



सत्यमेव जयते

THE  
ECONOMIC GEOLOGY AND MINERAL  
RESOURCES OF SAURASHTRA

*(With a Mineral Map of Saurashtra)*

BY

B. C. ROY, D.I.C., M.Sc. (London), Dr.-Ing. (Freiberg),  
*Superintending Geologist-in-charge, Western Circle,*  
*Geological Survey of India*

*Published by*  
Government of Saurashtra,  
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PLATE  
(MINERAL MAP OF SAURASHTRA)

# **THE ECONOMIC GEOLOGY AND MINERAL RESOURCES OF SAURASHTRA**

By

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*Superintending Geologist-in-charge, Western Circle,*  
*Geological Survey of India.*

## **PART I—ECONOMIC ASPECTS OF GEOLOGY IN SAURASHTRA**

### **CHAPTER I**

#### **INTRODUCTION**

A brief resume of the various minerals that are known to occur in the State of Saurashtra was prepared by the Geological Survey of India in 1948 at the request of the Government of Saurashtra. The summarised statement, however, was too concise, and it was decided that the subject should be dealt with more fully at a subsequent date.

As the Superintending Geologist-in-charge of the Western Circle, comprising the States of Bombay, Saurashtra, Rajasthan, Ajmer-Merwara and Kutch, with headquarters in Bombay, it has been the privilege of the author to be closely associated with the Government of Saurashtra for eight years. During this period he has been in contact with all the Government Departments of Saurashtra interested in the various aspects of the geological work in the State, giving advice on all matters concerning the mineral development within the State and attending periodic meetings and discussions.

In December 1948, Mr. Manubhai Shah, the then Minister of Industries and Commerce, Government of Saurashtra, requested the Geological Survey of India to send an officer on deputation to the Saurashtra Government for some time. The Government of India were pleased to sanction the establishment of a local Geological Survey office at Rajkot at the cost of the Saurashtra Govern-



ment, and a senior officer of the Geological Survey was posted there in May 1949 under the general supervision of the Superintending Geologist-in-charge of the Western Circle. The local office at Saurashtra assisted the commercial public in advising them in their problems of exploitation of minerals and in disseminating up-to-date information on minerals. Subsequently it was felt that the volume of the work at Rajkot did not justify a separate establishment, and as a measure of economy the office was eventually closed down in July 1951.

Mr. A. J. Marin, a Belgian Mining Engineer, was engaged by the Government of Saurashtra on a short contract between 1948 and 1949, for advising on the mineral possibilities within the State. Mr. Marin spent some time in the Geological Survey office at Calcutta for eliciting published information and submitted a report on the basis of his investigations in parts of the State.

The Geological Survey of India possesses a fair knowledge of the mineral resources of the State and the information is scattered in numerous published and unpublished reports of the Department. Besides, useful information is also available in the office files and records of the Geological Survey of India. The present Brochure on the Economic Geology and Mineral Resources of Saurashtra will give a fairly detailed account of all mineral deposits known to the Geological Survey of India to date, including those of the small enclaves of Bombay State. The information in this Brochure, it will be thus seen, is primarily based on the knowledge gained by the Geological Survey of India over the last century, but also incorporates to some extent, the results of the efforts of private workers and commercial firms engaged in the exploitation of certain mineral deposits.

The main object of this work has been to state clearly the present position with regard to all known mineral occurrences within the State, to suggest the lines of future search of minerals, and to assess the mineral resources with a view to expansion of the present mineral industries or development of new industries. Under each mineral heading, information on uses, localities, mode of occurrence, reserves, quality, grading, prices and future scope is given. In order to get full detailed information of individual mineral deposits, reference may be made to the Bibliography at the end of the account on each mineral.

This account has been written on the lines of Dr. M. S. Krishnan's "Mineral Resources of Madras" and Dr. J. A. Dunn's "Economic Geology and Mineral Resources of Bihar Province", published by the Geological Survey of India in recent years.

The earlier information on the mineral resources of India is available in La Touche's invaluable "Bibliography of Indian Geology and Physical Geography with an Annotated Index of Minerals of Economic Value", published by the Geological Survey of India in two parts in 1917 and 1918, respectively. The information in the published *Records* and *Memoirs* of the Geological Survey has been freely drawn in preparing this account. Some additional information contained in the numerous unpublished reports of the Geological Survey has also been incorporated in this work.

The interest taken by Mr. Jamnadas G. Shah, Joint Secretary, Department of Industry and Supply, Government of Saurashtra, in the publication of this Brochure, is gratefully acknowledged. The author is thankful to Mr. A. T. Jadeja, Quarry Superintendent, Government of Saurashtra, for much information and data in connection with minerals in the State.

The author is particularly grateful to Dr. M. S. Krishnan, Director, Geological Survey of India, for kindly permitting him to write up this account of mineral resources of Saurashtra, and for going through the manuscript. He is also indebted to Mr. C. Karunakaran, Geologist, Geological Survey of India, for checking up the co-ordinates and for assistance in compiling the Mineral Map of Saurashtra.

The information provided in this work will be of some assistance to the Government of Saurashtra in formulating their future plans towards the mineral development within the State. The district and other Government officials who often have to concern themselves with problems of mineral matters may also consult this Brochure for reference. The industrialists who are in need of raw materials for their existing products or who propose to undertake new mineral developments, the information provided herein should be of value. To the individual prospectors and the mining concerns, a knowledge of the various minerals, with regard to uses, reserves, quality, beneficiation, marketing, etc., is essential, and it is hoped that the data presented may be helpful in the furtherance of their work.

Any exaggerated notions with regard to mineral deposits would be detrimental towards the proper growth of any industry based on mineral resources. On the other hand an under-estimation of the mineral deposits may lead to slow, inadequate or improper development. A correct appraisal of mineral deposits is highly desirable as otherwise no mineral industry can properly thrive. No co-ordinated and planned development of the mineral resources of a State could be carried out without a full and adequate knowledge of its mineral resources, and therefore it is hoped that the present work will be of some help towards that end.

## CHAPTER II

### MINERAL PRODUCTION

The relative importance of the different industries in various States is judged from the statistics of mineral production. Although a variety of the minerals have been recorded from time to time in different parts of the State of Saurashtra, the chief mineral industries, adding to the revenue of the State, providing work for people and contributing to the development of other industries, concern only a few items of minerals and rocks, e.g., building stones and road metals, limestone, salt, gypsum, fire-clay and other clays.

The recorded mineral production in Saurashtra, between the years 1947 and 1951, given in the recent issues of the "Mineral production of the Indian Union", is shown in Table 1. The average annual value of minerals produced during the period, it will appear, was about Rs. 88,12,800. Indeed the mineral production in the State is meagre, compared to the neighbouring States of Rajasthan and Bombay, and comprises chiefly building materials, limestone, salt, gypsum, fire-clay and other clays.

A variety of useful rocks, building materials, clays, Fuller's earth, calcite, mineral pigments, glass-sands, moulding sand, etc., are being produced in parts of the State, but no statistics of their production are available. Full reliable particulars of these should be collected from all districts and the returns consolidated by the local Government should be regularly sent to the Geological Survey of India, for incorporation in the annual mineral review. These statistics are not only important from all-India point of view but are also useful for the State Governments and the industrialists for assessing the trend and growth of mineral industries in any particular State.

TABLE 1.—*Mineral production of Saurashtra State between 1947 and 1951.*

|   | 1947               |                  | 1948               |                  |
|---|--------------------|------------------|--------------------|------------------|
|   | Quantity.<br>Tons. | Value.<br>Rs.    | Quantity.<br>Tons. | Value.<br>Rs.    |
| Limestone .. ..   | 198,000            | 5,20,000         | 99,000             | 2,60,000         |
| Sandstone .. ..   | 33,880             | 2,00,600         | 16,940             | 1,05,300         |
| Miscellaneous building materials and road metals. .. .. | 25,000             | 3,80,000         | 12,500             | 1,90,000         |
| Fire-clay .. ..   | 10,000             | 2,00,000         | 7,500              | 1,50,000         |
| China-clay .. ..  | 6,000              | 1,20,000         | 4,000              | 90,000           |
| Other clays .. ..                                       | 4,000              | 1,00,000         | 1,000              | 20,000           |
| Gypsum .. ..  | 10,000             | 2,00,000         | 5,000              | 1,00,000         |
| Salt .. ..  | ..                 | ..               | 263,775            | 35,04,760        |
| <b>Total .. ..</b>                                      | <b>286,880</b>     | <b>17,20,600</b> | <b>409,715</b>     | <b>44,20,060</b> |

TABLE 1.—*Mineral production of Saurashtra State between 1947 and 1951—contd.*

|   | 1949               |                    | 1950               |                    |
|---|--------------------|--------------------|--------------------|--------------------|
|   | Quantity.<br>Tons. | Value.<br>Rs.      | Quantity.<br>Tons. | Value.<br>Rs.      |
| Limestone .. ..   | 107,286            | 2,60,020           | 26,877             | 4,82,346           |
| Sandstone .. ..   | 22,000             | 1,32,000           | 12,000             | 60,000             |
| Miscellaneous building materials and road metals. .. .. | 22,376             | 83,104             | 8,856              | 69,434             |
| Fire-clay .. ..   | ..                 | ..                 | ..                 | ..                 |
| China-clay .. ..  | ..                 | ..                 | ..                 | ..                 |
| Other clays .. ..                                       | 6,521              | 4,108              | 610                | 6,100              |
| Gypsum .. ..  | 2,780              | 55,600             | 5,550              | 1,04,500           |
| Salt .. ..  | 340,441            | 1,01,99,575        | 447,245            | 1,09,49,465        |
| <b>Total .. ..</b>                                      | <b>501,404</b>     | <b>1,07,34,407</b> | <b>501,138</b>     | <b>1,16,71,845</b> |

**TABLE 1.—Mineral production of Saurashtra State between 1947 and 1951—contd.**

|  |    |    | 1951(a)        |                    |
|--|----|----|----------------|--------------------|
|  |    |    | Quantity.      | Value.             |
|  |    |    | Tons.          | Rs.                |
| Limestone  | .. | .. | 125,210        | 5,05,200           |
| Sandstone  | .. | .. | 10,000         | 50,000             |
| Miscellaneous building materials and road metals | .. | .. | 23,885         | 99,495             |
| Fire-clay  | .. | .. | ..             | ..                 |
| China-clay                                       | .. | .. | ..             | ..                 |
| Other clays                                      | .. | .. | ..             | ..                 |
| Gypsum   | .. | .. | 1,775          | 25,000             |
| Salt   | .. | .. | 647,522        | 1,48,37,500        |
| <b>Total</b>                                     | .. | .. | <b>808,392</b> | <b>1,55,17,195</b> |

(a) Figures are not complete.

## CHAPTER III

### PHYSIOGRAPHY

The Province of Saurashtra (Kathiawar), including the enclaves of the Bombay State and the Portuguese territory of Diu, constitutes the peninsula between the Gulfs of Kutch and Cambay. It is encompassed roughly by latitudes  $20^{\circ} 41'$  to  $23^{\circ} 8'$  and longitudes  $68^{\circ} 56'$  to  $72^{\circ} 20'$ . It is bounded on the north by the Gulf of Kutch and the Little Rann of Kutch; on the north-east and east by the Bombay State; and on the south-east by the Gulf of Cambay. The Arabian Sea borders the entire southern seaboard.

Irregular in outline, resembling a hatchet-head in form, the Saurashtra peninsula has a maximum length of about 220 miles and a greatest width of 165 miles, comprising roughly 23,445 square miles. About 2,543 square miles of territory comprises the enclaves of the present Bombay State; about 20 square miles form the foreign Portuguese territory; and the rest of the area, i.e., 20,882 square miles, hitherto forming 193 separate princely States of Kathiawar, has now merged within the present State of Saurashtra. The State is now divided into five administrative districts, Halar, Zalawad, Sorath, Gohilwad and Madhya Saurashtra.

There is a central table-land, the most elevated region, from where most of the rivers of the peninsula take their origin. The central table-land is surrounded for the greater part by an undulating country with low ill-defined hill ranges without any regular directions, the terrain generally sloping very gently towards the peninsular margin to merge into the coastal plains and the great alluvial stretches to the north-east and east.

The coast line fringing the Gulf of Kutch is ill-defined. The south-east shore is conspicuous by the presence of low cliffs of sub-recent formation. The south-west shore is in the form of an unbroken, straight line, and is bordered by low parallel ridges of consolidated shore sand and dune sand. The coasts, both in the Gulf of Kutch and in the Arabian Sea, are generally very slightly raised above sea level, and indicate recent upheaval.

#### HILLS

Apart from the minor hill features comprising Jurassic sandstones, laterite, sub-recent rocks, etc., the hills of the Province are

chiefly composed of volcanic rocks, commonly known as Deccan traps. The principal hills or hill ranges are described below.

Circular or sub-quadrangular in outline, the Mount Girnar with its group of hills, covers an area of about 64 square miles and forms the most imposing landscape in Saurashtra. The region may be dealt with under four heads:—

(1) *The outer hill ranges*, consisting of basalt with a core of intrusive granophyre, have an elevation varying between 1,500 and 2,000 feet, the highest peak being 2,779 feet. Four gorges cut across this circular hill ranges, to the west, north, east and south-east, and form the only outlets of the inclosed area. They are supported by torrential streams during rains; otherwise most of them dry up for the rest of the year.

(2) *The central mountain*, with high peaks such as 3,666 feet, 3,295 feet and 2,839 feet, is composed of monzonite and diorite with minor intrusions of nepheline-syenite and basalt.

(3) *The radial ridges* joining the central mountain to the outer hills, with an average height varying between 1,000 and 1,500 feet, consist usually of olivine-gabbro, with intrusion of nepheline-syenite and quartz-felspar rock.

(4) *The plains* are composed of basalt and gabbro or have a shallow alluvial cover.

The Gir range commences some distance south-east of Mount Girnar and extends roughly west to east for some 20-30 miles over a jungly terrain. The highest elevation is 2,110 feet above sea level at Sarkala. The Gir range continues eastwards and is linked with a 30-mile long and 5-8 mile wide hilly terrain in Bhavnagar; the isolated Shetranji hill (1,634 feet) of Palitana is some distance away at its north-eastern border.

The central Saurashtra massif is a group of high and low hills from where emanate a number of streams radiating in all directions towards the peninsular margin. The highest summit on this range is near Sanosra (1,117 feet). The hilly tract is roughly 40 miles by 40 miles and is bordered to the north by the townships of Than, Wankaner and Sayla, and to the west by Rajkot and Gondal cities.



This massif practically merges at its southern limit with the Gir range.

Covering an area of some 70 square miles, the Barda group of hills lies to the north-east of Porbandar, the peak of Venu being 2,091 feet above sea level. Other high summits are Khanmera (1,728 feet), Abapura (1,938 feet) and Dantala (1,620 feet).

The Alech group of hills, to the east of the Barda hills, shows maximum elevations of 570, 648, 533 and 518 feet, proceeding from west to east. The constituent rocks are hypabyssal felsites and granophyres, and traps. The highest summit is 977 feet above sea level.

Another hill range commences midway between the Barda and the Alech hills and ends at Tungi, although continuing as detached hills to the east of Padana and beyond. The highest point on this range is 517 feet at Rajwar.

The range of hills from Satodad to Jamnagar attains elevations of 825, 864 and 872 feet above sea level. The maximum width of the range is nearly 12 miles. The highest point near Gop is 1,191 feet above sea level.

Rising abruptly from the plain country, the isolated Osham hill is conspicuous between Mount Girnar and Alech hills. Its peak is 1,030 feet above sea level.

The south-eastern part of the Province has an unique relief in the form of numerous narrow serrated ridges extending for several miles. They often constitute parallel ridges sometimes intersecting each other at right angles, and are at times as high as 200-300 feet above the plain country. This remarkable feature is attributed to the basic dykes cutting through the traps and is also seen in other parts of Saurashtra.

#### CLIMATE

The climate of the Province is generally pleasant. The winter months from November to January are generally healthy, when heavy dews and thick fogs are not uncommon. The summer months from April to June are considered as the healthiest period in the year. Hot wind is conspicuous in summer in the south of the

peninsula. The monsoon begins in June and lasts till October, the maximum precipitation being in July to September. The climate from September to early November is generally considered unhealthy.

#### RAINFALL

Although Saurashtra comes within the influence of the south-west monsoon, its rainfall is very much less than that of the Indian peninsula. The wettest months of the year are July, August and September. The amount of rainfall in general is light and varies in different parts of the State. The average annual rainfall usually ranges between 20 and 28 inches. The rainfall is generally heaviest in Junagadh averaging 40-50 inches per annum. Scanty rainfall due to failure of south-west monsoon is responsible for famine conditions in certain parts.

#### RIVERS

As already stated, the numerous but small rivers of the Province emanate from the central elevated country, and as such they radiate on all sides, towards the north, north-east, east, south-east, south, south-west and north-west.

The northerly flowing important streams, draining into the Little Rann, are Aji by Rajkot, Machhu by Wankaner, Morvi and Malia, Bhamban and Phulka by Dhrangadhra. Minor northerly flowing rivers, discharging into the Gulf of Kutch, are Und by Dhrol, Rangmati by Jamnagar, Sasoi, Fuljar, Ghi, etc.

The largest river in the Province, i.e., Bhadar, in the south-western part, passes Jetpur and Kutiyana, and runs for about 120 miles. It finally drains into the sea at Navibandar. Other minor streams flowing south or south-west into the Arabian Sea, in the south-west, are Bhogat, Wartu, Ojat, Megal, Saraswati, and Singavada by Kodinar.

The easterly flowing streams in the eastern Saurashtra, i.e., two Bhowgawas, one passing by Muli and Wadhwan, the other by Limbdi, Bhadar by Ranpur and Dhandhuka, Keri, Ghela, Kalubhar and Shetrunji passing Talaja, join the Gulf of Cambay. The narrow Gulf between Piram Island and Cambay receives a great amount of sediments in the monsoon from the streams of Saurashtra and

Gujerat. High tides sometimes forcing salt water inland 20-30 miles up the rivers also convert arable land into waste tracts.

The south-easterly or southerly flowing streams, in the south-eastern peninsula, are the minor rivers, e.g., Malan by Mahuva, Rawal, Machundri, etc.

#### LAKES

There are no big lakes in the Saurashtra peninsula, apart from the remarkable expanse of water at Nal lake, at the head of the Rann of Cambay, and the Gheds near Madhavpur, on the south-west coast.

#### ISLANDS

The islands include Piram in the Gulf of Cambay, Jegri, Chanch, Shial, Panikota and Diu off the south coast, and the islands of Beyt, Nora, Chanka, Bhaida, Ajar, Panera, Gandhia, Karumbhar and Pirotan in the Gulf of Kutch.

#### SALT WASTES

There are two remarkable Ranns or salt wastes almost encircling the north-east and east of Saurashtra, i.e., the Rann of Kutch and the Rann of Cambay.

The north-eastern border of the plains of Saurashtra merges with the Rann of Kutch, an almost flat, low-lying country, not very much elevated from the mean sea level. The Rann is a great salt marsh, covering an area of about 9,000 square miles. It is divided into two parts, the Great Rann and the Little Rann, joined by a 2-mile wide strip between Piprala and Ardesar. The Rann once formed a part of the sea, when two arms of which ingressed at both entrances at Khori creek and Hansthal creek during recent geological times. It was subsequently raised to its present level by later earth movements and was thus cut off from the sea. In summer the Rann presents an appearance of a barren waste land, almost devoid of vegetation and human habitation. During the monsoon, practically the entire tract is converted into a large sheet of water to a depth varying between one and seven feet, owing to the strong winds from south-west and S.S.W. forcing the sea water

into the Rann and due to flood waters from the adjoining territories of Sind, Rajasthan, Saurashtra and Kutch.

