy.

APPENDIX V.
NEMA specifications for standard mica splittings (muscovite).*

NEMA grade.	Standard commercial grading.	Size.	Thick-ness in inches per 10 films.	Manufacture.	REMARKS.
	E. M. 4-10 : muscovite splittings.	-			
A	No. 5—1st quality B. F.; P. P.; loose with powder; loose.	Standard No. 5† commercial grading (3 in. to 7½ sq. in.).	0-007 0-009	Must be evenly split to specified thickness; no thick edges or corners; absolutely clean cut films.	Must be clean films; sound muscovite mica; free from all spots and stains.
B	No. 5½—1st quality B. F.; P. P.; loose with powder.	Standard No. 5½ commercial grading (1½ in. to 2½ sq. in.).	0-007 0-009	Same as A	Same as A.
C	No. 5½—2nd quality; loose with powder; loose.	Do.	0-007 0-010	Evenly split to thickness and, as above, but edges may be slightly uneven.	Same as A.
D	No. 6—1st quality; loose with powder; loose.	At least 60 per cent. of splits to be full standard No. 6 (1 to 1½ sq. in.), balance to pass over ½-in. mesh screen.	0-007 0-009	Same as A	Same as A.
E	No. 6—2nd quality ..	At least 50 per cent. of splits to be full standard No. 6, balance to pass over a ½-in. mesh screen.	0-007 0-010	Same as C	Must be clean films; sound muscovite mica containing not more than 5 per cent. slightly weathered or earth-stained films. No mineral stains permissible.
F	No. 6—3rd quality; loose ..	Splittings shall be of a minimum area of ⅜ sq. in. and should pass over a ½-in. mesh screen.	0-008 0-012	Same as C	Must be clean films; sound muscovite mica containing not more than 7½ per cent. slightly weathered or earth-stained films. No mineral stains.

* National Electrical Manufacturers Association of the United States. Adopted standard 8th December, 1932.

† No. 5 grade should be large enough to cut rectangular pieces measuring 1½ by 2, 2 by 2 and 2 by 2½ inches, etc., and thus, instead of total area, rectangular area in each grade is to be looked for.

APPENDIX V—concl'd.

NEMA grade.	Standard commercial grading.	Size.	Thick-ness in inches per 10 films.	Manufacture.	REMARKS.
	E. M. 4-15 : phlogopite (amber) splittings.				
M	No. 4—1st quality B. F.; P. P.; loose with powder; loose.	No. 4 standard grading (6 to 9 $\frac{1}{2}$ sq. in.).	0-007 0-009	Must be evenly split to specified thickness; no thick edges or corners; absolutely clean cut films.	Must be free from stone or other mineral inclusions and must withstand heat of 300 degree C. without becoming puffy.
N	No. 5—1st quality B. F.; P. P.; loose with powder; loose.	No. 5 standard grading (3 to 5 $\frac{1}{2}$ sq. in.).	0-007 0-009	Same as M	Same as M.
O	No. 6—1st quality; loose with powder; loose.	At least 60 per cent. of splits to be full standard No. 6*, balance passable over $\frac{1}{2}$ -in. mesh screen.	0-007 0-009	Same as M	Same as M.
P	No. 6—2nd quality; loose ..	At least 50 per cent. of splits to be full standard No. 6, balance passable over $\frac{1}{2}$ -in. mesh screen.	0-007 0-009	Evenly split to thick-ness and as above, but edges may be slightly uneven.	Same as M.

* 1 to 1 $\frac{1}{2}$ sq. in.

APPENDIX VI(b).
Approximate average prices of India ruby mica in foreign markets.