Stretching for some 35 miles north from the mouth of the river Sabarmati, the Rann of Cambay constitutes a shallow dry estuary, joining the Nal lake during the south-west monsoon and forming a great expanse of water over the tracts of Bhal and Nalkantha.

The most important salt-water creeks are (1) Hansthal, linking the outer and inner Gulf of Kutch, (2) Bhavnagar, connecting the city and the Gulf of Cambay, (3) Sundrai, eight miles north of Bhavnagar, (4) Bavliali, two miles north of the Sundrai creek, and (5) Dholera, stretching 10 miles inland from the Gulf of Cambay.

## CHAPTER IV

### GENERAL GEOLOGY

The earliest reference to the geology of Saurashtra is given in the works of Hugel, Falconer, Theobald and Blandford. The general geology of Saurashtra, however, is well known thanks to the classical work of Francis Fedden (1), published in the *Memoirs* of the Geological Survey of India in 1884: According to Fedden, the following are the geological formations in Saurashtra, arranged in order of increasing antiquity:—

|  |   |                                    |
|--|---|------------------------------------|
| Alluvium, etc.                                     | } | .... Post-Tertiary.                |
| Milliolite series                                  |   |                                    |
| Dwarka beds (Post-Pliocene)                        | } | .... Tertiary.                     |
| Gaj beds (Upper Miocene)                           |   |                                    |
| Lateritic rocks (Lower Eocene)                     | } | Deccan traps<br>(Cretaceo-Eocene). |
| Traps (Cretaceo-Eocene)                            |   |                                    |
| Trappean grits (Cretaceous)                        |   |                                    |
| Wadhwan sandstones...Cretaceous (Infra-trappeans). |   |                                    |
| Umia beds...Jurassic.                              |   |                                    |

*Umia beds.*—The oldest rocks in Kathiawar comprise the Umia beds, equivalent to the Upper Gondwana System (Jurassic) and cover some 1,000 square miles in the north-eastern part commonly known as Zalawad. They consist of sandstones and are considered equivalent to the Umia group of Kutch, judging from geographical proximity, lithological resemblances and plant impressions. The older Jurassic beds, equivalent to Katrol, Chari and Patcham of Kutch, are not developed in Kathiawar.

The Umia beds consist chiefly of sandstones, with gritty or conglomerate layer and some shale bands. No continuous vertical sections showing the full succession are available because of the usual flatness of the country and the marked horizontality of the beds. It is thus difficult to assess the total thickness of the beds. Besides, weathering has denuded the original rock surface, and the

basal beds are nowhere exposed. Fedden has estimated the thickness of this group as about 1,500 feet. A great development of these beds is seen near Dhrangadhra, Than, Wankaner, etc. Oblique lamination or current-bedding is common. Between Chotila and Than the Umias are about 500 feet thick.

Ironstone bands in the form of red clay-shale with earthy hematite or highly ferruginous sandstone are seen at widely separated places, e.g., near Wankaner, Mate, Deosar, Chorvira, Kantrori, etc.

Black carbonaceous shale or coaly shale is present near Than. Fragmentary impressions of fossil plants, leaves, seeds, etc., are noticed near Songadh,  $2\frac{1}{2}$  miles N.N.E. of Than and three-fourths of a mile north-west of Than. Indications of plant-bearing shales are also reported in the stream sections of Phulka and Godra.

The Umia beds are bounded on the north and north-east by alluvium; on the south and west they are overlain unconformably by the Deccan traps. Cretaceous sediments (Infra-trappeans) fringe their south-eastern boundary. Several intersecting trap dykes cut through them at the south-west. Deccan trap outliers are seen particularly at the south-western limits of the formation near Chotila and Wankaner.

Separated from the main belt of the Umias, to the north-west, is an isolated strip of Umia beds in alluvium, stretching for some 12 miles along the Rann border. A part is covered by dune sand, but near Handi Bet to the east, the hill scarps show a 50-foot thick formation of horizontal or gently tilted, girts and sandstones.

*Wadhwan sandstones.*—A series of sandstones fringing the Umia beds and overlying them to the south-east, particularly conspicuous near Wadhwan, is termed as Wadhwan sandstones. In Kathiawar they are probably next in order of age to the Umias, although not clearly separable from them, and comprise a group of brick-red or dull reddish-brown sandstone with some agrillaceous layers, the top of the formation sometimes consisting of thin cherty or chalcedonic limestone beds very much resembling the infra-trappean Bag beds. The Deccan traps abut against or overlap the Wadhwan sandstones.

The bedding of the Wadhwan sandstones is indistinct, but appears to be horizontal. Tilting is detected at places. Marine organic remains, mostly bryozoa and some corals, have been recorded near Wadhwan. Similar sandstones in a limited extent crop out in the ravines to the north of Sitha, 10 miles north of Wadhwan Railway Station. The same rocks, 30-40 feet thick, are sparingly exposed westwards in the Morvi area, in the Jhinkiali stream section, and possibly occur as small inliers to the east of Morvi town. An inlier of current-bedded, calcareous gritty sandstone, south of Ghotu, possibly with a gentle tilt towards E. 30° S., probably represents similar Wadhwan sandstones. Similar beds are also exposed from near Paneli up to Gidach.

There are a number of inliers of Wadhwan sandstones in the Deccan traps to the south-west of Wadhwan. Fedden has described several sections between the two Bhogawa rivers, near Chotila, Bhaduka, Sidsar, Timba, Kharwa and Sejakpur.

*Trappean grits.*—They are well developed in Kutch and represent a group of gritty and trap-like deposit, occurring at the base of the Deccan traps. They occur very sparingly in Kathiawar and constitute an isolated thin deposit, some three square miles of a plain country, four miles north of Than. The rock is yellow or olive-green in colour, resembling a decomposed trap, sandy or gritty in appearance, contains quartz grains, and shows a laminated or shaly structure. It represents a type of volcanic accumulations at the beginning of the Deccan trap period, deposited in water with sand.

The isolated gritty volcanic rock near Abhepura, on the Umia sandstone beds, occupying a hollow on the sandstone surface, and another similar outcrop on sandstone about a mile and a quarter to the south, are considered as trappean grits. The earthy felstones, volcanic ash and agglomerates, at the base of the Deccan traps, occupying depressions in the Umia sandstones, at several localities, also probably represent trappean grits. Ashes, felsites, etc., in irregular depressions or hollows in the Umia beds near the scarp border of trap area, near Mewasa, 10 miles south of Chotila, also indicate trappean grits.

*Deccan traps.*—By far the largest part of the Province is occupied by the Deccan trap lava flows, which on account of their extreme fluidity, spread over wide areas in the form of horizontal sheets and gave rise to the topography so common in the Deccan

trap country. They represent extensions of traps in Kutch, Gujerat and Malwa. The traps indicate great outpouring of igneous rocks at the close of the Cretaceous period, covering some 200,000 square miles in other parts of India.

The traps commonly appear to be horizontal, but may be also gently tilted, as it is difficult to find a smooth surface for measurement with clinometer. The average thickness of the flows may be of the order of 40 feet. Fedden estimates that the total thickness of the traps in the greater part of Kathiawar is about 1,750 feet. The maximum thickness of the traps represented in Mount Girnar cannot be less than 3,500 feet.

Dr. W. D. West (13), who examined the cores from several deep bores at Dhanduka and Jamnagar, states that the traps at these localities are over 1,500 and 1,000 feet in thickness, respectively, and are cut by dykes, indicating the rise of dyke magma to a great height. Many 'normal' Kathiawar lavas are said to resemble the central magma type but differ from the plateau basalt. Some of the traps are stated to be ultrabasic in composition.

The most prevalent trap rocks are basalts and dolerites. Fedden distinguished felstones, felsites, trachytes, trachy-felsites, diorites, obsidians, pitchstones, etc. E. H. Adye (3 & 4) recognised from rocks in Nawanagar and Porbandar, felsite, granophyre, obsidian, rhyolite, porphyritic basalt, olivine-basalt, amygdaloidal basalt, olivine-dolerite, picritoid-dolerite, limburgite-basalt, limburgite, trachylyte and palagonite-rock.

According to Fermor (2), some of Fedden's trachy-felsites are identical to the rhyolites of Pavagad hill in the Panch Mahals district and the Malani rhyolites of Rajasthan.

Dr. M. S. Krishnan (5 & 6), who examined, in London, Dr. J. W. Evans' collection from the Girnar and Osham hills, identified the following rock types:—Nepheline-syenite, alkali-syenite, augite-granophyre, quartz-porphyry, syenite, porphyry, syenodiorite, diorite-gabbro, andesite, olivine-gabbro, lamprophyre, dolerite, basalts, limburgite, obsidians and rhyolites. The extrusion of basalts, according to him, was followed by intrusion of gabbro, diorite, followed by nepheline-syenite, limburgite and lamprophyre.



Dr. S. K. Chatterjee (9), who also studied specimens obtained by Dr. J. W. Evans from the Gir forest, distinguished the following basic dykes, e.g., dolerite, olivine-dolerite, basalt, hornblende-porphyrite or lamprophyre and gabbro, apart from acid dykes such as granophyre, pitchstone and rhyolite. Two types of basic dykes are identified, e.g., (1) saturated, with high ferric and titanite oxide, and normative quartz, and (2) unsaturated, with low titania and high magnesia, and containing olivine.

In Bhavnagar K. P. Sinor (8) recognised dolerite, olivine-dolerite, quartz-dolerite, glassy basalt, porphyritic basalt, olivine-basalt, diabase, tuff, felsite, granophyre obsidian, pitchstone, rhyolite and soda-felspar rock.

The rock types identified by Mathur, Dubey and Sharma (7), in Mount Girnar, are olivine-gabbro, diorite, monzonite, nepheline-syenite, syenite, granophyre, quartz-felsite, lamprophyres and basalt.

Fedden described the Girnar hills as having originated from the dioritic core of an ancient volcano forming an eruptive centre, as indicated by the quaquaversal dip in the surrounding basalt and the physiography, but according to Mathur, Dubey and Sharma (7), the rocks represent a plutonic laccolithic intrusion of a number of differentiated types, into a thick basalt cover lifted up as a dome. Olivine-gabbro, diorite-monzonite and granophyre indicate three phases of movement. Diorite and monzonite, surrounded by olivine-gabbro, constitute the centre; granophyre forms intrusive dykes in the basalt in the outer hill ranges, possibly indicating a series of circular fractures in basalt caused by arching. The differentiation, as a result of slow cooling, is attributed to fractional crystallisation, sediment assimilation or liquid immiscibility being considered as improbable. The plutonic rocks are intruded by later nepheline syenite masses and lamprophyre and basalt dykes.

The rocks of the Deccan traps are mostly massive or amygdaloidal. Scoriaceous breccia, agglomerates, tuffs, ash beds, etc., are also occasionally seen. Geodes, with zeolite, chalcedony, agate and calcite are often found in the amygdaloidal types. On account of the widespread miliolite limestone bed and soil cover, it is rather difficult to say for certain which rock type is more prevalent in the State, but normally the hill tops are mostly composed of hard and tough massive flows, whereas the soft amygdaloidal

varieties usually occupy the flanks and also the valley floors and plain ground. The traps are invariably jointed. Besides sheet jointing, more or less parallel to the surface, other vertical or inclined joints are also observed. Columnar or prismatic jointing, generally at right angles to the bedding planes of the flows, is also seen sometimes. The traps often show usual spheroidal weathering and alter into a black soil.

In hand specimens both massive and amygdaloidal traps have a greenish grey to dark grey or black colour. The weathered rocks are yellowish green and often develop an ochrous-brown outer crust. In granularity, they vary from compact massive types to fine or coarse grained rocks; rarely they are porphyritic and show lath shaped felspar phenocrysts. The amygdaloidal basalts contain vesicular cavities with infillings of zeolite, chalcedony, agate and calcite.

Thin slices of the basalts, under the microscope, show usual ophitic texture. The groundmass is fine grained, the constituent minerals being mostly colourless augite and felspar (labradorite). Rarely, a few large phenocrysts of felspar, augite or olivine are observed. Magnetite is an important accessory, occurring as dust and granules. Chlorite and serpentine form usual alteration products. Occasionally some amount of interstitial glass, usually devitrified and altered to a pale green 'palagonite' is also seen.

*Inter-trappeans.*—Inter-trappean beds, i.e., sedimentary beds interbedded with the lava beds, are developed in a few localities in Kathiawar. An inter-trappean horizon of porcellaneous shale occurs near Kherdi and Kalasar and 2-3 miles west of Chotila. Some imperfect organic remains of very small fish were indentified by Fedden near Nawagam, 10 miles from Chotila. It is present near the top of another hill in the vicinity and also caps the ridge scarp between Lakhawand and Shekdod. The bed is about 10 feet thick.

*Trap-dykes.*—A number of parallel basic dykes (dolerites), sometimes intersecting each other, are present in the Deccan traps, particularly in central and south-eastern trap area. They form low knolls, elongated mounds or serrated ridges which may be followed across country for many miles, sometimes attaining a height of 200 to 300 feet above the level of the country. The Sardhan dyke in central Saurashtra runs for nearly 45 miles, and is 100

feet across at places. An E.-W. trend of the dykes is common. There are some N.-S. or N.W.-S.E. cross dykes. They are younger than the E.-W. trending dykes.

The contacts of the dykes with the traps are vertical with definite walls, but sometimes they are indistinguishable from the adjoining beds or flows. The dykes are usually jointed and sometimes show a prismatic or columnar structure, the prisms lying horizontally and at right angles to the walls.

The dyke rocks are mostly compact and rarely pass into vesicular or amygdaloidal types near the surface. They are greyish green to black in colour and usually show a micro-crystalline fine grained texture. Thin slices, under the microscope, show a fine grained groundmass of feldspar (labradorite) laths and augite. The texture is distinctly ophitic; numerous thin laths of labradorite feldspar form a plexus around the anhedral grains of a colourless augite. Magnetite granules in the form of grains or skeletal crystals are very common.

The dykes in the Deccan traps, in Saurashtra, Gujerat and the Konkan, according to earlier observers, represent channels for the eruption of the trap flows, but Dr. J. B. Auden (14), judging from their peculiar concentrations in the form of clusters, swarms, arcuate dykes and networks in definite areas, linked partly to the three plutonic masses of Saurashtra and partly to zones of folding in the trap regions of Gujerat and the Konkan, concludes that some of them possibly indicate a post-trappean hypabyssal phase, but not as the source of the lavas. According to him, the existence of calderas in Saurashtra and further east along the Narbada is probable, but by far the greater part of the Deccan trap shield is as a rule free from eruptions of the 'central type'. It is suggested that all future studies of the dyke problem should be aimed at collecting the following data:—

- (1) Regional distribution of the dykes.
- (2) Vertical extension of the dykes.
- (3) Thickness of the dykes and extent of crustal stretch.
- (4) Dips of the dykes in relation to the lie of the lavas.
- (5) Regional folding and faulting of the lavas.

- (6) Relationship between dykes, sills, lavas and plutonic intrusions.
- (7) Possibility of metamorphism and pneumatolysis of lavas and dykes by plutonic intrusions.
- (8) Petrology of the dykes, sequence of magma types and nature of intersections of dykes of possibly different ages.
- (9) Detailed study of the pre-trap topography and possible modifications thereof by subsequent folding or faulting.

*Lateritic rocks.*—They occur along the Deccan trap border, as large or small, separate, linear belts or strips, and are mostly overlain by the Gaj beds, miliolite series and alluvium. The most prominent belt is in Bhavnagar, 20 miles long and some two miles wide. The lateritic rocks probably represent an original volcanic eruption subsequent to the Deccan trap flows.

The average thickness of the lateritic rocks is about 50 feet, but sections showing 200-250 feet thick formation are also known. A large part of the rocks must have been denuded before the deposition of Tertiary sediments in Kathiawar.

The lateritic rocks are usually unstratified and consist of soft, variegated clays or concretionary, ferruginous earthy rock, representing decomposed and lateritised volcanic rocks. They are identical with the so-called 'high level laterite' of the Indian peninsula. A variety of white or coloured, mottled, soapy clay, containing lumps and lapilli of an altered ash or tuff, is reported near Bakharla and other places in Porbandar. Similar rock is excavated near Habardi and Asota in Nawanagar. Ferruginous red and mottled earthy rocks are seen at Tukra in Porbandar, west of Asota and near Bhatia in Jamnagar. A type of white lithomarge or Fuller's earth is present in Bhavnagar, Junagadh and Jamnagar.

*Gaj beds.*—The rocks of the Gaj group occur as small or big isolated patches, at intervals, near the coastal areas, from Bhavnagar up to Jamnagar, along the margin of Deccan traps and laterites, and also as some inliers in the alluvium. The formation is marked by the typical prevailing yellow colour of the constituents, namely, limonitic limestone, sandstone, grit, conglomerate, yellowish clays and marls. Gypsum is found in clays and marls.

The beds are commonly horizontally disposed and invariably carry numerous fragmentary fossils of pelecypods, gastropods, bryozoa, corals, etc. They are often overlapped by miliolite of varying thickness.

No continuous vertical sections showing the full succession are available because of the usual flatness of the country and the marked horizontality of the beds. The thickness of the individual sections usually varies between 25 and 50 feet. The total thickness of the formation would amount to several hundred feet.

Commencing from the south-eastern area in Bhavnagar, the fossiliferous Gaj agate-conglomerate is seen near Akwara. Marine fossils similar to those found near Akwara are recorded near Bhumbhli, in cross-bedded, coarse, sandy and calcareous grit with small agates. Ferruginous and agatiferous conglomerate bed is noticed further to the south, on bluish grey clay-shale.

Agate-bearing conglomerate is seen at Kharaslia in a stream section and contains some fossil wood. The following section, in descending order, is noticed further upstream:—sandstone; agate-bearing conglomerate with partings of ferruginous sandstone; light yellow clays and pale-bluish white clays.

The crest of the hill ridge two miles west of Hathab, six miles south of Gogha, shows a hard, ferruginous, red and yellowish conglomerate, with agates, flint, jasper, etc., overlying a mottled yellow clay, which in its turn is underlain by a coarse earthy sandstone.

On the Gogha coast are seen flags and sandstones containing conglomeratic bands, similar to the Piram Island rocks. The Little Piram Island in the vicinity is well known for the discovery of a number of fossil mammalian bones by Baron Carl Von Hugel and other geologists. The Piram beds are considered marine or at least estuarine and are equivalent to the formations on the mainland at Gogha.

Gaj beds crop out, continuing further round the coast, near Jafrabad where yellow marly limestone rich in fossils is noticed. Other exposures are seen between Natej and Umes. At Wasawar fossiliferous shaly and flaggy limestones are common.

In the south-west coast, the Gaj beds consist of yellowish argillaceous limestone with large remains of fragmentary organisms. Around Chorvad the rocks cover some 16 square miles and are mostly yellow argillaceous or marly limestone and yellow clays. The Gaj beds continue further in the Porbandar area, near Miani creek, Bharwara, Visawar, Tukra, Bhogat, etc.

Continuing further north-westwards from Porbandar area, the fossiliferous Gaj beds are very conspicuous and widespread in the Okha Mandal and Jamnagar areas. Apart from north of Gurgat and Pindara, where the beds show a gentle tilt towards north, the beds in general are horizontal.

The Tertiary rocks around Gogha have been studied in recent years by Drs. P. K. Ghosh (10), H. Crookshank (11), and J. A. Dunn (12), in reference to possible oil-bearing structures. Their work has shown that the Tertiary beds in this part of the peninsula have been more seriously disturbed by strong faulting and local flexuring than what was hitherto believed.

*Dwarka beds.*—Largely developed near Dwarka and in Nawagar area in the north-western part of the Kathiawar peninsula, the Dwarka beds are lithologically different from the underlying Gaj beds, and consist of variously coloured limestones and yellow, earthy, marly or clayey beds, partly gypseous with iron-stained harder bands.

These beds have been separated from the Gaj beds, on account of the absence of any Gaj fossils, although fossil evidence is too meagre for determining their relationship with the Gaj beds. Indeed, apart from a concretionary gritty band near Gogha, showing a small *Pecten*, not detected in the underlying Gaj beds, and organic fragments of shells, corals, etc., no fossils have been recorded in them.

The typical Dwarka beds forming the Dwarka cliffs along the coast show 20-30 feet thick beds of generally impure limestone with shelly fragments. The formation is suggestive of a littoral sea deposit judging from characteristic current or cross-bedding.

Dwarka beds are conspicuous in the low-lying areas and in some parts of the southern Okha Mandal. The marly clays, together with sandy limestone and calcareous sandstone, indicate similar rocks in Beyt Island. The limestones and marls at Positra

and Mulwasar, rarely showing hollow casts of some branching coral, also represent the Dwarka beds. The porous or partly compact gritty yellowish limestones, hardly found at any great distance from the coast, designated as, 'coast-fringing rocks', are tentatively regarded by Fedden as members of the Dwarka group.

*Miliolite series.*—A group of an almost pure variety of fossiliferous limestone in Kathiawar is known as the miliolite or Porbandar stone. A typical miliolite limestone is a finely oolitic freestone composed of minute foraminifera whose tests form the nuclei of the oolitic grains. This formation appears to be mostly a marine-littoral deposit, although partly it may represent wind-borne aeolian accumulation. Throughout the Province of Kathiawar these deposits are found in the gorges in the hills and on their tops or flanks, indicating that the country was submerged under the sea within recent times. The fact that miliolite limestone occurs in some of the hills to a height of some 1,000 feet above sea level is explained on the assumption that the period of depression was followed by one of upheaval.

The miliolite series forms low hills and cliffs along the coast and also extends inland, covering a great part of the country. The hills along the seaboard generally follow the coast line, but in the interior they are mostly ill-defined. The miliolite series also overlaps the Gaj beds and covers a large portion of the laterite formation. It spreads over the Deccan traps as incrustations.

The constituent members of this series are limestone, earthy concretionary limestone, calcareous sandstone, consolidated shell-sand, grit and conglomerate. Grading of one type into another is common. The rocks differ considerably in texture, and the size and the nature of the individual beds also vary both vertically and horizontally. The purer limestone bands are homogeneous and fine grained and usually vary from 1-3 feet up to over 100 feet in thickness. They have a white grey or cream colour. The impure varieties have a yellow or pink colour and are fine or coarse grained in texture. The sandstones vary from occasionally massive types to flagstones and even sandy shales. They vary from fine grained rocks to grits or conglomerates. Their colour is usually grey, buff or greyish-brown.

The rocks of the miliolite series are practically horizontal. Occasionally the outcrops show dips between 10 and 15 degrees, generally to the south, south-east or south-west, although northerly

dips are also observed. Strong oblique lamination due to current-bedding or aeolian action is a common structural feature. Sometimes the rocks appear to be poorly cemented, showing cross-bedding in various directions; they may represent submerged sand dunes, the sand being cemented partly by percolation of lime. The rarely observed inclination of the beds may not represent true dips, the inclination being due to cross-bedding or slump of beds consequent upon undercutting along the coast. The beds along the coast are mostly littoral accumulations and appear to have been slightly raised in recent times. The presence of dead coral reefs fringing the coast, and dead oyster beds above the head of the Gulf of Kutch, are suggestive of the uplift of the land during recent times.

The total thickness of the miliolite formation is not yet known with certainty; the cliffs are 50-150 feet high, and the quarries and wells in the interior have not penetrated the full depth of the deposits to meet the Deccan traps. The total thickness may perhaps amount to several hundred feet. Of course, the individual sections are highly variable, ranging from a mere streak of a few inches in thickness to beds 150 feet or more in thickness. In general the outcrops show a great diversity of form and size, varying from isolated patches a few yards across to those of large extent.

*Alluvium.*—Under this are included a variety of deposits, e.g., sand dunes, consolidated shore sand, tidal mud flats, raised beaches, coral reefs and fresh water alluvium. A large part of the area along the seaboard is covered by this formation. Sand dunes are common in the vicinity of coasts and in the Rann border. Fresh water alluvium is observed along the river valleys. The alluvial stretches along the northern border of Kathiawar merge into the Rann of Kutch, a low-level saline waste, representing an arm of sea from the present Gulf of Kutch, now silted up by mud and sand accumulations brought by streams of the surrounding terrain.

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## CHAPTER V

### GEOLOGY IN ENGINEERING AND AGRICULTURE

#### GENERAL

In the preceding chapters a general outline of the physiography and general geology of Saurashtra has been given, and it is now proposed to discuss the general principles which govern the application of geology to the various aspects of engineering and agriculture, in the light of available geological information in Saurashtra.

While it is perhaps not essential for the civil engineer to consult a geologist on minor problems, there should be a closer co-operation between them to the advantage of both, particularly in major engineering undertakings. The Geological Survey of India has been the principal governmental agency, giving technical advice on diverse problems on engineering geology, namely, dam-sites, ground water surveys, road and railway alignments, construction materials, earthquakes, etc.

In view of the ever increasing number of investigations all over India including geological mapping, mineral investigations and engineering geology, hitherto it has not been possible for the Geological Survey to pay much attention to Saurashtra, particularly in view of the lack of sufficient number of trained personnel. With the steady expansion of the Geological Survey the position has been slowly improving, and it is hoped that the Department would be able to assist the State to the desired extent, particularly on long term regional investigations.

In recent years various geophysical methods, e.g., gravity, magnetic, seismic and electrical surveys, although primarily concerned with locating hidden mineral deposits and in elucidating sub-surface conditions, have proved successful in solving certain problems connected with dam foundation, ground water supply, tunnelling, etc.

#### UNDERGROUND WATER SUPPLY

The subject of water supply is closely connected with geology. Civil engineers have great responsibilities in maintaining public

water supply, and greater emphasis should be laid on a careful study of geological data on all specific or regional problems, apart from the technical and engineering side of water supply, whenever new water works are installed or augmentation from existing sources is planned.

In abstracting water from river beds it is often drawn by infiltration through porous sand or gravel beds. Success of wells and tube wells, shallow or deep, either for irrigation, industry or domestic requirements, will depend on geological factors, and therefore a closer co-operation between geologists and engineers should be of great value. The present practice of indiscriminate borings, often resulting in unnecessary and even wasteful expenditure, should be avoided.

The ground water characteristics in Saurashtra, in relation to the various geological formations and structures, are dealt with in a general way in Chapter VII.

#### DAM SITES AND RESERVOIRS

Reservoirs or surface storages of water are meant for irrigation, generation of hydro-electricity and water supply. Although there are no great prospects of impounding water for hydro-electric purposes in Saurashtra, owing to lack of large catchment basins, all possible sites should be explored for creating reservoirs for irrigation and town water supply. Hitherto, the interests of the individual princely States proved a handicap to proper development of projects.

Most of the towns in Saurashtra have to face increasing population and therefore there is a great need for additional or new storage of water. Besides, there is also a growing necessity for surface reservoirs for agricultural purposes in view of scanty rainfall in general.

No reservoir should be built unless the engineering aspects and geological considerations have been carefully examined. Broadly speaking, there should be no difficulty in creating storages by building dams in Saurashtra, as could be judged from our geological knowledge of the State, but then each project will have to be thoroughly investigated from the geological point of view in co-operation with the civil engineers.

Besides questions relating to the availability of construction materials for dams and the watertightness of the reservoirs, the most important consideration in the selection of a site is the problem of foundation conditions. There is no use building a dam if the reservoir is not likely to hold water or if the foundation rock is not capable of bearing the weight of the dam. A reservoir when full exerts a considerable amount of water pressure, and unless founded on a suitable rock, the dam might fail and cause very serious damage to life and property.

The geology of the catchment area, as given in the existing one inch geological maps, may be useful in getting an idea of run-off and percolation, but further geological observations will have to be made in some cases. The area to be flooded, i.e., the reservoir basin, should be geologically examined in detail with a view to ascertaining the possibility of serious leakages under hydrostatic pressure. Large scale geological mapping would indicate any possible faults or pervious formations.

The position of the water table has an important bearing on the permeability of the reservoir basin and should be investigated, along with questions affecting silting. Sometimes it may be advisable to determine the permeability of the reservoirs by means of actual tests, i.e., by pumping or injecting water down drill holes under pressure and observing the actual losses. The alluvial areas along the coast should be preferably avoided, so also the lateritic belts and gypsum-bearing Gaj formations.

The preparation of a large scale geological map of the dam-site is essential. Exploratory bores will have to be undertaken at the dam-site to determine the foundation conditions and to avoid weak formations or geological structures liable to cause sliding or subsidence of the dam foundation. Generally fresh Deccan traps would provide excellent foundation condition unless underlain by inter-trappeans or red boles at a shallow depth. All structural features such as bedding planes, dip of strata, presence of folds, faults, joints, fissures, crushed zones, etc., will have an important bearing on the dam foundation. The bearing power or crushing strength and porosity of the rocks are also important factors to be determined.

Often it may be necessary to condemn a site after geological examination and to find an alternative site in the neighbourhood

or some distance away. Modern engineering practice often makes it possible to design the structure so as to avoid the zones of weakness, eliminate leakage possibilities below dam or strengthen the weak zones by cement or asphalt grouting, etc.

Mention may be made here of the Willingdon reservoir built in 1936, on the western flanks of the Girnar hills, about  $1\frac{1}{2}$  miles S.S.E. of Junagadh city. The dam is 850 feet long and 45 feet high. There is considerable leakage from the masonry of the dam, which, besides, is not founded on sound trap at its left abutment. Constructed with the object of impounding 200 million gallons of water, this reservoir has never been filled to date, although further supplemented by a 15-inch hume pipe feeder line from another catchment.

In areas liable to earthquake shocks, the structure is made sufficiently strong to resist the vibrations and a large factor of safety is included in the design.

#### ROAD AND RAILWAY ALIGNMENTS

A knowledge of the local geology should be of great help in the choice of alignments for road and railway. Surveys will have to be undertaken for obtaining detailed particulars about the availability of construction materials, water supply, bridge foundations, and safety of cuttings or tunnels, excavations, embankment fills and retaining walls.

#### TUNNELLING

Tunnels are driven to maintain an alignment through a mountain or ridge, avoiding long detours, for the construction of roadways or railways. The engineers want to know about the condition and structure of the rocks likely to be met with in tunnelling. This information is needed not only to prepare estimates of works but also for guarding against possible risk of accident due to underground water or looseness of the rocks, etc.

Similarly, in case of any pressure tunnels, engineers require geological data for helping in questions of design and construction methods. A detailed geological examination of tunnel alignments may often save much expenditure and give much useful information of practical value to the engineer.

## AIRPORTS

It is said that one accident in every eight in aviation in America is due to faulty landing ground, and therefore preliminary geological exploration is considered necessary to examine the sub-surface nature of the airport area.

A knowledge of local geology should be of great help in selection of sites for airports or landing strips. Engineers want to know about the ground conditions with a view to designing a drainage system over a wide strip of level ground with a proper gradient and a minimum of excavation. In a porous formation there would be no difficulty, but in case of a clay or non-porous rock underlying the site, great care will have to be exercised to build a system of efficient drainage and to prevent the development of a marshy condition.

Nowadays the tendency is to build airports or landing grounds near all important cities. It is always worthwhile obtaining geological advice about the suitability of the sites before incurring expenditure on construction.

## DOCKS AND HARBOURS

Geology has a bearing on the construction of harbours or docks and process of silting, sedimentation, etc. Geophysical exploratory methods are nowadays employed to determine the thickness of the alluvial silts overlying rocky floors while building docks and ports along rivers or coasts. An underwater geophysical survey was recently carried out successfully at the port of Algiers for locating the bed rock surface below the superficial sediments.

Although the Gulfs of Kutch and Cambay might offer some problems due to heavy silting, some coastal areas in Saurashtra should be very favourable, as rock surface is likely to be met with at shallow depths for development of harbours and ports. Prior geological examination, aided by borings when necessary, should be undertaken as a matter of routine, for improvement and maintenance of the existing harbours.

## BRIDGE FOUNDATIONS

It is widely known that many bridges, ancient and modern, have failed because of defective foundations of the bridge piers

and abutments. Although efficiently designed and constructed with excellent materials, under proper supervision, no bridge would be considered safe unless built on a suitable foundation.

Often not much choice could be exercised in selection of a site, owing to considerations based on economy and shortest alignment, and the engineer is forced to accept the foundation conditions and design the bridge accordingly. A preliminary geological survey is, however, sometimes helpful in locating an alternative alignment, possibly not far away from the proposed alignment, but at the same time offering better foundation conditions.

Settlement of bridge foundations are generally due to one or other causes, e.g., scouring action, deformation by crushing or alteration of water content, lateral shifting of underlying strata and failure of a weak foundation bed. These factors are determinable by a detailed geological examination of the site and laboratory test of samples.

### BUILDING FOUNDATIONS

In designing and constructing buildings, the engineers determine the load on the foundations, find the nature of the bed rock or sub-soil and other relevant details.

No foundation difficulties are encountered when rocks are either exposed or occur near the surface. Generally all fissures, joints, fractures, etc., will have to be treated, and weathered rocks removed in founding buildings. In case of exceptionally heavy structures, the presence of any weak intercalations in an otherwise sound trap rock at a shallow depth might cause subsidence. Any faulted and sheared zones in weak formations will have to be avoided. The bearing strengths of the foundation rocks are of importance. Other structural features of the bed rock have also to be taken into account.

When the rock surface is concealed by a shallow superficial cover, the load could be transmitted by certain forms of foundation, e.g., by piles, rafts and piers. The maximum depth reached by such form of foundations economically is said to be 250 feet. The determination of the contour of the underground rock surface

by sub-surface exploration, laboratory tests of soil samples, and investigation of the ground water conditions are essential.

When buildings have to be founded on unconsolidated foundation, i.e., in case the bed rock cannot be utilised as a foundation being at a great depth, explorations are also desirable to determine the sub-surface conditions, for efficient and successful designs in case of heavy structures. Small structures or buildings, however, do not present any problem, unless in a region liable to some earthquake shocks, when earthquake proof designs in building constructions would be helpful. Grouting of cement or injection of chemical solutions often improves the loose soil which is partly consolidated during the process.

### CONSTRUCTION MATERIALS

As most of the construction materials used in engineering projects, e.g., earth, clay, sand, lime, building stones, aggregates, etc., are directly connected with the materials of the crust of the earth, the civil engineers are often faced with the problem of locating adequate sources of such materials. Geological maps often give valuable help in that direction, but specific information with regard to the available quantity of the desired materials will have to be obtained by surface explorations and laboratory tests.

The various factors which generally determine the suitability of the different stones for constructional purposes (building stones, road metal, ballast and aggregates) are availability in large quantities, workability, colour or appearance in case of ornamental building stones, cost of dressing in case of dimension stones, strength, durability and porosity. Some standard physical tests (density, porosity, crushing strength, etc.) are desirable, particularly when a high quality material is to be selected.

Petrological study will reveal the nature and grain size of the mineral constituents, texture, nature of cementing materials (siliceous, ferruginous or calcareous), etc., and will give an idea of the durability of the stone.

The building materials available in Saurashtra will be dealt with in Chapter XII.



## SOILS

Generally considered, there are two types of soils. One variety, known as transported soil, represents transported materials, e.g., alluvium, sand, silt, etc., which have deposited along river valleys and coastal areas. Barring the coastal sandy soil and saline mud flats, the alluvial soil along rivers is extensively used for agricultural purposes. The second type of soil called residual soil, results from the alteration of underlying rocks and is found on tops of mountains, hills or plateaus. This type of soil is also used for cultivation. Geologically speaking it takes several thousands of years for nature to convert rock into soil one foot deep, suitable for cultivation, but it may be eroded and washed away quickly if not protected.

The north-eastern part of Saurashtra, adjoining the rich, fertile tracts of Gujerat, is a flat alluvial terrain consisting of grey or dark soil supporting extensive cultivation. The mud flats and tidal creeks along the coast and the Rann alluvium are too highly saline to be of any use for cultivation.

The alluvium and miliolite formation along the coast are covered by a variety of black cultivable soil, at times containing *kankar* concretions, but a reddish or brownish sandy soil is not uncommon over such formation. The Gaj and Dwarka beds sometimes alter into large, thick spreads of a yellowish soil or loam, although parts of these formations appear to be under a grey or black soil, suitable for agricultural purposes.

A red or variegated earthy soil is common over lateritic rocks. The lateritic soil varies in thickness from a few inches to several feet and is generally not suitable for cultivation owing to its ferruginous and colloidal nature.

The Deccan traps produce black cotton soil, known as *regur*, although sometimes spreads of lateritic soil are not uncommon. *Regur* often contains lime-rich *kankar* nodules and constitutes by far the most prevalent soil type in Saurashtra. It varies in thickness from a few inches to many feet and is suitable for agricultural purposes. It is akin to the Russian "Chernoziem", American "prairie soil" of the cotton-growing areas and Californian "black adode". The soil is highly argillaceous, retains considerable moisture even if dry and is high in lime, magnesia and alumina.

It is generally poor in phosphorus, nitrogen and organic matter and contains a moderate range of potash; the proportion of iron is high.

The Jurassic formation is a poor soil-former and generally alters into a sandy soil, at times reddish or yellowish in appearance, and generally does not support cultivation except sparse vegetation.

With the exception of some organic materials derived from vegetable and animal life present in soil, practically the entire constituents of soil, e.g., silica, clay, lime, potash, phosphate, manganese, etc., owe their origin to transported sediments or the underlying rocks. A knowledge of geology therefore should be very helpful to foresters and agricultural engineers. Only a general outline of the distribution of soils and their bearing on the solid geology, i.e., underground rocks, is given in the above paragraphs but a detailed scientific soil survey should be undertaken in Saurashtra in the near future.

In certain parts of India soil erosion has caused widespread destruction of agricultural lands and forests and offered serious problems to the foresters and agricultural engineers in the matter of soil conservation. Excessive soil erosion also presents grave problems to the civil engineers who are concerned with minimising silting in reservoir basins, rivers and canals.

Naturally the processes of soil erosion are more pronounced in steep hill sides and highly dissected mountainous regions than in a flat terrain. In areas of heavy rainfall, soil erosion can be very prevalent. Wind erosion also plays an important part in removal of soil. Over-grazing and deforestation cause serious erosion particularly in hilly and mountainous terrain.