	UNITED KINGDOM. (Per lb. in sterling, ex-warehouse.)										HAMBURG.* (Per lb. in sterling.)			UNITED STATES. (Duty paid per lb. in dollars)			
	1913-14		1919-20		1929-30		1932-33		1937		1914	1920	1933	1929	1933-34	1936	
	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.				
Special grade:																	
CLSS.	13 6 to 16 0		37 0		24 0 to 28 0		..		..		16 6	60 0	43 2	7-20-13-58	8-29	12-64
F.S.	..		26 0		19 0 to 20 0		..	17 6	..		13 9	45 0	28 9	6-25	6-79	10-54	
G.S.	..		..		..		..	..	..		..	..	..	..	6-04	8-40
Std.	..		16 0 to 24 0		12 9 to 13 0		..	..	..		9 7	24 0	17 3	4-85	5-29	7-54
B.S.	..		16 0 to 19 0		10 6 to 11 6		6 0 to 7 9	..	..		..	..	..	..	2-22	2-29
A-1 grade:																	
CLSS.	10 7		26 0 to 28 0		..	24 0		..	17 6		30 0 to 35 0	12 10	42 0	28 9	4-50-5-50	6-79	3-94
F.S.	8 1		16 0		14 0 to 20 0			21 0 to 28 0	10 7	25 0	20 2	4-85-5-85	5-44	6-04
G.S.	..		..		12 9 to 13 0		..	..	..		13 0 to 15 0	8 1	16 0	15 7	5-29	5-89
Std.	..		16 0 to 19 0		10 6 to 11 6		6 0 to 7 9		12 0 to 13 0	5-10	4-09	4-84
B.S.	..		..		..		..	..	..		..	..	..	2-50	2-14	2-21
No. 1 grade:																	
CLSS.	8 9 to 9 3		20 0 to 30 0		19 0 to 20 0		14 0 to 16 0		25 0 to 30 0		10 8	34 0	23 0	5-0-5-75	4-24	8-44	
F.S.	8 0		16 0 to 18 0		12 6 to 13 0		11 0 to 11 6		14 0 to 18 0		9 3	20 0	13 3	3-0	3-64	4-09	
G.S.	..		..		11 6 to 12 0		9 0 to 9 9		12 0 to 13 0		..	..	..	..	3-12	3-09
Std.	6 6 to 7 4		12 0 to 13 0		10 6 to 11 0		9 0 to 9 0		11 0 to 12 0		7 4	12 0	9 9	2-75	2-89	3-34	
B.S.	..		10 6		8 0 to 8 6		4 9 to 6 0		..		..	..	..	2-05	1-99	2-06
No. 2 grade:																	
CLSS.	7 4 to 8 3		15 0 to 19 0		16 0 to 17 9		12 0 to 14 0		18 0 to 22 0		9 3	30 0	18 5	4-20	3-49	6-94	
F.S.	7 0		..		9 6 to 10 6		9 0 to 9 6		12 0 to 16 0		7 4	19 0	10 4	2-30	2-74	3-04	
G.S.	..		13 6		9 0 to 9 6		6 6 to 8 6		10 0 to 11 0		..	..	..	..	2-59	3-14
Std.	5 9		9 6 to 10 0		8 0 to 8 6		6 0 to 7 0		8 0 to 10 0		6 0	10 0	6 4	2-15	2-14	2-44	
B.S.	..		..		..	6 6	3 8 to 4 10		..		..	..	..	1-80	1-47	1-54
No. 3 grade:																	
CLSS.	6 9 to 7 9		12 0 to 16 0		..	16 0		11 0 to 11 6		17 0 to 20 0		7 9	26 0	14 0	3-60-3-80	2-89	5-14
F.S.	5 3		10 6		7 6 to 9 0		5 3 to 6 0		10 0 to 15 0		6 9	16 0	8 1	1-50-1-85	2-29	2-89	
G.S.	..		..		6 9 to 7 3		5 0 to 5 6		8 0 to 12 0		..	..	..	1-45	1-99	2-74
Std.	3 6		6 9		6 0 to 6 6		4 8 to 5 0		7 0 to 9 0		6 8	6 6	6 4	1-18-1-50	1-62	1-84	
B.S.	..		..		3 9 to 4 3		3 0 to 3 3		..		..	..	..	0-90-0-95	0-99	1-09

* *Vide* Mr. Richard Schroeder's leaflet on Mica and Mica Products, printed in 1933, by H. S. Hermann, Berlin, S.W.19.