In Saurashtra the problem of soil erosion is not serious. The usual methods of checking it by contour trenching or ridging, control of over-grazing, afforestation on steeper slopes, plugging of gullies, construction of weirs and barriers (detention dams) in checking streams to flatter gradients and other engineering conservation means should be successful in checking serious erosion of soil.

In parts of the western coast of India, e.g., at Bombay, Saurashtra and Kutch, evidence of recent rise in the land has been

observed. The slow crustal uplifts in the coastal areas of Saurashtra have presumably caused certain amount of rejuvenation of streams but no large scale erosion of the soil cap has been noticed because of this.

In recent years great progress has been made in the subject of soil mechanics, in methods of sampling, mechanical analysis, classification and laboratory tests of soils. These ultimately help the civil engineers in working out plans and designs of engineering projects.

## CHAPTER VI

### EARTHQUAKES

The Himalaya mountains and the connected arcs around the northern limits of India, representing an orogenic belt, indicate an unstable region liable to severe earthquakes. The junctions of the mountain arcs in Assam, Kashmir, Baluchistan and Sind are particularly susceptible to strong seismic disturbances. The Indo-Gangetic alluvial region, a depression consisting of unconsolidated alluvium, possibly a fractured sag in the earth's crust, is also liable to seismic shocks. The Indian peninsular shield, an ancient landmass, is a region of comparative stability, where no great shocks are usually anticipated.

The Rann of Kutch, linked to the unstable region of Sind and the delta of the Indus, experienced a severe earthquake in 1819, resulting in the creation of a 16-mile long elevated mound-like feature rising above the plain, parallel to the northern Rann border, commonly known as the *Allah-Bund* (dam of God). According to R. D. Oldham (1), both rising and sinking movements occurred, amounting to a total displacement of 20 feet 6 inches. This earthquake, which had its epicentre north of Kutch, destroyed many buildings between Paliyad and Ahmedabad, and wrecked the alluvial regions along the northern and western coasts of Saurashtra. Central Saurashtra, composed of a great basalt shield, however, suffered very little or no damage (2).

An unstable terrain is found to the north-east of Saurashtra in the plains of Gujerat up to the Gulf of Cambay, and the Tapti and Narbada valleys, where signs of recent uplifts are very common. These regions are also susceptible to earthquake shocks.

A minor earthquake shock was recorded in 1864 in many parts of the Saurashtra peninsula. It was preceded by a rumbling noise followed by a vibration for six seconds. A shock was felt at Rajkot in 1881. Minor shocks occurred in Saurashtra in 1899 and in other years, without causing any damage.

According to Dr. H. Crookshank (5), the series of earthquake shocks at Paliyad (22°15': 71°33') in Saurashtra in 1938 was the

first of its kind with epicentre in Saurashtra. This was felt in Viramgam, Bhavnagar, Morvi and Rajkot, over an area of at least 4,000 square miles, the maximum intensity reaching VII on the Mercalli scale. Regarding another severe earthquake at Rampur, 12 miles from Paliyad, recorded by Oldham in 1926, Dr. Crookshank suggests that it was due to the existence of some favourable subterranean features.

The recent geological history of Saurashtra shows a general uplift of some 1,200 feet, judging from the evidence of miliolite on Chotila hill, 1,173 feet above sea level, and the presence of raised beaches, coral reefs, etc., much above the high-water mark of recent times.

The past history of Saurashtra indicates that a major destructive earthquake, with epicentre in Saurashtra, is most unlikely, although it is probable. The possibility of a future earthquake of great intensity, with epicentre in Sind or in the Indus delta, from where two serious earthquakes originated in historical times (3), cannot be ruled out. If such an earthquake occurs, the country occupied by alluvium and unconsolidated rocks in the coastal areas and in the region abutting the Rann of Kutch is liable to serious destructions. The trap areas may be considered much safer.

Japan has carried out extensive researches on earthquake resistant structures for buildings, dams, bridges, etc. The idea is to design suitable structures making allowance for a seismic factor, e.g., resistance to horizontal acceleration. Countries like Japan, New Zealand, Italy, Greece, Mexico and California, have nowadays advantageously adopted standard earthquake designs for constructions in regions liable to seismic disturbances.

The general principles to be observed in design of buildings and structures in seismic areas have been discussed in Geological Survey of India publications on earthquakes. The following notes from Messrs. Auden and Ghosh's report on 1934 earthquake in Bihar (4), with regard to the general design of buildings, would be of interest:—

“Buildings should be of simple design, the parts so well-tied and the whole structure so rigid that it would react as one unit to earthquake waves. The several parts of irregular buildings

do not synchronise during a shock, and severe stresses are set up between the individual units. These remarks apply especially to high structures, e.g., a church steeple erected on a tower is frequently destroyed from the base of the steeple; the tower and steeple each having a different vibration period and opposing directions of movement, with the result that the acceleration can be doubled."

"Buildings should be kept as low as is conveniently possible compared with their lateral dimensions. The object should be to keep the amplitude of vibration as low as possible at the highest part of the structure, and so reduce acceleration, for any particular period of vibration."

"Buildings of irregular shapes, with wings, protruding verandahs, porches, etc., have invariably suffered. The same applies to buildings to which additions have been made by the abutting of new walls directly, on earlier ones, without dovetailing. The whole building should form one unit. Verandahs and porches should not consist of a series of independent pillars with a roof resting on top, but should be integral parts of the building."

"Excrescences, such as towers, turrets, pinnacles, etc., are dangerous both to human beings and to buildings, and should be avoided. Flimsy parapets, balustrades, and similar structures have caused death to many."

"Windows are a source of weakness to buildings, and a more careful and better spacing should be attempted. Windows should be kept away from outer corners of buildings as far as possible. Wide window areas should be compensated by stronger intervening walls."

"The use of timber-frames in *kutch*-*pucca* and *kutch* buildings should be encouraged. Buildings consisting of a platform or sole-plate supporting timber verticals that are well-tied by cross and diagonal beams and firmly attached to the roof are preferable. The weight of the roof would thus be shared both by the walls and the pillars and the tendency of the walls of such a building would be to move together as a unit. Timber pillars are greatly to be preferred to brick pillars."

Dr. H. Crookshank in his report on 1938 earthquake shocks at Paliyad (5), refers to certain points on design of buildings, roofing, mud huts and width of streets, which are reproduced below:—

*“Design of Buildings.*—There are some very old houses in Paliyad made of masonry with a wooden framework. These were not damaged at all by the recent earthquake. I have no doubt that an extension of this form of building in Kathiawar would be a valuable insurance against earthquakes, but it is doubtful whether suitable timber for this purpose could be obtained nowadays at a reasonable cost.”

*“Roofing.*—Lightness is the object to be aimed at in roofing. The Mangalore and country tiles now used for the purpose are rather heavy. In a severe earthquake they might crash down as one piece, burying everything under them. The large sheets of asbestos now sold for roofing would be much lighter and less destructive if they fell. They are said to be little dearer than Mangalore tiles. If they could gradually replace the tiles throughout Kathiawar it would greatly reduce the danger from earthquakes.”

*“Mud Huts.*—The homes of the cultivators have mud walls. Where these have been built on a good wide stone plinth, and with a suitable taper, they have not collapsed. Those walls that have fallen were damp, the moisture having risen and permeated them through a badly constructed and inadequate plinth. If these plinths had watertight lime fillings, it would be a great improvement.”

“It is the local practice to add straw, pieces of tile, or pottery, and small chips of stone to the mud walls. This practice is probably excellent but in some of the mud walls which had fallen I saw quite large rounded boulders. These are undoubtedly a source of danger, and should be avoided in this form of building.”

“Nearly all the mud walls were cracked at the corners. Cracking of this sort would be greatly reduced if there is a timber framework such as has already been described. It is doubtful, however, if this would be worth the expense.”

“Most of the mud huts have roofs made of half-round country tiles. These would certainly crash down and bury the inhabitants in a bad earthquake. I regard them as much more dangerous

than the mud walls, which would probably collapse without doing much harm. Thatch or asbestos sheeting would be a great improvement. Unfortunately the former is not available in this part of Kathiawar and the latter is probably too expensive. The use of these materials for roofing should be encouraged as soon as possible."

*"Width of streets.*—The streets in Paliyad and in most of the older towns in Kathiawar are narrow. Every opportunity should be taken to increase their width. The coastal towns in Kathiawar, especially those in the north and west, are probably the most vulnerable to earthquakes. If their streets are as narrow as those in other parts of Kathiawar, steps should be taken as soon as possible to widen them."

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## CHAPTER VII

### WATER SUPPLY

#### GENERAL

In many respects water may be considered as a mineral, with the exception of one fact that unlike minerals in general it is replenished annually by rainfall and migrates under suitable conditions from higher levels to lower levels, its underground movement depending on several factors like topography, sub-soil, nature and structure of rocks, etc. It will be thus realised that no ground water will be available unless favourable conditions are present. Other alternative sources of water, e.g., storage reservoirs, tanks, etc., will have to be depended on in the event of inadequacy or lack of ground water.

Rain water is the principal source of both surface and ground water. While a part of rain water runs off to the sea by the natural drainage system, a part sinks into the soil down to bed rock to form the ground water, and a part is lost by evaporation, the proportions varying in accordance with local relief, climate and geological conditions. Absence of gradient, porosity of rocks, warm temperature, vegetation, etc., facilitate underground seepage of water, whereas compactness of rocks, steep gradient, absence of soil cap, lack of structural features in bed rocks such as bedding, fissures, etc., cause severe losses by run-off. Much rainfall in a short period encourages floods and quick run-off, but a small rainfall spread over a long interval generally facilitates percolation.

A part of the surface water from natural or artificial storage and from canals may also find its way into the ground and augment the ground water resources. The bottoms of the storage reservoirs are sometimes impervious as a result of silting by clays.

Ground water may emerge out as ordinary springs, due to certain conditions of geological structure. The artesian springs or bores owe their origin to confined water in a porous bed between impervious beds under hydrostatic pressure. In order to have favourable conditions for an artesian supply, the aquifers should

have a suitable gradient, and have satisfactory means of receiving rain water.

The location of sites for bores to tap underground water should be based on available geological information, supplemented by additional observations. In order to avoid unnecessary waste in time and money, it would be always worthwhile to get expert geological advice on the location of bore hole and well sites. Nowadays geophysical surveys are also undertaken to locate concealed aquifers with great success.

The spacing of wells or bores should be so arranged so as to avoid mutual interference, with due considerations of the probable size of the cone of depression around wells or bores. Indiscriminate drawing of water or overpumping may often lead to exhaustion or lowering of the ground water, and may cause brackishness in certain areas. The capacity or safe yield of wells should be determined by actual pumping tests. As the abundance of water is governed by textural and structural features of the bed rocks, it should be emphasised that deepening of wells or bores will not necessarily augment the yield beyond certain limits.

The ground water resources of any region are determined by actual calculations of run-off, percolation, etc., water table observations, and geological considerations based on large scale mapping, aided by exploratory bores whenever necessary.

The conservation of this natural resource is necessary in thickly populated cities. It is necessary to avoid, either by legislation or other means, the serious, steady depletion of ground water resources. Excessive borings in an artesian basin, lack of regulation of private operations, overpumping, etc., depress the water table considerably, lower the yields of wells, undermine the pressure in artesian wells, and may result in contamination of ground water by saline or brackish water. Eventually, perhaps, a system of licence for wells and bores and closing of wasteful bores, as provided in the Burma Underground Water Act of 1930, would be necessary.

The ground water resources of Saurashtra will eventually have to be determined by detailed geological mapping, but the lack of large scale contoured topo-sheets is a handicap at present. This is a long range problem which will have to be studied in colla-

boration with an exploratory drilling programme. The ground water potentialities of the principal geological formations in Saurashtra, however, could be discussed in a broad way, under the following sub-heads, i.e., alluvium and miliolite formation, Gaj and Dwarka beds, Deccan traps and Jurassic rocks.

#### ALLUVIUM AND MILIOLITE FORMATION

With the exception of the low-lying tidal flats or saline tracts along the coast, generally abundant water is available for domestic needs and for some irrigation in alluvium and miliolite formation, within a shallow depth from the surface. In Veraval coast wells yield a good supply of potable water usually within 20 to 35 feet. The water table in Bhavnagar coast, a low saline tract, generally ranges between 20 and 25 feet in winter, the average yield per well being 300 to 500 gallons per hour; the water is mostly brackish. The coastal areas near Jafrabad at times contain abundant water for domestic and irrigation purposes, the water table being generally within 10 feet in winter.

Deep tube wells for irrigation will depend on the thickness of the alluvium and the disposition of the underlying Gaj beds or Deccan traps. This aspect will have to be considered after exploratory borings which would further indicate the quality of water. Brackish water was struck at Gogha by one 1,016-foot bore, yielding 24,900 gallons per day, presumably from Gaj formation.

In the Rann region sub-surface water is entirely brackish as could be judged from areas bordering Khuda, Kharaghoda and elsewhere. The deep bores generally strike brackish water but instances are known where moderately deep bores struck reasonably potable water. The desiccation of the Rann, once connected directly with the sea, is responsible for the general salinity of the tract. At Kharaghoda there is an 8-inch artesian bore sunk to 317 feet depth, reported to be yielding 6,000 gallons of water per minute. The valve, however, is partially closed to yield only 360 gallons per minute. Near Udoo siding there is an 8-inch artesian bore, sunk to a depth of 273 feet, yielding 331,200 gallons per day when the valve is fully opened. The water from these bores is very slightly brackish but drinkable. The Kharaghoda and Udoo bores appear to have met with the Jurassics below a cover of Rann alluvium.

In the alluvial portion north-east of Saurashtra, contiguous to the alluvial tract of Gujerat, the depth of the alluvium overlying the Deccan traps is highly variable. The formation comprises irregular beds of clays, sands, sandy clays, gravel beds, etc., often with *kankar* nodules, commonly passing into black soil at the surface. As in Gujerat, both potable and brackish water have been struck by shallow or deep bores, the water coming out under artesian condition at times. A bored well at Viramgam is long known to have yielded 200 gallon per minute, from 770 feet depth below the surface. At Gedia, in the Viramgam *taluk*, a 270-foot bore yielded 240 gallons per minute. An 800-foot bore at Dholera gave a supply of 489,400 gallons per day, while another 610-foot bore in the same locality was abandoned as further driving of pipe was not possible. At Dholka a supply of 100 gallons per minute was recorded in an 800-foot bore, possibly all in alluvium.

A regional survey aided by exploratory bores would be necessary to correlate the aquifers in the alluvial tract north-east of Saurashtra and to determine their capacities and quality. The origin of salt may be attributed to the presence of salt in the strata during original deposition or percolation from the Gulfs of Cambay or Kutch.

#### GAJ AND DWARKA BEDS

The aquifers in the Gaj formations are grits, coarse sandstones, limestones, conglomerates, etc. The wells in the Gaj beds near Veraval coast generally yield a good supply of water usually within 20 to 35 feet from the surface. Enough potable water is sometimes met with along the junction of the Gaj rocks overlying the traps, the reason being that the Gaj beds being at times pervious, water freely percolates till it strikes the underlying traps which for all practical purposes represent an impermeable base.

The wells in Bhavnagar in the Gaj beds are sometimes saline, the water table varying between 20 and 30 feet during winter. Their average yield is about 500 gallons per hour.

The Dwarka beds comprising shelly limestone and sandstone, yielded some quantity of water from a 390-foot bore at Adatra (Okha port). The bore was taken to a depth of about 1,000 feet when the underlying Deccan trap was struck.

## DECCAN TRAPS

Practically the whole of Saurashtra, with the exception of the coastal areas and the extreme eastern and north-eastern parts, is covered by the Deccan lava flows. Their characters and total thickness have been already dealt with in Chapter IV. The traps are unreliable yielders of water, although water for domestic needs may be obtained usually between 15 and 40 feet, the water being stored in thick soil cover, decomposed rock, junction between flows, joints and fissures.

Presence of porous "ash bed", sedimentary inter-trappeans, "red bole" and vesicular horizons often augments the yield of water. Wells located on river banks or at the junction of streams are usually more productive. Laterite caps, if any, may hold abundant supply of water under certain conditions. Large concentration of water may also be found along the margins of basic dykes acting as barriers to movement of ground water.

The author, while examining the Central Railway tunnels in the Western Ghats, noted a marked downward migration of water through the vertical or highly inclined shear zones in traps, representing a strain pattern of N.-S. extension in an area of several thousand square miles. A detailed study of the shear zones in traps in Saurashtra, their spacings and vertical range, etc., would be helpful in locating large ground water bodies. Under certain conditions, a large seepage of water is inevitable when open, bedding planes, "red bole" beds, inter-trappeans, joints, fissures, etc., are cut across by shear zones. Intersecting shear zones would cause a greater percolation of water. In case of deep fissures or shearing, e.g., in the Konkan and along the Tapti river in Gujerat, the shear zones are known to have marked influence on the topography and on the orientation of the streams.

In Bhavnagar area the average yield from wells in traps is of the order of 1,000 to 3,000 gallons of water per hour, and in Amreli 1,000 to 5,000 gallons per hour.

In Morvi area the open wells in traps are 25 to 40 feet deep and yield 1,000 to 3,000 gallons of water per hour.

Though wells with fairly large yields can be used for some irrigation, large scale irrigation does not seem feasible in Saurashtra, utilising the ground water sources in traps, as far as could be judged from our present day knowledge. Experience shows that

in other parts of India as in Saurashtra, although it may be possible to get occasional successful bores in traps, bores cannot be recommended universally, except in case of special circumstances or as an exploratory measure. The old records of unsuccessful borings for water in traps, e.g., at Botad (501 feet), Dhanduka (1,951 feet), Jamnagar (1,020 feet), Khambalia (710 feet), etc., are very significant.

The author recently noted two unique bores in traps at Borivli near Bombay, yielding large quantities of potable water, from a sponge-like, chlorophaeite-bearing tuff, under sub-artesian conditions. One bore 270 feet deep, sunk below a 40 feet deep well, struck water at a depth of 293 feet from the surface, the water rising up to the well bottom under its own pressure, the yield being estimated at 7,000 gallons per hour. Another 282 feet deep bore met with water at a depth of 264 feet, the water rising up to five feet below the surface, the pump depression being only five feet below the static level in the bore, in spite of continuous pumping for four hours at 6,000 gallons per hour. According to a recent news item, a six-inch bore below a 40 feet deep well, also near Borivli, yielded 14,000 gallons of water per hour at a depth of 240 feet from the surface. The high rainfall in the area (80 inches per annum), gentle tilting of the traps towards west, flatness of the terrain receiving large quantities of water from the mountainous region to the east, presence of thick and porous aquifer, etc., have contributed towards the success of the bores.

The Californian basalts, by virtue of their folding, are sometimes known to be structurally suitable for storage of underground water, but similar conditions have not been noticed so far in Saurashtra, although the presence of synclinal folds suitable for storage of water is not altogether ruled out. The detailed geological mapping of the trap flows, their structural features, and associated dykes, shear zones and faults, when large scale contoured top-sheets would be available, might be of great help in future. An accurate determination of the pre-trappean relief, whether flat or dissected by ridges and valleys, by exploratory bores whenever necessary, would be most useful in locating large ground water possibilities.

#### JURASSIC ROCKS

The Jurassic rocks occupying the extreme north-eastern part of Saurashtra with their beds of sandstones, clays, shales, etc., yield

both sweet and brackish water in the open wells which are generally 25 to 40 feet deep. The surface wells in Jurassic rocks in Morvi yield 2,000 to 4,000 gallons of water per hour. The brackishness is probably linked to saline water from the Gulfs of Cambay and Kutch or to the salt content of original sediments.

In Morvi sub-artesian water, yielding 10,000 gallons or more per hour, is reported from bores taken in Jurassic rocks. There are three principal aquifers, i.e., one near the surface, one at about 200 feet depth, and one at about 500 feet.

The deep borings between Dhrangadhra and Halvad, about 108 feet up to 514 feet, gave large amounts of potable water, the water sometimes coming out to the surface under its own hydrostatic pressure. The maximum yield recorded in a 500-foot bore at Halvad is 36,000 gallons per hour. A boring for water in Wadhwan, however, struck brackish water at a depth of 648 feet in sandstone, but no water was encountered in overlying traps (40-352 feet). Borings between Bajana and Vasavda near the Rann border yielded brackish water at a depth of 309-360 feet, all in Jurassic rocks. Recently a 500-foot bore for coal at Khakrathal, carried out under the supervision of the author, struck artesian water at 65 feet, yielding 1,500 gallons of potable water per hour.

The Jurassic formations which apparently extend below the Gulf of Kutch contain potential sources of water in Kutch. This could be judged from over 2,500 irrigation wells in Bhuj and Anjar areas, where bores are usually taken down to a depth of 80-150 feet from the base of the wells. The presence of folding, giving rise to high hydraulic gradient, is considered favourable for ground water possibilities in Kutch.

The determination of the structure of the Jurassic rocks might delineate artesian areas, while precise location of faults and dykes cutting through the formation would be most helpful in locating large ground water resources. Regional geological surveys on large scale contoured maps should be undertaken in Saurashtra, but then the work will have to be delayed till such maps are available. Parts of the Jurassics of Kutch are being geologically mapped by the Geological Survey on new topo-sheets and photo-mosaics on the scale of two inches to one mile, for assessing the ground water possibilities.

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## CHAPTER VIII

### FUTURE SEARCH FOR MINERALS

#### INTRODUCTION

The general geology of the Saurashtra State is fairly well known thanks to the classical work of Francis Fedden of the Geological Survey of India. Further work by officers of the Geological Survey was carried out both in the past and in recent years, in geological surveys and mineral investigations, and our present knowledge about the mineral resources of the State is thus chiefly due to the activities of the Geological Survey. Our earlier and recent surveys have considerably limited the field of search for minerals, proved the absence of important minerals such as high-grade iron-ores, coal and oil within workable depth in the State and showed the type of minerals which are likely to occur in certain areas.

#### GEOLOGICAL DISTRIBUTION OF MINERALS

The mineral deposits do not occur entirely in a haphazard fashion. There is a relation between the geological formations or rock types in any region with the types of minerals known to occur in that region. The following list gives an idea of the minerals known to be present in the various geological horizons in the State of Saurashtra:—

- |                        |  |
|------------------------|--|
| <i>Alluvium</i>        | .. <i>Kankar</i> , brick and pottery clays, sand, miliolite limestone, chalk, ilmenite, magnetite, gold, <i>reh</i> soil, gypsum and salt. |
| <i>Dwarka beds</i>     | .. Building stones, limestone, clay, marl, gypsum and calcite.   |
| <i>Gaj beds</i>        | .. Building stones, limestone, moulding sand, ochre, clay, gypsum, natural gas, chalcedony, opal, agate, carnelian, etc.                   |
| <i>Lateritic rocks</i> | .. Bulding stones, bauxite, lithomarge, Fuller's earth, iron-ore, manganese-ore, ochre, etc.   |

- Inter-trappeans* . . . Building stones, limestone, shale, ochre, etc.
- Traps* .. Building stones, road metal, railway ballast, pyrite, copper-ore, native copper, lead-ore, gold, ochre, agate, carnelian, jasper, opal, rock crystal, calcite, zeolites, etc.
- Trappean grits* .. Building stones.
- Wadhwan sandstones* .. Building stones, limestone, sandstone, glass-sand and calcite.
- Umia beds* .. Building stones, sandstone, glass-sand, fire-clay, ochre, iron-ore, coal, quartz, jasper, etc.

#### DISTRIBUTION ACCORDING TO DISTRICTS

In the following are listed all the districts in the Kathiawar peninsula, arranged alphabetically, with various types of rocks and minerals which are known to occur in each district:—

- Amreli* .. Building stones, calcite, coal, gypsum, limestone, natural gas, salt and zeolites.
- Gohilwad* .. Bauxite, building stones, calcite, clays, copper-ore, Fuller's earth, gemstones, gypsum, ilmenite, iron-ore, limestone, lithomarge, magnetite, moulding sand, ochres, *reh*, salt and zeolites.
- Halar* .. Bauxite, building stones, calcite, clays, copper-ore, Fuller's earth, gemstones, glass-sand, gold, gypsum, ilmenite, iron-ore, limestone, lithomarge, magnetite, ochres, *reh*, salt and zeolites.
- Madhya Saurashtra* .. Building stones, coal, copper-ore, fire-clay, gemstones, glass-sand, limestones, ochres, salt and zeolites.

|          |  |
|----------|--|
| Sorath   | Bauxite, building stones, calcite, chalk, clays, felspar, gemstones, gold, gypsum, iron-ore, kaolin, lead-ore, limestone, lithomarge, magnetite, mineral water, moulding sand, ochres, <i>reh</i> , salt and zeolites. |
| Zalawad. | Building stones, calcite, clays, coal, fire-clay, glass-sand, iron-ore, limestone, ochres, pyrite, salt and zeolites.  |

#### GEOLOGICAL MAPPING

A detailed systematic mapping in selected areas, along the coastal belt, is being carried out in recent years from time to time. This work has brought to light the existence of high-grade limestone, Fuller's earth, ochres, clays and gypsum. Part of this work will have to be postponed for some years due to lack of large scale topo-sheets. Even then it is doubtful, if new mineral finds would be forthcoming, although considerable valuable information would be expected as a result of a new survey. Metamorphic and crystalline formations, which are indeed the host of the majority of mineral deposits, are absent in Saurashtra. By far the greater part of the area of the State is occupied by the Deccan traps which are not carriers of important minerals.

Hitherto the Geological Survey of India has been seriously handicapped due to insufficient number of trained officers, but with the programme of steady expansion of this Department, the position has been slowly improving, and it is hoped that the Geological Survey would very shortly undertake further and more systematic mapping in the State in the near future. The detailed geological maps are not only useful for advice on mineral prospecting and industrial development but are also helpful in soil surveys for agricultural purposes and in engineering problems such as underground water supply, reservoir projects, railway or road alignments, foundations and construction materials.

## CHAPTER IX

### MINERAL CONCESSIONS

#### EARLIER PROCEDURE

The princely States of Saurashtra, before their integration with the Indian Union, enjoyed mineral rights, and controlled the grant of mineral concessions within their respective territories. In certain cases individuals like *inamdars* claimed mineral rights as a matter of practice and offered mineral leases.

The practice of the individuals having mineral rights is not conducive to proper growth of mineral industry and mineral conservation owing to various reasons, and perhaps the Government of Saurashtra would eventually acquire mineral rights by legislation, but that would involve compensation to the landlords or *inamdars*. It is only possible for the State Government to take a long view of things whereas the individuals would not generally look beyond short term policies which may be detrimental to the future mineral industry.

Although most of the former States of Saurashtra adopted a procedure similar to what was in vogue in British India, in practice no uniform policy was followed with respect to granting of prospecting license, mining lease, area of lease, period of lease, payments of rents and royalties, etc.

Encouragement of private prospecting and mining often lead to fresh mineral discoveries and consequent development of mineral industries. Many Rulers, however, discouraged private enterprisers in the belief that they would surreptitiously pilfer their precious stones and gold.

Formerly it was not uncommon to see an outsider ousting the holder of a prospecting license from his claim to a mineral concession, by offering enhanced payments of *salami*, rents or royalties. The original licensee sometimes lost his hold on the concession if he disagreed to pay the higher royalties or rents. In such case,

the property was auctioned with the higher offer as the minimum bid. Such a policy meant immediate financial gain to the State but eventually proved a deterrent to future private prospecting.

The value of long term leases with provision for renewals on reasonable terms fixed beforehand was not fully appreciated in many States of Saurashtra. Persons holding mining leases were not sure about their renewals on reasonable terms, and as such they generally worked most unsystematically with the sole object of winning the mineral with minimum capital outlay, without due regard to conservation, often damaging the mineral asset at the end of the period of lease. Such practices in the long run not only discouraged private mining enterprise but were also most harmful to the mineral industry.

No uniform policy of rent and royalty payments was enforced by the former States. Some of the earlier royalty rates are reviewed below.

In Jamnagar State the rate of royalty for gypsum was calculated according to the following schedule:—

|                          |   |            |          |
|--------------------------|---|------------|----------|
| For the first 5,000 tons | @ | Rs. 3- 4-0 | per ton. |
| „ „ next 1,000           | „ | Rs. 2-14-0 | „ „      |
| „ „ „ 1,000              | „ | Rs. 2- 8-0 | „ „      |
| „ „ „ 1,000              | „ | Rs. 2- 4-0 | „ „      |

The amount of royalty on gypsum realised by the Government of Jamnagar between 1939 and 1946 is tabulated below.

|         |    |    |              |
|---------|----|----|--------------|
| 1939-40 | .. | .. | Rs. 19,227/- |
| 1940-41 | .. | .. | Rs. 20,518/- |
| 1941-42 | .. | .. | Rs. 29,522/- |
| 1942-43 | .. | .. | Rs. 25,283/- |
| 1944    | .. | .. | Rs. 32,500/- |
| 1945    | .. | .. | Rs. 43,501/- |
| 1946    | .. | .. | Rs. 50,606/- |

A statement showing the schedule of royalty on rocks and minerals prevalent in various States before integration is shown in the following table.

## ROYALTY RATES BEFORE INTEGRATION

| Name of rocks or minerals.  | Rates of royalty.   |
|---|---|
|   | <i>Rs.As.Ps.</i>  |
| White, Porbandar building stone   | { 0-1-0 per <i>maund</i> for export.<br>0-0-6 per <i>maund</i> for local use.   |
| Paneli building stone<br>Chorwad building stone<br>Dungerpur building stone<br>Kabutri building stone | { 0-0-5 per <i>maund</i> .<br>Quarries were leased out by public auction every year.  |
| Dhrangadhra building stone  | { 0-0-7 per <i>maund</i> for local use.<br>0-0-3½ per <i>maund</i> for export.  |
| Rajula and Rajkot building stone  | .. 0-0-2 per <i>maund</i> .   |
| Wankaner and Morvi building stone   | .. 1-0-0 per 100 c. ft.   |
| Superior quality limestone chips for manufacture of lime  | { 0-0-1 per <i>maund</i> (Paneli stone).<br>0-0-2 per <i>maund</i> (Porbandar stone).<br>0-8-0 per ton for industrial use.<br>At Chorwad, Verawal, etc., quarries were given on <i>Izara</i> system every year by public auction. |
| Inferior quality limestone chips other than that shown in item above                                  | { At some places royalty was not at all charged. At places a charge of three <i>pies</i> or six <i>pies</i> per cart load was levied.   |
| Sand and <i>moram</i>   | .. —ditto—  |
| Trap metal, etc., of Botad and other places   | .. 0-2- 0 per 100 sq. ft.   |
| White, Porbandar clay   | .. 0-2-10 per <i>maund</i> .  |

ROYALTY RATES BEFORE INTEGRATION —*contd.*

| Name of rocks or minerals.                    | Rates of royalty.   |
|---|---|
|   | <i>Rs.As.Ps.</i>  |
| Coloured, Porbandar clay                      | .. 0-2-10 per <i>maund</i> .  |
| Pottery clay, fire-clay and<br><i>bhutada</i> | { 0-2- 0<br>to<br>0-4- 0 per cart load.   |
| Moulding sand                                 | .. <i>Izara</i> system.   |
| Silica stone and sand                         | .. <i>Izara</i> system.   |
| Calcite                                       | { 0-2-0 per <i>maund</i> in Porbandar.<br>1-4-0 per ton at other places.                                      |
| Gypsum  | { 0-2-0 per <i>maund</i> in Porbandar.<br>2-8-0 per ton at other places.<br>3-0-0 per ton for cement factory. |

## QUARRY DEPARTMENT

After the integration of the various States in 1948, the Government of Saurashtra established a separate Quarry Department under the administrative control of the Industries & Supply Department, with a view to developing the quarry industry. All the executive work relating to quarries, mines and minerals is done by the office of the Quarry Superintendent located at Rajkot. Besides, there are five sub-offices of Quarry Inspectors, one for each district of Saurashtra, to assist the Quarry Superintendent.

The leases and prospecting licenses for minor minerals are given by the Quarry Superintendent as per Quarry Rules. The licenses and leases for major minerals and certificates of approval are granted by the Industries & Supply Department of the State Government as per Mineral Concession Rules, 1949.

The royalty on minerals is collected by the Quarry Department, where the income of royalty justifies the separate establishment,

whereas at other localities royalty is collected with the co-operation of the Revenue Department through their *Talaties*, etc. The royalty on building materials consumed in the contract works of the Public Works Department is recovered from the contractors by the Quarry Inspectors of the districts concerned, on the actual quantities of materials used in the works. The figures of quarry materials consumed are furnished by the Public Works Department to the respective Quarry Inspectors, who subsequently recover the royalty on the furnished figures and issue "No dues certificate" to the contractors. The contractors then produce the "No dues certificate" to the Public Work Department officers, who on production of the certificate arrange to refund the security deposits to the contractors deposited by them at the time of giving out contracts.

Contracts for recovery of royalty are also given on yearly basis in some towns to private individuals through public auction. These contractors recover royalty on behalf of the Quarry Department at the same rates of royalty and pay to the Government a lump sum offered in the auction.

At some places, Municipalities also co-operate with the Quarry Department in recovering royalty. In such cases, a remuneration up to 5 per cent. of the total collection is paid to the Municipalities for doing this work.

Leases for quarries are given for a period varying from 5 to 20 years according to the presumed depth of the materials, subject to renewal for half of the period. Leases for small quarries are given on yearly basis and are renewed from year to year on payment of the prescribed fees.

A statement showing the rates of royalty at present prevalent in Saurashtra is given in the following table.

#### ROYALTY RATES AFTER INTEGRATION

| Names of rocks or minerals.        | Rates of royalty. |     |              |
|------------------------------------|-------------------|-----|--------------|
|                                    | Rs.               | As. | Ps.          |
| White, Porbandar building stone .. | 0                 | 0   | 9 per maund. |
| Panali building stone ..           | 0                 | 0   | 6 per maund. |
| Chorwad building stone ..          | 0                 | 0   | 6 per maund. |



## ROYALTY RATES AFTER INTEGRATION —contd.

| Names of rocks or minerals.  | Rates of royalty. |     |               |            |                                |
|--|-------------------|-----|---------------|------------|--------------------------------|
|  | Rs.               | As. | Ps.           |            |                                |
| Dungerpur building stone ..  | 0                 | 0   | 6             | per maund. |                                |
| Kabutri building stone ..  | 0                 | 0   | 6             | per maund. |                                |
| Dhrangadhra building stone ..  | 0                 | 0   | 4             | per maund. |                                |
| Rajula and Rajkot building stone ..  | 0                 | 0   | 2             | per maund. |                                |
| Wankaner and Morvi building stone ..                                       | 0                 | 0   | 1             | per maund. |                                |
| Superior quality limestone chips<br>used for manufacture of lime           | }                 | 0   | 0             | 4          | per maund.                     |
|  |                   | 0   | 8             | 0          | per ton for<br>industrial use. |
| Inferior quality limestone chips<br>other than that shown in item<br>above | }                 | 0   | 0             | 1          | per maund.                     |
|  |                   |     |               |            |                                |
| Sand and <i>moram</i> ..   | 0                 | 0   | $\frac{1}{2}$ | per maund. |                                |
| Trap metal, etc., of Botad and<br>other places ..                          | 0                 | 0   | 1             | per maund. |                                |
| White, Porbandar clay ..   | 0                 | 2   | 3             | per maund. |                                |
| Coloured, Porbandar clay ..  | 0                 | 2   | 3             | per maund. |                                |
| Pottery clay, fire-clay and <i>bhutada</i>                                 | 0                 | 0   | 6             | per maund. |                                |
| Moulding sand ..   | 0                 | 1   | 6             | per maund. |                                |
| Silica stone and sand ..   | 0                 | 1   | 0             | per maund. |                                |
| Calcite ..   | 0                 | 1   | 6             | per maund. |                                |
| Gypsum   | }                 | 0   | 2             | 0          | per maund.                     |
|  |                   | 3   | 0             | 0          | per ton for<br>cement factory. |

## INDIAN BUREAU OF MINES

Acting upon the recommendations of the National Mineral Policy Conference in Delhi in January 1947, the Government of India drew the attention of all State Governments including Saurashtra, to the subject of fresh grant and renewal of mining concessions within their respective territories, on an uniform basis, with the object of ensuring systematic mining and mineral conservation. Some tentative, general principles were outlined with regard to minerals which are mined solely for export in foreign countries, and it was pointed out that the Indian Bureau of Mines, when set up, would examine the existing rules and practices prevailing in various parts of the country, so that eventually the Government of India would adopt an uniform policy in the matter of grants of mining concessions.

Since then the Indian Bureau of Mines has been established and new mineral concession rules have been drawn up, and it is expected that the Government of Saurashtra would now fall in line with other States of the Indian Union in the matter of mineral concessions within its own territory.

The old mining concession rules framed by the various local Governments are no longer valid. Those interested in the mineral industry of Saurashtra should get the "Mineral Concession Rules, 1949", issued by the Central Government, and acquaint themselves with the new conditions and procedure regarding grant and renewals of prospecting licenses and mining leases.

The State Governments are expected to maintain a register of prospecting licenses and mining leases, giving necessary particulars, which can be inspected by holders of certificates of approval, prospecting license and mining lease, or their agents, on payment of fees to be determined by the State Government.

#### MINING CONCESSION TERMS

Brief explanatory notes on the various terms commonly applied in the new mineral concession rules are given in the following paragraphs.

*Minor minerals.*—Hitherto the term *minor minerals* as opposed to the so-called *major minerals* was used to denote certain minerals or rocks (slate, limestone, clay and building materials, etc.) for which no regular royalty was payable. Each State or Province had its own definition of *minor minerals* for which nominal rates or taxes were levied at certain flat rates. This system had given rise to some complications in the past, as after all a *minor mineral* may become a *major mineral* if used in certain large industries. A high-grade limestone used for chemical purposes or cement manufacture, or high quality clay needed for pottery works, for example, should be treated as a mineral for which royalty should be paid.

According to the Mineral Concession Rules, 1949, the *minor minerals* comprise only building stone, boulder, shingle, gravel, limestone, limeshell and *kankar* used for lime-burning, *moram*, brick-earth, ordinary clay, ordinary sand and road metal. The new mining concession rules do not apply to *minor minerals*, and

the State Government is entitled to prescribe their own rules with regard to the working of such minerals.