APPENDIX VI(c).

Approximate prices of Indian splittings in foreign markets.

	London and Continent. (Prices per lb. in sterling.)								America. (Duty paid New York in dollars.)	
	1929-30		1932-33		1937		1929	1932		
<i>ook Splittings—</i>										
No. 4 ..	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.			0.93-1.20	
No. 4½ ..	5 3 to 5 6	4 4	4 3	5 0 to 6 0	4 6 to 5 6	4 6 to 5 6	..	1.08	0.83	
No. 5-1st quality ..	3 6 to 5 0	4 4	3 0	2 9 to 3 0	4 0 to 4 3	3 0 to 3 6	0.90-0.96	0.75	0.75	
No. 5-2nd quality ..	3 0 to 4 0	4 0	2 1	1 10 to 2 1	3 0 to 3 6	2 0 to 2 6	0.65-0.90	0.75	0.75	
No. 6-1st quality ..	2 4 to 3 0	3 0	2 0	1 10 to 2 0	2 0 to 2 6	1 6 to 2 0	0.60-0.64	0.50-0.60	0.60	
No. 6-2nd quality ..	..	..	..	..	..	..	..	..	..
<i>ss Splittings—</i>										
No. 3 P. P. ..	..	5 3	..	..	..	..	0.40	..	..
No. 4 ..	3 9 to 4 3	4 3	..	..	3 0	..	1.00	..	..
No. 4½ ..	3 6 to 4 6	4 6	..	..	3 3	..	0.90	..	..
No. 5 extra spl. ..	2 9 to 3 0	3 0	2 0 to 2 3	2 9 to 3 0	3 0	..	0.75	..	..
No. 5 special ..	2 6 to 2 10	2 10	1 9 to 1 11	2 0 to 2 6	2 6	0.60-0.72	..	..	..
No. 5 "O" and 5½ ..	1 10 to 2 4	2 4	..	1 10 to 2 0	2 0	0.48-0.64	..	..	..
No. 5 sq. p. ..	2 0 to 2 7	2 7	2 0	..	..	..	..	..	..
No. 6 extra spl. ..	1 4 to 1 6	1 6	1 3	1 0 to 1 3	1 3	..	..	..	..
No. 6 special ..	0 10 to 1 0	1 0	..	0 10 to 0 11	0 11	..	..	..	..
No. 6-A ..	0 8 to 0 10	0 10	..	..	..	..	..	..	..
<i>est Loose Splittings—</i>										
No. 4 ..	..	..	..	3 9 to 4 0	4 0	..	..	..	..
No. 4½ ..	..	..	..	3 0 to 3 6	3 6	..	..	..	..
No. 5 special ..	..	..	2 0	2 6 to 3 0	3 0	..	..	..	..
No. 5 ordinary ..	..	..	1 2 to 1 6	1 6 to 2 2	2 2	..	..	..	..
No. 5½ ..	..	..	1 2 to 1 6	1 6 to 2 2	2 2	..	..	..	..
No. 6-1st quality ..	..	..	0 11	0 10 to 0 11	0 11	..	..	..	..
No. 6-2nd quality ..	..	..	..	1 0 to 1 4	1 4	..	..	..	..
<i>ose Splittings—</i>										
No. 3 ..	..	..	2 6	..	..	..	..	..	..
No. 4 ..	..	..	2 7	..	..	..	..	..	..
No. 5 ..	..	..	1 0	2 3 to 2 6	2 6	0.60	0.75	0.45	0.35
No. 5½ ..	..	..	..	1 6 to 2 0	2 0	0.36-0.38	0.45	0.35	0.35
No. 6 extra spl. ..	0 10½ to 1 0	1 0	..	1 2 to 1 4	1 4	0.24-0.26	0.35	0.35	0.35	
No. 6 S. C. ..	0 9 to 0 9½	0 9½	..	0 9½ to 0 10½	0 10½	..	..	..	..
No. 6-1st quality ..	0 7 to 0 8	0 8	..	0 7½ to 0 8½	0 8½	0.20-0.30	0.25	0.175	0.175	
No. 6-2nd quality ..	0 6 to 0 7	0 7	..	0 5 to 0 6	0 6	0.18-0.21	0.175	0.13	0.13	
No. 6 cheap ..	0 5 to 0 6	0 6	..	0 4 to 0 4	0 4	0.09-0.11	0.10	0.10	0.10	