*Specified minerals.*—The Government of India have recently classified certain strategic minerals of national importance as *specified minerals*, in the matter of granting prospecting license and mining lease of which the prior sanction of the Central Government is essential. No State Government can work any such mineral departmentally without the approval of the Government of India. The list of *specified minerals*, according to the Mineral Concession Rules, 1949 (latest issue), is given below:—

- (1) Coal.
- (2) Gypsum.
- (3) Vanadium ores.
- (4) Beryl.
- (5) Ilmenite and other titanium ores.
- (6) Monazite and other thorium minerals.
- (7) Pitchblende and other uranium ores.
- (8) Columbite, samarskite and other minerals of the "rare earths" group.
- (9) Zircon.
- (10) Lead, zinc and copper ores.
- (11) Gold, silver, platinum and other precious metals and their ores.
- (12) Precious stones.

*Certificate of approval.*—Any person intending to obtain a prospecting license or a mining lease should possess a certificate of approval from the State Government. A fee of Rs. 100 is payable for the certificate which can be renewed on payment of Rs. 50 if the application for renewal is received within three months from the date of expiry of the certificate.

The State Government is not entitled to issue a certificate to an individual who is not an Indian citizen without a prior sanction of the Government of India.

Certain particulars about the status and technical competence of the applicant will have to be supplied while applying for the certificate.

A certificate is valid for the whole State and covers all minerals except petroleum and natural gas, unless the State Government, with the concurrence of the Central Government, limit it to any specified mineral or minerals.

With regard to the grant of exploring and prospecting licenses and mining leases for petroleum and natural gas, the Government of India have framed the Petroleum Concession Rules, 1949. A separate certificate of approval is needed before obtaining any petroleum concession. The State Government is competent to issue prospecting license, exploring license and mining lease with regard to petroleum and natural gas, with the concurrence of the Central Government.

A holder of a concession need not renew his certificate, as the expiry of a certificate of approval does not affect the validity of a license or lease already granted to the holder of such certificate, or the right of the holder of a prospecting license to apply for a mining lease.

*Prospecting license.*—It is granted by the State Government only to the holders of certificate of approval and allows the licensee the right to prospect for minerals in a specified area over a certain time limit. It is renewable under certain conditions. Issue of any prospecting license with regard to *specified minerals* will need the prior approval of the Government of India.

In addition to the information about the name, nationality, status, etc., all applicants for a prospecting license, whether individuals or firms, must submit the following particulars:—

- (1) The number and date of the notification of the grant or renewal of the certificate of approval.
- (2) A map or plan indicating the situation, boundaries and area of the land to be prospected.
- (3) The period for which the applicant intends to prospect.

- (4) The mineral or minerals for which the prospecting license is needed.

The fee payable is Rs. 50/- for the first square mile and Rs. 10/- for each extra square mile or part thereof. A security deposit of Rs. 100/- for each square mile or part thereof is payable, before the issue of the prospecting license, for proper implementation of the terms of the license.

Priority is given to the application received first in case there are more than one applications for the same area. The State Government, however, can grant the license otherwise, with the previous sanction of the Government of India.

With regard to mica the period for which a prospecting license may be obtained cannot exceed one year, although the license may be renewed for a further period not exceeding one year. In case of other minerals prospecting license is issued for a term of two years and may be renewed for one or more further periods not exceeding one year each time, but subject to a total term of four years.

The holder of a prospecting license has a right to a mining lease or leases over the whole or part of the area in respect of which the license is granted.

The prospecting fee is to be paid according to the rate fixed by the State Government, not less than two *annas* and not exceeding one *Rupee* per acre of the land covered by the license, for each year or part of a year of the period of license.

With regard to gold, silver, precious stones or mica, the licensee can remove any amount of mineral won on payment of usual royalty. In case of other minerals the licensee has no right to win or remove the minerals for industrial requirements although a certain specified maximum quantity of ores and minerals can be removed free of royalty; any quantity in excess of the specified limits, as is incidental to prospecting, may be removed on payment of royalty.

The licensee can transfer his license to a holder of certificate of approval with the sanction of the State Government on payment of Rs. 100/-.

A prospecting license may also include other conditions which may be imposed by the State Government.

*Mining lease.*—A mining lease granted by the State Government permits the licensee to mine for a mineral or minerals over a specified area for a particular term which is renewable under certain conditions. It is issued to holders of certificate of approval. No prospecting license is essential for obtaining mining lease, i.e., a person holding a certificate of approval can directly apply for a mining lease.

No mining lease can be given to an individual who is not a citizen of India, without the prior consent of the Central Government. The sanction of the Government of India is also required for granting a mining lease for *specified minerals*, and in case the State Government desire to work any such mineral departmentally.

Priority is given to the application received first in case several applications are made with respect to the same area. The State Government, however, can grant the lease otherwise, with the previous concurrence of the Government of India.

The applicant for a mining lease is required to submit his name, nationality, status, etc., in addition to the following particulars:—

- (1) The number and date of the notification of the grant or renewal of certificate of approval.
- (2) A map or plan indicating the situation, boundaries and area of the land.
- (3) The mineral or minerals for which the lease is required.
- (4) The particulars about his other mining concessions within the State.
- (5) The particulars of the prospecting license for the area, if any.
- (6) The period for which the applicant intends to mine.
- (7) An idea of any possible industry which the applicant intends to develop.

The application fee for a mining lease is Rs. 200/-, and the applicant is required to deposit a sum not exceeding Rs. 500/-,

as would be fixed by the State Government, for covering preliminary expenses. A security deposit of Rs. 1,000/- in case of metalliferous minerals and Rs. 500/- in case of other minerals is also to be paid before the grant of the lease.

The lessee may transfer his lease to a holder of a certificate of approval on payment of a fee of Rs. 100/-, with the approval of the State Government. He can also terminate the lease at any time under certain conditions.

In addition to any special condition, subject to the prior sanction of the Central Government, and other conditions as considered necessary by the State Government, each mining lease should include the usual clauses with regard to area and period of lease, payment of surface rent, dead rent and royalty, erection of boundary marks, maintenance of mine plan and records of mining operations, minerals won or removed, inspection by officials, etc.

A mining lease is to be obtained with respect to any new mineral find in the leased area, as otherwise the State Government may give a lease in respect of such mineral to any other person in case the lease holder fails to apply for such lease within a year from the discovery of the mineral.

A lessee is expected to commence operations within one year from the date of execution of the lease and continue the work in a proper manner.

A lessee is not allowed to undertake mining operations within 50 yards of any railway line, reservoir, canal, public works or buildings, except with the prior approval of the Railway Administration or the State Government.

The Government have the right of pre-emption of the minerals won, with respect to the lease, at the prevailing fair market price.

Any breach by the lessee or his transferee or assignee with regard to certain conditions of the lease is governed by the clauses XIV, XV and XVI of Rule 41 of the Mineral Concession Rules, 1949.

*Area of mining lease.*—The aggregate area of mining leases that can be held by any lessee, either singly or jointly with any

person, should not exceed 10 square miles, with regard to one mineral or allied group of minerals within any single State.

The 10-square mile limit rule may be relaxed in cases of large concerns like iron and steel manufacturers whose activities necessarily cover a large group of minerals such as iron-ore, coal, limestone, refractory minerals, manganese-ore, chromite, etc.

In case of petroleum and natural gas, the limit has been fixed at 150 square miles.

The length of the area in a mining lease is not allowed to exceed four times its breadth. In case of coal, however, the length may not exceed twice the breadth, and the area leased or sub-leased may not be less than 100 acres. The provisions of the rule can be relaxed by the State Government in any particular case.

*Period of mining lease.*—The maximum period for which a mining lease for iron-ore for the manufacture of iron and steel and bauxite for the manufacture of aluminium is granted is 30 years. The maximum period for which a mining lease is granted with respect to any other minerals, unless the applicant desires for a shorter term, is 20 years.

The mining lease may be renewed for a further one or two periods. In the case of iron-ore and bauxite for the manufacture of aluminium, each period of renewal must not exceed the duration of the original lease. With regard to other minerals, only one period of renewal not exceeding the duration of the original lease is permissible.

In case of renewals, royalty and surface rent and dead rent are to be levied at such rates in force at the time of renewals.

*Grant of concessions by private persons.*—Private persons, i.e., individual landlords or *inamdars*, having mineral rights, may also grant mineral concessions to holders of a certificate of approval within the State concerned. The sanction of the Government of India is needed if a prospecting license or mining lease is proposed to be granted to an individual who is not an Indian citizen or in case the license or lease concerns any *specified minerals*. The



lessor is required to apply through the respective State Government for obtaining any sanction of the Government of India.

The conditions under which a prospecting license may be issued by a private person are practically the same as the conditions under which a prospecting license is granted in respect of land in which the minerals belong to Government. The following conditions, however, are obligatory:—

- (1) The period of license is not to exceed two years.
- (2) The licensee is required to pay for each year or portion of a year a fee, between two *annas* and one *Rupee* per acre, as per agreement between the parties.

The conditions under which a mining lease may be issued by a private person are generally same as the conditions under which a mining lease is granted in respect of land in which the minerals belong to Government. The following conditions, however, are obligatory:—

- (1) The maximum period of lease is 20 years, but the lease is renewable, for one period not exceeding the duration of the original lease.
- (2) The length of an area leased is not to exceed four times its breadth.

In case of grant of mineral concessions by private persons, no prospecting license or mining lease can be transferred or assigned except to a person possessing a certificate of approval within the State concerned.

All holders of prospecting licenses or mining leases, granted from a private person, must submit a certified copy of the license or the lease to the State Government concerned, within three months of the award of the license or lease.

Communication of transfer or assignment of a prospecting license or a mining lease should be also made by transferee or assignee, to the State Government concerned, within a month of such transfer or assignment, along with the terms of transfer or assignment.

While granting or transferring a prospecting license or a mining lease no person can charge any premium in addition to or in lieu of the specified prospecting fee, surface rent, dead rent or royalty.

Any person issuing a prospecting license or mining lease is required to submit to the State Government annual returns and statements of the mineral concessions granted by him.

The granting of prospecting licenses and mining leases in contravention of rules is liable to punishment with imprisonment extending to six months, or with fine up to Rs. 1,000/- or both, and the license or lease so granted becomes invalid. There is also a penalty prescribed for failure to furnish returns, documents, information, etc., on the part of the licensee or lessee or his transferee or assignee, with respect to Rules 41, 49 and 50 of the Mineral Concession Rules, 1949.

*Revision of cases.*—Any person desirous of bringing to the notice of the Government of India, any order of the State Government, with regard to refusal to grant a certificate of approval, prospecting license or mining lease, cancellation of a prospecting license or mining lease, and refusal to permit transfer of a prospecting license or a mining lease, as a protest or grievance, is at a liberty to apply to the Government of India for reviewing the same. An application for revision is to be accompanied by a fee of Rs. 25/-, within two months from the date of such order. The finality of order, however, rests with the Government of India.

*Surface rent.*—The lessee has to pay for the surface area, within a lease, occupied by the superficial part of the mine, i.e., works, buildings, etc. The rate should not exceed the land revenue and cesses assessable on the land and is to be specified in the lease by the State Government.

*Dead rent.*—Dead rent is payable for the whole area covered by the mining lease, at a certain rate per acre, and should be considered as a *minimum* royalty. No dead rent is to be paid in the first year of a mining lease. Only dead rent or royalty, whichever is greater, but not both, is to be paid.

The State Government has a right to charge separate dead rent in respect of each mineral in case the lease allows the winning of more than one mineral in the same area.

Generally speaking, in the early stages of development of a mine, the dead rent is payable, but during the actual period of active mining, royalty will form the chief source of revenue to the lessor. The idea is to keep the amount of dead rent at a rate which should not cause undue hardships to the mining industry in the initial period when expenses are highest and the return is at a minimum. On the other hand if the dead rent is very low, there would be a tendency on the part of inefficient lessees to apply for an unnecessarily large area and to sit tight on the property without working vigorously.

The various factors involved in calculating *minimum* royalty are size of the deposit, market value of the mineral, nature of concentration, prospective market, etc., and in fact each mineral occurrence should be considered on its own merit. However, some arbitrary rates have been hitherto prescribed for the sake of convenience. The following dead rents have been fixed according to the latest Mineral Concession Rules:—

|  | Per acre.   |          |
|--|---|----------|
|  | Minimum.  | Maximum. |
|  | Rs.   | Rs.      |
| Coal .. .. .   | 1   | 5        |
| Iron-ore for extraction of iron ..   | 1   | 5        |
| Bauxite for extraction of aluminium .. .. .                                  | 1   | 5        |
| Mica .. .. .   | 2   | 8        |
| Gold, silver, platinum and other precious metals and precious stones .. .. . | To be determined according to the circumstances of each case. |          |
| All other minerals .. .. .   | 5   | 10       |

*Royalty.*—Minerals are wasting assets because once removed they cannot be replenished like agricultural products. The charging of royalty on the minerals enables the lessor to get a reasonable return for his diminishing assets.

Hitherto, in the past, the normal basis of assessment for different minerals has been  $2\frac{1}{2}\%$  or  $5\%$  of the pit's mouth value for majority of the minerals, although special rates prevailed with regard to gold or silver, iron-ore, precious stones, etc.

The pit's mouth value of a mineral is obtained by deducting the transport charges and other incidental expenses involved between the mine and the place of sale.

The rates of royalty on different minerals, according to the Mineral Concession Rules, 1949, are given in a following table. They are liable to be revised at the beginning of 1955, and thereafter once in every 10 years. In the case of a lease granted after the coming into force of the new concession rules of 1949, the lessee is not required to pay during the period of his lease, a rate of royalty exceeding  $1\frac{1}{2}$  times the original rate specified in his lease.

Coal— .. .. . Five per cent. of *f.o.r.* statutory price subject to a minimum of As. 8 per ton.

Mica— .. .. . *Either*

(a) Crude mica .. .. . Re. 1 per *md.*

(b) Trimmed mica, all qualities other than heavy stained, dense stained and spotted .. .. . Rs. 3 per *md.*

(c) Trimmed mica, other than (b) .. .. . Rs. 1-8 per *md.*

(d) Waste and scrap mica .. .. . As. 2 per *md.*

*Or*

5 per cent. of the sale value of mica at the pit's mouth, at the option of the lessor.

Gold, silver, platinum and other precious metals and their ores; copper, lead and zinc ores. } To be fixed by the Central Government in each case.

Iron —

(a) Used for extraction of iron .. .. . As. 8 per ton.

|  |   |
|--|---|
| (b) Used for other purposes                                | Re. 1 per ton.  |
| Precious stones— .. .. .                                   | 20 per cent. of the value.  |
| Manganese-ore —  |   |
| (a) High grade (45 per cent. Mn. and over) .. .. .         | Five per cent. of the sale value at the pit's mouth, subject to a minimum of Re. 1 per ton.   |
| (b) Low grade (below 45 per cent. Mn.) .. .. .             | Five per cent. of the sale value at the pit's mouth, subject to a minimum of As. 8 per ton.   |
| Chromite —   |   |
| (a) 45 per cent. $\text{Cr}_2\text{O}_3$ and above .. .. . | Five per cent. of the sale value at the pit's mouth, subject to a minimum of Rs. 1-8 per ton. |
| (b) Less than 45 per cent. $\text{Cr}_2\text{O}_3$ .. .. . | Five per cent. of the sale value at the pit's mouth, subject to a minimum of As. 12 per ton.  |
| Limestone or Dolomite— .. .. .                             | Five per cent. of the sale value at the pit's mouth, subject to a minimum of As. 4 per ton.   |
| All other minerals not specified above— .. .. .            | Five per cent. of the sale value at the pit's mouth.  |

*Maximum quantities of minerals removable free of royalty—*  
Among the conditions of a prospecting license or mining lease is a clause permitting the lessee to remove certain quantity of ores and minerals, within specified limits as follows, without payment of any royalty.

1. Auriferous rock and gravel containing no visible gold .. .. . 2 tons.
2. Metalliferous ores meant for extracting aluminium, iron and manganese .. .. . 10 tons.

3. Metalliferous ores meant for extracting antimony, arsenic, bismuth, chromium, copper, lead, nickel, tin, titanium, tungsten and zinc .. 5 tons.
4. Metalliferous ores meant for extracting cadmium, cobalt, mercury, molybdenum, silver, thallium and vanadium .. .. . 2 tons.
5. Compound ores containing the metals of class 4 in smaller quantities than those of class 3 .. 5 tons.
6. Concentrates of the ores enumerated in classes 3 to 5 .. .. . 2 cwts.
7. Minerals of the "rare-earths" group .. 5 cwts.
8. Gypsum, iron pyrites, pyritous shales, and bauxite used for purposes other than aluminium making .. .. . 5 tons.
9. Barytes, bitumen, borax, corundum, emery, felspar and fluorspar .. .. . ½ ton.
10. Asbestos, graphite, mica and native sulphur ... 1 cwt.
11. Sillimanite, kyanite, magnesite, serpentine, steatite, vermiculite, fire-clay, kaolin and other refractory materials .. .. . 5 tons.

## PART II.—THE RECORDED MINERAL OCCURRENCES OF SAURASHTRA

### CHAPTER X

#### ABRASIVES

##### GENERAL

Under this heading are included the natural products and artificial compounds which are extensively used for cutting, polishing, grinding, sharpening, etc., in industry. They are used as powders of all grades of fineness (liquid polish, metal polish, powders, sand paper, emery paper, emery cloth, etc.), as pebbles or balls (steel balls, pebbles of flint, quartz, quartzite, granite, etc.) for pulverising and grinding paints, clays, etc., or after shaping into suitable millstones, grindstones, pulpstones, honing stones, etc.

Hardness and toughness are the essential properties of abrasives. The following classification of hardness, known as Moh's scale of hardness, in which the minerals are graded from 1 to 10, gives an idea of the comparative hardness.

- |              |              |
|--------------|--------------|
| 1. Talc.     | 6. Felspar.  |
| 2. Gypsum.   | 7. Quartz.   |
| 3. Calcite.  | 8. Topaz.    |
| 4. Fluorite. | 9. Corundum. |
| 5. Apatite.  | 10. Diamond. |

##### NATURAL ABRASIVES

The natural abrasives are divided into three types, i.e., "high-grade", "siliceous" and "soft", and are commonly employed in natural state, after processing and bonding or shaping into suitable forms.

No "high-grade" natural abrasives, e.g., diamond, corundum, emery and garnet are reported to occur in Saurashtra.

The "siliceous" abrasives include agate, chert, flint, granite, quartz, quartzite, sand, sandstone, pumice, volcanic dust, etc. The

harder or indurated Jurassic sandstones (Umias) are being utilised as grindstones or millstones in Dhrangadhra and elsewhere.

Well turned and polished stones would make rollers for paper pulp and salt press (2). Pebbles of agate, chert, flint, etc., suitable for use in rotating ball mills for grinding rocks, ores, minerals, ochres, clays, etc., may be obtained from Saurashtra. The known occurrences are mentioned in Chapter XVIII. The Deccan traps suitable for use as millstones are very common, and are particularly worked for similar purposes near Bhaivadar in Central Saurashtra. Friable sandstones and sand, suitable for the manufacture of sand paper, should be easily available. Friable pumice and volcanic ash (tuff), if located in trap, would form excellent abrasive.

The "soft" abrasives comprise bauxite, calcite, chalk, clays, diatomite, ground felspar, lime, magnesite, talc, carbon black, etc. The bauxite deposits are described in Chapter XI, calcite in Chapter XIII, chalk in Chapter XIV, clays in Chapter XV, felspar in Chapter XXXIII and lime in Chapter XII. Carbon black, if made from the burning of gas at Gogha (Chapter XXIX), might be suitable as a metal polish. No deposits of diatomite and magnesite, however, are known to occur in the State.

#### ARTIFICIAL ABRASIVES

The artificial abrasives are manufactured from mineral products like bauxite, boron, carbon, clay, lime, magnesia, natural gas, oil, salt, steel, silica and tungsten minerals, including some natural abrasives. The main products are classified in four groups: silicon carbide (carborundum, crystolon, carbolon, etc.); fused alumina (alundum, aloxite, lionite, etc.); metallic abrasives (steel shot, grit and steel wool); and metallic oxides. The hardest of these abrasives, approaching the hardness of diamond, is marketed under trade name norbide (boron carbide). Artificial abrasives are chiefly manufactured in America and Canada, where cheap electrical power is easily available.

#### FUTURE

The use of sand paper is bound to increase in view of the industrial expansion in the country, and the prospects of manufacturing sand paper in Saurashtra should be explored. Location of



suitable sand in the stream beds, aided by systematic grading and sampling, would ensure regular supply of adequate and graded materials.

The natural abrasives such as calcite, chalk, clay, lime and sand are readily available in the State, and therefore an industry to market these materials in the form of powders could be easily established with a small capital. The Rann and the coastal alluvium sometimes yield beds of abrasive silts which are locally used in many places as metal polish.

There is a local demand for the grinding wheels made of Jurassic sandstones and Deccan traps, and the cottage industry with regard to these is likely to continue in the face of the competition of artificial grinding wheels from abroad.

The agate from Bhavnagar may find a use in ball mills as a result of industrial development in India. Similar agate-bearing conglomerates could be located by further diligent search in the Gaj beds and along the coastal areas of Saurashtra.

The use of abrasives is on the increase, and in recent years the natural abrasives are being supplanted by the artificial abrasives, particularly in industrial metalwork, in the field of industries like automobile, airplane, etc. The essential raw materials for the manufacture of artificial abrasives like silicon carbide and fused alumina are readily available within the State or in the adjacent States, but it would be difficult to establish such an industry owing to lack of cheap electrical power in the State. Although there are some firms in Bombay and elsewhere manufacturing abrasive goods, e.g., emery paper and cloth, sand paper, abrasive wheels and discs, etc., mostly from imported materials, hitherto no attempts have been made to manufacture artificial abrasives in India.

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## CHAPTER XI

### BAUXITE

#### GENERAL

Bauxite or aluminous laterite is an altered rock formed in humid tropical climate with alternating dry and wet periods, generally forming good relief. It is white, grey, brown or red in colour, and compact, pisolitic or vermicular in appearance. It contains a high percentage of alumina and water, and variable but small amounts of silica, ferric oxide, titanium oxide and other impurities. For commercial purpose it is grouped under four varieties, i.e., normal bauxite, white or siliceous bauxite, titaniferous bauxite and ferruginous bauxite.

The reserves of high-grade Indian bauxite, mostly in Bihar, Madhya Pradesh, Bombay and Madras, have been roughly calculated at 25 million tons.

#### USES

Bauxite is primarily used as a source of aluminium, although a small proportion also finds its way in the manufacture of chemicals and in the preparation of abrasives, refractories and high alumina cement. A small quantity is used for the purification of kerosene. Barring a small portion of Indian bauxite utilised in this country for minor industries, and some export trade from time to time, the Indian bauxite industry has never been actively developed in spite of large resources. However, the Indian Aluminium Company and the Aluminium Corporation of India are nowadays manufacturing aluminium, utilising the ore from Bihar.

Many years ago bauxite with less than 55 per cent of  $\text{Al}_2\text{O}_3$  was not regarded as suitable for reduction purposes, although the exigencies of war necessitated the use of ore much inferior to that quality. In recent years ore containing about 50 per cent. or even less  $\text{Al}_2\text{O}_3$  is utilised to recover most of the  $\text{Al}_2\text{O}_3$  in bauxite. Hitherto, bauxite for extraction of aluminium was required to contain less than 6.5 per cent.  $\text{Fe}_2\text{O}_3$  and 5 per cent.  $\text{SiO}_2$ , but somewhat inferior ore is permissible now. For the manufacture of aluminium,

iron oxide may be up to 25 per cent., although for refractories the iron oxide should be less than 1.5 per cent.

#### DISTRIBUTION

Along the Deccan trap margins, not far away from the coastal areas, are seen numerous isolated or continuous strips or belts of lateritic rocks, in Bhavnagar, Junagadh, Porbandar and Nawanagar, varying from a few miles up to 30 miles in length and up to a few miles in width. They are shown in Fedden's geological map. They are mostly covered by Tertiary and alluvial deposits, and are about 50 feet thick on an average, although a maximum thickness of 200-250 feet is noticeable sometimes.

Proceeding west to east, the outcrops are located in the following areas in Saurashtra:—

- (1) A north-south strip, 30-mile long, from south-west of Panera Island in the Gulf of Kutch to near Lamba in the Arabian Sea.
- (2) Several isolated exposures between Miani and Bakharla in Porbandar, along a distance of 16 miles.
- (3) Two N. W.-S. E. outcrops near Myari, the longest one being traceable for about four miles.
- (4) A N.W.-S.E. strip, five miles long, E. N. E. of Mangrol.
- (5) A 10-mile long E-W. strip north-east of Dolasa.
- (6) An E. N. E.-W. S. W. belt, five miles long, north-east of Una.
- (7) An E. N. E.-W. S. W. strip, four miles in length, between (6) and (8).
- (8) A 10-mile spread between Rajula and Nagasari, north of Jafraabad.
- (9) A five-mile long strip near Dongar, north-east of (8).
- (10) A six-mile long belt north-west of Mahuva.
- (11) A small outcrop near Talaja.
- (12) A 20-mile long N.-S. belt, swinging N. N. W.-S. S. E. at the northernmost limit, west of Gogha.
- (13) A small strip near Bhavnagar.

## Nawanagar

Dr. B. C. Roy (3) recently examined some of the bauxite deposits in Nawanagar. In Between Bhopalka and Bhatia Railway Stations, the isolated patches of laterite show some Fuller's earth, coloured clays, yellow or red ochre and ferruginous bauxite. The most widespread patch of laterite, however, lies to the north of the area, forming a 12-mile long and 1-4 mile wide continuous strip, almost up to the Gulf of Kutch, covering the regions around Nandana ( $20^{\circ}8' : 69^{\circ}20'$ ), Ran ( $22^{\circ}10' : 69^{\circ}20'$ ), Mewasa ( $22^{\circ}13' 30'' : 69^{\circ}21'$ ), Habardi ( $22^{\circ}13' : 69^{\circ}25'$ ) and Virpur ( $22^{\circ}15' : 69^{\circ}21' 30''$ ). Here, the terrain comprises low, isolated hills or hill chains and plains, where apart from large resources of white Fuller's earth, coloured clays and ochres, large deposits of a reddish, ferruginous bauxite are envisaged. Pisolitic, hard, greyish white or high-grade bauxite and bauxitic clays, however, appear to be limited, covering small patches, e.g., 200 feet x 200 feet, 75 feet x 50 feet and 60 feet x 30 feet, where the thickness ranges from 1-5 feet. The lateritic areas are at times covered by 1-5 feet of miliolite limestone, and need detailed prospecting and sampling to prove the existence of workable bauxite deposits. The high-grade material if found in abundance could be exported to foreign countries. The area has been partly leased out for prospecting to Messrs. Bombay Mineral Supply Co. Ltd. Samples from Mewasa on analysis gave the following results:—

## Per cent.

|              | (1)   | (2)    | (3)   | (4)   |
|--------------|-------|--------|-------|-------|
| $Al_2O_3$ .. | 64.16 | 60.52  | 48.32 | 42.44 |
| $Fe_2O_3$ .. | 1.80  | 4.04   | 1.29  | 33.26 |
| $SiO_2$ ..   | 1.00  | 2.12   | 0.80  | 0.30  |
| $TiO_2$ ..   | 2.03  | 2.50   | 2.39  | 2.02  |
| $CaO$ ..     | trace | nil    | 12.45 | trace |
| $MgO$ ..     | trace | trace  | trace | trace |
| $SO_3$ ..    | -     | 0.24   | -     | -     |
| $P_2O_5$ ..  | -     | 0.07   | -     | -     |
| $H_2O$ ..    | 30.70 | 30.51  | 34.44 | 21.84 |
| Total.       | 99.69 | 100.00 | 99.65 | 99.86 |

Analysts:—Nos. 1, 3 & 4—Geological Survey of India.

No. 2—Hughes & Davies, Bombay.

The analyses Nos. 1 & 2 represent a very high quality ore, very low in iron, silica and titania. The analysis No. 4 indicates a ferruginous bauxite, exceptionally low in silica and titania.

#### FUTURE

In view of the presence of enormous quantities of high-grade bauxite in other parts of India, the lateritic rocks in Saurashtra have not received any special attention. No idea about the quality and quantity of the materials present in various localities is available, and therefore nothing definite could be said about their future possibilities.

The bauxite in Saurashtra, however, is said to be highly ferruginous, and therefore no future industry in the form of aluminium extraction and alumina refractories is visualised, particularly in the absence of any hydro-electric projects. Beneficiation of the low grade ore would be expensive.

Recently some good quality bauxite deposits have come to light, but their extent is yet to be proved by prospecting. The good quality material, if found in large quantities, could be exported to foreign countries.

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## CHAPTER XII

### BUILDING MATERIALS

#### GENERAL

Strength and resistance to weathering, i.e., durability, are most important factors in determining the value of building stones. The crushing strength of good materials varies from 5,000 lbs. to 25,000 lbs. per square inch. Usually stones with a crushing strength of 5,000 lbs. are considered satisfactory. The textures, structures and porosity of rocks affect the strength and durability, the fine, medium grained and massive rocks being more favourable than the coarse rocks. Workability has an important bearing on the selection of building stones. A pleasing colour is needed in ornamental and high quality stones.

Building stones and dimension stones (cut and dressed) are obtained by surface quarrying methods, taking advantage of the lines of weakness such as bedding planes, joints, fissures, cracks, etc., during extraction. The presence of well spaced bedding and joint systems facilitates quarrying and dressing operations, as otherwise the stones will have to be properly dressed on all sides to get flat surfaces, involving extra expenditure.

In opening up a new quarry, judicious selection of the site gives a long life to the quarrying operations and ensures economy. The weathered rock at the surface should be rejected and only the fresh material used. The material should be examined as a matter of routine by carrying out the usual tests, i.e., density, porosity, crushing strength, shearing strength, etc., which will be useful in the selection of materials where great strength will be needed. There is a fairly good degree of correlation between the results of the physical tests and the amount of alteration of rock as determined microscopically.

Saurashtra is well endowed with various kinds of rock suitable for the construction of buildings. These comprise clays for the manufacture of bricks, sands for mortar and concrete, limestones and *kankar* for lime-making and cement manufacture, numerous kinds of building and ornamental stones, and materials for road

metal, concrete and railway ballast. Hitherto, Porbander stone was used in large quantities in building constructions in Bombay city.

### BUILDING CLAYS

Clays for the manufacture of bricks are found in the river alluvium in almost all the districts, although suitable materials for the best quality bricks or tiles are not available everywhere. Clays are also required in the manufacture of cement. Some research with regard to the suitability of the various types of clays in Saurashtra for the manufacture of bricks, roofing tiles, etc., could be profitably undertaken.

### BUILDING STONES

*Felspar porphyry.*—The light pink felspar porphyry near Bedia ( $20^{\circ}59' : 71^{\circ}7'5''$ ) and Khambha ( $21^{\circ}9' : 71^{\circ}17'30''$ ) in the Gir forest, according to Mr. S. Krishnaswamy (8), would give handsome building materials after dressing.

*Laterite.*—It is very common in parts of the State and is described in Chapter XI.

*Limestones.*—The important limestone occurrences within the State are given in Chapter XXIV. They are extensively quarried for building purposes in a number of localities, particularly in Porbandar, Gondal, Junagadh, Nawanagar, etc. A few of the recorded occurrences are given below.

Fedden (1) has described the "Porbandar stone" quarries at the western base of the Barda hills, in the vicinity of Ranpur ( $21^{\circ}50' : 69^{\circ}45'$ ), in Porbandar.

A detailed account of the limestone quarries in Porbandar and Nawanagar is given by E. H. Abye in his economic geology of the States concerned.

La Touche (4) records the following occurrences of limestone in Amreli:—

- (1) A brown flaggy limestone at Shedaya ( $20^{\circ}53' : 70^{\circ}51'$ ).

- (2) A brecciated fine grained limestone near Rajpura Bandar (20°24' : 69°9').
- (3) A pinkish yellow shelly limestone near Bardia (22°12' : 69°5').
- (4) A calcite vein yielding a variety of marble near Pipalwa (21°7'30" : 71°15').

Adye (3) refers to extensive quarrying for building materials in Porbandar with respect to the following rocks:—

- (1) Flaggy Dwarka limestone, locally known as Chaya stone, near Chaya in Porbandar.
- (2) White and ruddy flagstones in the Dwarka beds at Kunchri, Degam and Khambhodra. They are also available in slabs and blocks of large dimensions.
- (3) Sub-aerially consolidated recent and sub-recent shell-sand, along the coast from Porbandar city north-westwards for 4½ miles up to Kunchri.
- (4) Stone derived from sub-aerially consolidated blown-sand along the coastal areas of Porbandar, particularly around Chaya, Madhavpur, Gosa, Nawagam, Adodar and Pata.

Sir Cyril Fox (11) noted a 12-24 inch thick bed of infra-trappean type of siliceous limestone at Sundari (28°52' : 71°7'), in addition to *kankar* deposits at Halvad (23°1' : 71°12') and elsewhere, in Dhrangadhra. The materials are limited in quantity and are used for local lime-burning.

Dr. B. C. Roy (9) reports a number of miliolite limestone quarries in Junagadh, in the vicinity of Dada Mahadeo (21°0' : 70°16'), Chorvad Road Railway Station, Samadhiala (21°3'40" : 70°20'20"), Dari (20°57' : 70°22'), Veraval (20°54' : 70°25'), Savni (20°57'30" : 70°29'), Chankathal (20°56'15" : 70°25'30"), Patan (20°53' : 70°27'), Kadwar (20°51' : 70°29'30"), Lakhipur (20°55'45" : 70°36'30"), Gorakhmudi (20°54'20" : 70°34'40"), Warodra (20°49' : 70°34'), Lodhwa (20°50' : 70°36'30") and other localities.

According to Dr. Roy (9), large deposits of Gaj limestones, suitable for ordinary building purposes, are available in easily accessible localities in Junagadh.



*Sandstones.*—Fedden (1) refers to a fine textured and evenly laminated sandstone bed near Baoli ( $22^{\circ}56' : 71^{\circ}27'30''$ ), six miles south-west of Dhrangadhra. It was being used as whetstones and ornamental stones.

The Jurassic sandstones are extensively quarried in Dhrangadhra, Morvi, etc. The stone is very much esteemed for building purposes.

Mr. R. K. Taploo (6) reports extensive quarrying for sandstones near Waghela and Kharva in Wadhwan.

Mr. J. M. Master (7) noted quarries for sandstones near Naldhari, Chorvera and Khada in Sayla State.

*Trap.*—A greater part of Saurashtra is covered by the Deccan lava beds, and it is not necessary to refer to localities where the rocks are available or have been quarried for building purposes. Being dense, hard and durable, the rocks are among the best materials obtainable in India, and are quarried on a large scale near Rajkot, Gondal, Morvi, Botad, Rajula and Amreli.

Dykes of acidic trap suitable for high class buildings are reported (4) at Damnagar ( $21^{\circ}42' : 71^{\circ}35'$ ), Sakhpur ( $21^{\circ}33' : 71^{\circ}34'30''$ ) and Dhalkania ( $21^{\circ}14'30'' : 70^{\circ}59'$ ) in Amreli.

Dr. B. C. Roy (9) reports that the rhyolites in the neighbourhood of Khorasa ( $21^{\circ}3' : 70^{\circ}22'$ ), Khanderi ( $20^{\circ}58'20'' : 70^{\circ}37'$ ), Jhilala ( $20^{\circ}57'40'' : 70^{\circ}37'30''$ ) and Wadala ( $20^{\circ}57'30'' : 70^{\circ}43'30''$ ) in Junagadh could be dressed for building purposes.

#### ORNAMENTAL STONES

The ornamental stones found in Saurashtra have never received any attention for development, presumably due to the cheap imported materials, but attempts may be made to enquire into the possibilities of utilising such stones in the near future. Some of the known occurrences of stones which might find a use for ornamental purpose are indicated below:—

Fedden (1) records the presence of a white-mottled hard marble forming an irregular vein in the traps near Khirasra ( $21^{\circ}57' : 70^{\circ}22'$ ) and Sejriala ( $21^{\circ}56' : 70^{\circ}37'$ ), in the Bhaivadar

*pargana*, about 15 miles north-west of Dhoraji. The vein is about 30 inches wide and is associated with some quartz, calcite and aragonite. It takes a good polish and may be used in a small way for ornamental purposes.

E. H. Adye (3) recommended the use of following rocks in Porbandar as excellent ornamental stones. They are easily dressed and are capable of taking a high polish:—

- (1) Banded rhyolite dykes in Barda hill, Porbandar.
- (2) Orbicular granophyre in Porbandar, particularly for the manufacture of table-tops, mantle pieces, caskets, vases, etc.
- (3) Granophyres of the Ranawao ranges, specially for making polished columns, pedestals, monuments, mantle-shelves, table-tops, etc.
- (4) Spherulitic felsites from Krishna jhar and Javantara Gara in Porbandar.
- (5) Ruddy-grey, sun-baked, incipient granophyre at the summit of Bhatwari Dhar.
- (6) Limonite limestone, termed by Adye as *Bharwarlite*, 1½ miles south-west of Bharwara in Porbandar. It is a pale, uniform, fresh looking, cinnamon coloured Gaj limestone, free from black spots or blemishes.
- (7) A distinct variety of laterite-conglomerate with Gaj matrix termed by Adye as *Turkalite*, covering a large area near Turka.
- (8) A limonitic limestone, named *Pindaralite* by Adye, near Bokhira, one mile north of Porbandar.
- (9) A laterite-conglomerate, called by Adye as *Habardalite*, near Turka in Porbandar, found and used near Habardi in Jamnagar.

According to E. H. Adye (2), the following rocks in Nawanager could be used as ornamental stones:—

- (1) Felsites, granophyres, rhyolites, palagonite, etc.

(2) "Marmarised calcite", formed as a result of thermal contact metamorphism of calcite vein by basaltic dykes, suitable for manufacture of small ornamental wares, at half a mile S. E. by S. S. E. of Khajurda (five miles W. S. W. of Kandorna) and one mile E. by E. N. E. of Retala Kalawad (eight miles N. W. of Bhanwad).

(3) Laterite-conglomerate near Habardi ( $22^{\circ}13'30'' : 69^{\circ}26'$ ), near the base of the lateritic section.

(4) Fossiliferous finely textured Gaj limestones, termed *Pindaralite*. Such material is recorded at Pindara ( $22^{\circ}15' : 60^{\circ}19'$ ) and in the vicinity. Its colour varies from a bright dark-yellow to a rich orange-brown or crimson hue. It takes a good polish and can be easily tooled and carved and used as columns, balustrades, monuments, table-tops, mantles, etc. It is considered as a valuable substitute for the imported yellow marbles.