APPENDIX VI(d).
 Maximum price of Bengal ruby mica blocks in January 1918.
 (as fixed by British Ministry of Munitions, London).

Grade.	Size (area).	PRICES PER LB. IN STERLING, EX. WAREHOUSE.										Fixed prices for splittings.								
		Clear Govt. stand.	Part stained Govt. stand.	2nd quality clear.	2nd quality part stained.	F. S.	Ordinary stained (rust and clay).	Densely stained.	B. S.	Soft white.										
		<i>s.</i>	<i>d.</i>	<i>s.</i>	<i>d.</i>	<i>s.</i>	<i>d.</i>	<i>s.</i>	<i>d.</i>	<i>s.</i>	<i>d.</i>	<i>s.</i>	<i>d.</i>							
Extra Ex. Spl.	Over 70 sq. in.	30	0	25	0	23	6	22	6	21	0	20	0	16	0	15	0	17	6	
Ex. Special	60-70	23	0	21	0	20	0	19	0	18	0	17	0	13	0	12	0	15	0	
Special	48-59½	21	6	19	0	18	3	17	6	16	6	15	6	11	9	10	0	13	0	No. 4 up—4s. 9d.
A-1	36-47½	20	0	17	6	17	0	16	6	15	6	14	6	10	6	9	0	11	6	” 5 (white)—3s. 3d.
1	24-35½	17	6	15	0	14	9	14	3	13	0	12	0	9	0	7	6	10	6	” 5 (other qualities)—2s. 9d.
2	14-23½	16	0	13	6	13	0	12	6	10	6	9	6	6	9	5	6	8	6	” 6—1s. 9d.
3	10-13½	12	0	11	0	10	6	10	0	7	9	6	9	5	0	3	6	6	0	
4	6-9½	9	0	7	2	7	0	6	6	5	6	4	9	3	3	2	3	3	9	
5	3-5½	5	0	4	0	4	5	4	2	3	10	3	0	1	9	1	3	2	3	
5. (Govt. std.)	1-2½	3	0	2	6	1	9	1	6	1	3	1	0	0	11	0	9	1	0	

WORLD PRODUCTION OF MICA (IN METRIC TONS):

(1) Sheet mica (including blocks, splittings and films).

	1937	1936	1935	1934	1933	1932	1931	1930	1929	1928	1927	1926	1925	1924	1923	1922	1921	1920	1919	1918	1917	1916	1915	1914	1913	1912	1911	1910	1909	1908	1907	1906	1905	Ref		
India (exp.) (5)	14,598	9,028	7,204	4,716	2,932	2,389	2,691	4,212	5,897	4,850	3,937	4,569	5,065	3,561	4,232	2,192	1,650	3,887	3,002	3,046	3,178	2,779	1,514	2,058	3,174	3,388	2,487	1,268	1,662	1,403	1,772	2,463	1,174	(1)		
Canada	247	119	84	90	85	28	121	60	54	53	354	278	435	618	413	179	180	512	350	376	583	604	209	298	501	52	53	33	218	387	287	..	(1)			
South Africa*	138	34	19	..	54	23	47	178	310	726	337	230	214	181	3	..	..	1	2	24	69	12	..	..	..	..	..	..	..	..	..	..	(1)	
Tanganyika	74	44	47	31	11	12	9	21	29	34	43	53	69	56	33	11	3	27	131	17	a	a	a	46	111	..	..	..	..	..	..	..	(1)	
Rhodesia	20	12	6	3	6	13	68	168	175	190	194	170	132	136	83	60	77	89	5	..	..	..	..	..	..	..	..	..	..	..	..	..	(1)	
Oceania	85	21	45	122	43	30	30	26	27	25	7	7	4	3	3	1	4	1	..	..	18	1	3	4	..	..	..	..	..	..	..	..	..	(1)
Ceylon (exp.)	1	..	2	20	2	2	2	..	..	..	..	..	1	..	1	1	5	13	8	..	..	..	26	12	..	..	..	..	..	..	..	..	..	(1)
British Empire	15,163	9,258	7,407	5,009	3,126	2,497	2,968	4,665	6,492	5,878	4,872	5,307	5,920	4,555	4,768	2,446	1,916	4,533	3,499	3,469	3,848	3,396	1,754	2,418	3,786	3,445	2,543	1,336	1,695	1,621	3,159	2,750	1,174	(1)		
United States	769	598	425	265	165	153	436	665	923	763	685	985	814	663	936	489	337	764	701	746	579	393	252	252	771	383	856	1,123	821	441	486	546	420	(1)		
Guatemala	a	a	a	a	a	a	a	a	2	13	7	12	..	a	4	a	4	5	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	(1)
Argentina	a	209	225	175	75	55	52	61	53	53	76	84	119	120	102	64	147	273	146	172	63	6	..	1	6	7	14	21	12	1	..	..	..	(1)
Brazil	a	240	116	59	23	42	55	52	45	44	39	52	65	79	56	67	46	68	154	162	96	54	51	18	10	13	9	2	5	23	5	16	..	(1)		
Bolivia	9	..	2	4	23	8	1	15	2	..	..	17	25	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	(1)
Mexico	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	(1)
Madagascar	611	452	522	294	173	140	235	348	427	861	505	330	306	286	165	92	180	50	19	4	9	3	1	3	6	..	..	..	..	..	..	..	..	(1)
Norway	41	44	56	170	105	103	48	53	59	85	8	42	23	25	10	1	2	31	97	66	39	24	21	33	..	..	..	..	..	..	..	..	..	(1)
Sweden	68	125	32	16	68	61	65	73	66	12	10	53	95	4	5	8	a	a	a	(1)	
Rumania	26	82	(1)	
U.S.S.R. (Europe) †	a	a	a	a	a	a	a	a	a	266	15	65	a	a	a	8	a	a	135	71	(1)	
Spain	a	(1)	
Chosen	a	70	87	103	23	20	18	29	26	29	25	16	20	23	11	19	11	(1)
Total foreign countries	1,855	1,820	1,465	1,086	655	582	910	1,296	1,603	2,126	1,370	1,658	1,467	1,200	1,288	752	771	1,334	1,210	1,158	786	480	325	307	793	403	884	1,146	838	465	491	562	420	..		
World total (sheet mica)	17,018	11,078	8,872	6,095	3,781	3,079	3,878	5,961	8,095	8,004	6,242	6,965	7,387	5,755	6,056	3,198	2,687	5,867	4,709	4,627	4,634	3,876	2,079	2,725	4,579	3,848	3,427	2,482	2,533	2,086	2,680	3,322	1,594	..		

(2) Waste and scrap mica (including reclaimed)

United States	22,864	19,015	17,107	7,004	7,941	6,388	6,008	6,109	5,675	7,041	5,699	6,391	8,793	4,273	7,308	6,026	2,338	5,193	2,956	2,019	3,111	4,026	3,592	3,285	4,829	2,927	3,187	3,689	3,711	2,193	2,740	1,351	1,022	(1)	
Canada	568	643	513	815	772	252	1,093	1,001	3,623	3,267	2,130	2,031	3,212	3,093	2,784	2,859	457	1,722	2,153	679	1,060	1,080	379	540	1,004	470	478	615	300	..	..	..	..	(1)
South Africa	1,380	340	190	251	495	225	430	323	3,367	2,597	1,117	642	1,248	554	11	3	2	7	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	(3)
U.S.S.R. (Asia) †	a	a	8,291	4,442	5,790	7,806	a	a	a	1,496	1,523	487	a	a	a	a	a	a	a	a	a	a	..	..	..	..	..	..	..	..	..	..	..	(2)
United Kingdom (clay)	a	a	4,622	8,070	8,151	a	a	a	a	a	a	a	a	a	a	a	a	a	11,338	11,443	12,324	a	(1)
Japan	a	a	a	a	a	a	a	a	a	a	a	a	1,082	592	431	15	(1)
Total (world)	41,830	31,076	29,595	26,677	26,930	17,750	11,409	13,394	20,760	22,465	16,711	16,516	21,722	14,287	16,590	12,101	5,484	12,787	21,163	18,768	21,069	8,983	6,050	6,550	10,412	7,245	7,092	6,786	6,544	4,279	5,390	4,673	2,616	..	

(3) Lithia mica production

Germany	..	..	..	..	73	159	411	787	777	270	607	666	501	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Portugal	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
France	..	111	a	8	299	886	2,051	574	274	341	386	187	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
South West Africa	..	..	356	509	509	a	a	a	1,018	305	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
United States (b)	1,049	867	496	235	..	..	..	102	254	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Czechoslovakia	..	..	1,126	1,151	654	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Argentina	..	a	61	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Total	2,394	2,054	2,011	1,697	1,468	2,210	1,094	1,342	1,530	1,629	1,298	1,103	501	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
World total (all mica)	44,224	33,130	31,606	28,374	28,401	19,960	12,503	14,736	22,200	24,034	18,009	17,819	22,223	14,267	16,590	12,101	5,484	12,787	21,163	18,768	21,069	8,983	6,050	6,550	10,412	7,245	7,092	6,786	6,544	4,279	5,390	4,673	2,616	..	

* Almost entirely scrap (M. I. 1936) but to be conservative sheet production estimated at 10 per cent from 1931 and 20 per cent prior to 1931.

† Assumed as sheet.

‡ Production of Asiatic Russia and Japan taken as scrap.

mica (including reclaimed)

6,026	2,338	5,193	2,956	2,019	3,111	4,026	3,592	3,285	4,829	2,927	3,187	3,689	3,711	2,193	2,740	1,351	1,022	(1)
2,859	457	1,722	2,153	679	1,060	1,080	379	540	1,004	470	478	615	300	..	..	..	..	(1)
3	2	5	7	..	..	1	..	..	..	..	..	..	..	..	..	..	..	(3)
a	a	a	a	a	a	a	..	..	..	..	..	..	..	..	..	..	..	(2)
a	a	a	11,338	11,443	12,324	a	..	..	..	..	..	..	..	..	..	..	..	(1)
15	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
8,903	2,797	6,920	16,454	14,141	16,435	5,107	3,971	3,825	5,833	3,397	3,665	4,304	4,011	2,193	2,740	1,351	1,022	
12,101	5,484	12,787	21,163	18,768	21,069	8,983	6,050	6,550	10,412	7,245	7,092	6,786	6,544	4,279	5,390	4,873	2,616	

mica production

..	(2)
..	
..	
..	
..	
..	
12,101	5,484	12,787	21,163	18,768	21,069	8,983	6,050	6,550	10,412	7,245	7,092	6,786	6,544	4,279	5,390	4,873	2,616		

tion estimated at 10 per cent from 1931 and 20 per cent prior to 1931.

Jour. June 1922).

and 41 tons of scrap.
 statistics to comprise of 1,500 and 13,367 ong tons of blocks and splittings respectively

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