(5) A variety of dolomitised *Pindaralite*, noted at Ramwara *vovla*,  $2\frac{1}{4}$  miles E.N.E. of Gurgat ( $22^{\circ}12' : 69^{\circ}15'$ ), named by Adye as *Ramwaralite*.

K. P. Sinor (5) stated that the coarse crystalline diabase in Thapnath hill near Sihor, if properly trimmed and polished, gives a beautiful appearance of an ornamental stone. The granophyre from Chogat near Sihor is also recommended for similar purposes.

Mr. S. Krishnaswamy (8) records that the buff grey, crystalline calcite rock occurring in a mile long and seven feet wide zone, about  $1\frac{3}{4}$  miles N. N. E. of Kharadhar in the Gir forest in Junagadh, could be used as an ornamental building stone after polishing.

According to Dr. H. Crookshank (12), some of the Jurassic sandstones in Morvi can be carved into beautiful ornamental designs. The new Secretariat building and the temple at Rafaleshwar are reported to be built of such stones.

Dr. B. C. Roy (9) reports that some samples of Gaj limestone from the coastal areas in Junagadh were polished and appeared to be excellent for ornamental use.

## LIME AND CEMENT

The distribution of limestone in the State of Saurashtra is given in Chapter XXIV. Some of the deposits of limestone are employed for the manufacture of lime and cement.

Another principal source of lime in Saurashtra is *kankar*, a concretionary form of lime carbonate, distributed widely in river alluvium or occurring in soil mantle over Deccan traps and sedimentary formations. On burning, the material yields almost hydraulic lime or "natural cement" owing to the presence of a small proportion of argillaceous matter. The *kankar* is so universally scattered that it is not possible to refer to all the localities where it is available or is being used for lime-burning.

## ROAD METAL

The essential factors of good road metal are strength, hardness, toughness, and resistance to weathering (durability), largely determined by the structures, textures and porosity of the rocks. Determination of certain physical tests, i.e., specific gravity, porosity, crushing strength, toughness, etc., and microscopical examination would be essential, particularly when stones of high quality are to be selected.

Saurashtra is fortunate in having various kinds of road-making materials. With the exception of the coastal tracts, generally abundant and reasonably suitable rocks could be cheaply obtained in the neighbourhood of the roads. A reference to the available geological maps is particularly helpful. A proper selection of materials gives a long life to the roadways and minimises rapid wear under heavy traffic.

The fresh, fine grained or compact, basic igneous rocks, dolerites and Deccan traps are by far the most suitable and widely used rocks for road metalling.

Compact and fine grained sandstones in the Jurassic formation will provide fairly suitable road metal, but the use of softer sandstones should be avoided. The use of miliolite limestones as road stones should be discontinued.

Laterite is extensively found in the State and is employed for road surfacing in considerable quantities.

E. H. Abye (2) records a hard and compact brecciated conglomerate from the base of miliolite beds, capable of resisting severe attrition, and suitable for road dressing. The following localities are mentioned:—

- (1) Just east of Kandorna.
- (2) West of Jasapur, adjoining the south side of Kandorna.
- (3) At Rairi, five miles S. S. W. of Kandorna.
- (4) At Boria, near Kandorna.
- (5) East scarp of the river Phophal at the Bhadra ford.
- (6) Near Iswaria, on the west bank of the Phophal river at its confluence with the river Bhadar.
- (7)  $\frac{1}{2}$  mile N. N. W. of Nikawa.
- (8) On the W. N. W. bank of the Kalavari *vokala*,  $\frac{1}{4}$  mile S. S. E. of Kalawao.
- (9)  $\frac{1}{2}$  mile N. N. W. of Jasapur.
- (10) 200 yards south-west of Kaliana, on the Nagmati.
- (11) At Verawal,  $3\frac{1}{2}$  miles E. by E. S. E. of Nana Gop.
- (12) At Verari *vokala*,  $\frac{3}{4}$  mile north-west of Bhanwad.
- (13) At Dhandar near bank,  $\frac{1}{4}$  mile north-west of Lalpur.
- (14) One mile south-west of Arikhana, at the Jangi *vokala*.

#### BALLAST AND AGGREGATES

The Deccan traps, dolerites, limestones and sandstones are widely used for railway ballast, and may also be used as aggregates in concrete mixes. Fresh traps and dolerites, however, would be ideal for aggregates. Certain physical tests and microscopical examination would determine the suitability of the material for the purpose of aggregates. The main idea is to find out whether the rock is likely to undergo any alteration when mixed with cement, under the new environment, owing to the presence of any possible harmful ingredients.

#### SAND

Although a type of black sand is universally present almost throughout the State, the material usually needs some treatment by screening and cleaning before use. Nevertheless, the river sands and coastal sands, in parts of the State, do contain sufficiently

clean sand suitable for the plaster, mortar or concrete. No statistics of sand production are available.

Dr. B. C. Roy (10) reports that a type of impure sand from near Aditania quarries in Porbandar is used in manufacturing cement by the Porbandar cement factory, where it is delivered at Rs. 5/- per ton. About 25 tons are needed daily. The sand, analysed at the cement works, gave the following results:—

|                                |    |     |    | <i>Per cent.</i> |
|--------------------------------|----|-----|----|------------------|
| SiO <sub>2</sub>               | .. | ... | .. | 63.10            |
| Al <sub>2</sub> O <sub>3</sub> | .. | ..  | .. | 13.37            |
| Fe <sub>2</sub> O <sub>3</sub> | .. | ..  | .. | 6.36             |
| CaO                            | .. | ..  | .. | 6.77             |
| MgO                            | .. | ..  | .. | 1.30             |
| Alkalies                       | .. | ..  | .. | 0.50             |
| Loss                           | .. | ..  | .. | 8.60             |
| Total                          |    |     |    | 100.00           |

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## CHAPTER XIII

### CALCITE

#### GENERAL

Calcite or Iceland spar ( $\text{CaCO}_3$ ) has a rhombic crystal form and is doubly refracting, i.e., any mark seen through it will appear as two marks. It occurs as cavities in basic rocks, gangue minerals in hydrothermal deposits, secondary veins in limestone, etc.

Calcite lump of 99 per cent. purity from Rajputana is sold at Rs. 16/- per ton. Calcite powder ground to 300 mesh is priced at Rs. 98/- per ton in Calcutta market. The price of ground calcite (200-300 mesh) from Jamnagar, ex-godown, is quoted at Rs. 50/- per ton.

#### USES

The pure varieties are used for the manufacture of bleaching powder, as a flux in metallurgical operations, for making glaze in pottery, and in optical industry. The usual specifications of crystals suitable for the preparation of nicols prisms are: clearness, transparency, absence of cracks and twinning other than parallel to the base; some colour and minor inclusions are not considered harmful, but rhombic crystals measuring less than  $\frac{1}{8}$  inch on each edge are not accepted. Ground calcite is employed as a non-scratch metal polish. Calcite powder is also used in rubber, textiles, paper mills, glass works, tanneries, sugar factories, etc. Calcite is used in making industrial lime for gas purification, oil and salt refining, disinfectants, paints, etc.

#### DISTRIBUTION

##### *Amreli*

Mr. S. Krishnaswamy (10) carried out a detailed investigation of the calcite deposits in parts of Amreli in field season 1943-44. The following notes are taken from his report:—

*Panala deposits.*—This important occurrence is located about two furlongs west of Ingorala ( $21^{\circ}13'30''$  :  $71^{\circ}14'30''$ ), on the north-



ern outskirts of the Gir forest, possibly extending for a mile and a half westwards. The principal veins are lenticular and are found in the low hillocks to the south and south-east of Panala hill ( $\Delta$  1,133) and down the southern flanks of the latter hill, in association with greenish porphyritic traps intruded by basic trap dykes. The veins have a variable strike, their general direction being W. N. W. E. S. E. The shallow test pits show that these veins persist in depth generally up to about 10 feet. About 58,000 tons of calcite can be won from this area within this depth. The veins on Panala hill are associated with a white siliceous rock. These deposits are probably of hydrothermal origin. The calcite crystals are too opaque to be suitable for optical purposes. They can, however, be utilised in the manufacture of chemicals. The material is sent to Bombay, the *f.o.r.* price at the nearest Railway Station being reported to be Rs. 25/- per ton.

*Ingorala deposits.*—About 5-6 furlongs north and north-east of Ingorala ( $21^{\circ}13'30'' : 71^{\circ}14'30''$ ), there are two small parallel veins of calcite running discontinuously in an E. N. E.-W. S. W. strike. They are generally small, only a few hundred feet long, with an average thickness of half to three inches. They are generally more cherty than calcareous. According to R. Bruce Foote (*The Geology of Baroda State*, p. 159, 1898), these veins form part of the long Jikiali and Kotada veins, which extend for some  $9\frac{1}{2}$  miles in a discontinuous manner, from Gadhia in the west to beyond Jikiali ( $21^{\circ}15'30'' : 71^{\circ}15'30''$ ) in the east into the adjoining Bhavnagar State.

### *Bhavnagar*

Mr. K. P. Sinor (3) noted some calcite veins, partly appearing like marble due to contact metamorphism, near Abhrampura. They are reported to be sporadic and are not of large extent.

It is probable that large workable veins are present in parts of Bhavnagar, judging from extensive deposits in adjacent areas.

### *Junagadh*

Mr. S. Krishnaswamy (9) examined the calcite deposits in parts of Junagadh in field season 1943-44. The following notes are taken from his report:—

*Gadhagra deposits.*—A number of calcite veins are found around Gadhagra ( $21^{\circ}15' : 71^{\circ}26'$ ). The most important deposit is located about half a mile S.  $29^{\circ}$  W. of Ramgadh ( $21^{\circ}14'45'' : 71^{\circ}24'30''$ ). This vein strikes E. N. E.-W. S. W. in a discontinuous manner for about a mile and a quarter in Junagadh State territory, before extending into the adjoining Bhavnagar State. About 28,000 tons of calcite could be won from this deposit within a depth of 15 feet alone. There are, in addition, two other large veins, one about two miles to the south-east of Gadhagra, close to the boundary line of Bhavnagar State and another about a mile and a quarter to the south-west of that village bordering the Gadhagra Railway Station road. A number of smaller calcite veins also occur to the north, north-east and south of that village. They are associated with purplish-brown porphyritic traps, intruded by basic trap dykes. The calcite veins are believed to be of hydrothermal origin.

Some of the Ramgadh veins may yield small amounts of clear transparent calcite suitable for optical purposes. Most of the materials, however, are dense and opaque, and are not suitable for optical use. They may find a use in the manufacture of various chemicals. The material is despatched to Bombay, the f.o.r. price at the nearest Railway Station being reported to be Rs. 25/- per ton.

Mr. S. Krishnaswamy (11) also recorded numerous small occurrences of opaque calcite in the trap rocks in the Gir forest in Junagadh in the following localities:—

- (1) Two miles S. S. W. of Sarakaria ( $21^{\circ}0' : 71^{\circ}5'$ ).
- (2) Five furlongs E. N. E. of Itvaya ( $20^{\circ}56'30'' : 71^{\circ}0'30''$ ), where there is a small deposit of greyish white, crystalline limestone or marble.
- (3) Nearly a mile N. N. E. of Itvaya ( $20^{\circ}56'30'' : 71^{\circ}0'30''$ ).
- (4) A mile and a half almost due east of Kantala ( $21^{\circ}2' : 71^{\circ}12'$ ).
- (5) A mile and a half to the east of Kharadhar ( $21^{\circ}5'30'' : 71^{\circ}14'45''$ ).
- (6) A mile and three furlongs west of Kharadbar.

- (7) About  $1\frac{3}{4}$  miles N. N. E. of Kharadhar. Here two parallel bands of moderately crystalline rock, about 2-3 feet thick, dipping at high angles, occur in a zone one mile long and seven feet wide.
- (8) About one mile west of Khambha ( $21^{\circ}9' : 71^{\circ}17'30''$ ), there is a 2-foot wide band of crystalline limestone, with small crystals of calcite in the matrix.
- (9) Two miles W. S. W. of Khambha, on the high western slopes of the south spur of a big hill range, north of the Dhantrawari river.
- (10) About  $1\frac{3}{4}$  miles W. S. W. of Khambha, from the north-eastern flanks of a low hillock.

Calcite veins in traps, three feet in thickness, are reported by Mr. J. M. Master (4), about  $1\frac{1}{2}$  miles south of Malia, on the western bank of the Mengal river, and north-east of Keshod. The deposit at the former place is said to be 500 yards long.

According to Mr. B. F. Mehta (7), minor veins of calcite in traps are present to the south of the township of Bhesan, Junagadh.

### *Morvi*

In Morvi Dr. H. Crookshank (12) noticed small calcite veins in abundance but did not come across any large veins suitable for working.

### *Nawanagar*

A dye (1) records many calcite veins filling fissures in traps in Nawanagar, often running for long distances, sometimes in the form of branching veins, near Virpur, on the west bank of the Moti Phuljar river, and in the vicinity of Pithadia, on the river Manwar, at times up to 4-6 feet wide. Minor veins are reported from the following places:—

- (1)  $1\frac{1}{4}$  miles S. S. E. of Rinjpur, about six miles S. S. E. by S. of Lalpur, partly in association with aragonite.
- (2)  $\frac{1}{4}$  mile south-east of Khirasra,  $2\frac{1}{2}$  miles north-west of Lalpur. Here a N. N. W.-S. S. E. vein exposed for 180 yards shows a maximum width of four feet.

- (3)  $\frac{1}{4}$  mile S. S. E. of Govania, a 150-foot long branching vein strikes N. E.-S. W. and is  $1\frac{1}{2}$ -4 feet wide.
- (4)  $\frac{1}{2}$  mile north of Wadala on the roadside to Narmana, showing a N.-S. vein.
- (5) One mile south of Narmana, 20 miles S. S. E. of Jamnagar, exposing a couple of large, parallel N.-S. veins.
- (6) About  $\frac{1}{2}$  mile W. S. W. of Wadala, showing a large N. W.-S. E. vein.
- (7)  $\frac{1}{4}$  mile south of Sarwania,  $3\frac{1}{4}$  miles S. S. W. by S. from Kalawad, where a thick deposit is struck in a well.
- (8) South of Katkola, five miles north of Wansjalia Railway Station, exposing numerous anastomosing veins, two to six inches wide.
- (9) About four miles E. S. E. of Sarodar, where a vein, one foot wide, runs from N. N. W. to S. S. E. of Dhoraji.
- (10)  $1\frac{3}{4}$  miles E. N. E. of Darwi, 10 miles N. N. E. of Kandorna, showing thin irregular veins on the hilly ground.
- (11) At the base of Nana Baghudio Dhar,  $\frac{1}{2}$  mile S. S. E. of Khijaria,  $11\frac{1}{2}$  miles north-west of Kandorna, exposing an irregular vein.

According to Dr. B.C. Roy (13 & 14), numerous vertical or highly inclined calcite veins, one foot up to five feet wide, striking commonly between N. E.-S. W. and N. W.-S. E., are present as fissure fillings in the vesicular traps in the Jamnagar area, Halar district. They are possibly of hydrothermal origin. They are worked generally up to a depth of 10-20 feet, but 30-35 feet deep pits are also noticed at places. The bigger veins run uniformly for long distances, from a few furlongs up to a couple of miles or more in the form of single veins along the strike. The veins are at times branching and again coalescing in some instances. They are excavated intermittently along the strike, in the form of long trenches, in fallow lands only, a large part of the veins being concealed below a cover of black soil or miliolite limestone; the total thickness of the overburden varies from a few feet up to five feet.

Calcite is generally white, but occasionally some coloured varieties (red, pink, grey or yellow) are found, the crystals being in the form of large aggregates breaking into rhombohedra. The

veins rarely show minor irregular pockets, lenses or parallel bodies of chalcedonic silica, chert and zeolites. The depth to which the calcite veins persist will depend on the thickness of the flow concerned, and therefore much variations in depth are envisaged, although the average depth of mineralisation would be probably about 40-50 feet.

A list of the localities where calcite has been worked from time to time in the Halar district, by Messrs. Jamnagar Minerals Development Syndicate, hitherto possessing monopoly rights in calcite mining in Nawanagar, is given below:—

- |                      |   |
|----------------------|---|
| (1) Panchkoshi taluk | .. Konza and Alia Bada.   |
| (2) Khambalia taluk  | .. Sinhan, Khasota and Sirsaro.   |
| (3) Lalpur taluk     | .. Rafa Khatia, Rafudal, Govania, Jashapur, Jogwad, Chhikari, Mahadevia, Rasangpur, Pipli, Sapur, Navugam, Vili, Rangpur, Modpur and Dharampur. |
| (4) Kalawad taluk    | .. Moti Matli, Nana Matli, Modpur, Vavdi, Sahavania and Vijarkhi.   |
| (5) Vanthali taluk   | .. Vertiya, Pithadia and Hadmatia.  |
| (6) Kalyanpur taluk  | .. Sidsara and Asota.   |

Calcite is sorted in three qualities, i.e., best white (*superfix*), white (*calco*) and grey white (*gemco*), and ground to fine powder (200-300 mesh) in Raymond fine roller mill at Jamnagar. The product called *whiting* is despatched to Bombay, Calcutta and elsewhere for use in rubber, textiles, paper mills, glass works, tanneries, sugar factories, etc. It is also used for manufacturing varnishes, dyes, medicines, etc. This industry in wartime was flourishing when there was a scarcity of certain mineral powders. At present, as a result of cheaper fine mineral powders, e.g., kaolin, chalk, gypsum, talc, barytes, etc., the enterprise is facing severe competition, particularly in view of higher mining and production costs. The calcite deposits of Nawanagar are presumably the best in India, and efforts should be made to encourage the present industry.

The particulars with regard to analyses, test results, production cost, price and output, as gathered from Messrs. Jamnagar Minerals Development Syndicate, are reproduced below.

*Analyses*

Samples of calcite analysed in the Geological Survey laboratory showed the following results:—

|   | 1     | 2     | 3     |
|---|-------|-------|-------|
| CaCO <sub>3</sub> ..  | 96.49 | 96.77 | 96.20 |
| MgCO <sub>3</sub> ..  | 2.48  | 2.33  | 2.96  |
| Al <sub>2</sub> O <sub>3</sub> &<br>Fe <sub>2</sub> O <sub>3</sub> .. | 0.45  | 0.25  | 0.25  |
| SiO <sub>2</sub> ..   | 0.31  | 0.33  | 0.27  |

Localities:—

- (1) Moti Matli.
- (2) Sarvania.
- (3) Govania.

*Alipore Test House Results*

|   |    |    |                        |
|---|----|----|------------------------|
| Appearance .. ..  | .. | .. | Dry soft white powder. |
| Coarse particles retained on 240 mesh B. S. Sieve .. .. | .. | .. | 0.58 per cent.         |
| Whiteness .. ..   | .. | .. | Acceptable.            |
| Moisture .. ..  | .. | .. | 0.1 per cent.          |
| Oil absorption number ..                                | .. | .. | 14.6.                  |

*Production Cost and Price*

|  |    |    |                               |
|--|----|----|-------------------------------|
| Excavation cost .. ..                        | .. | .. | Rs. 5/- to Rs. 7/- per ton.   |
| Transport to Jamnagar ..                     | .. | .. | Rs. 10/- per ton.             |
| Sorting at mine & factory ..                 | .. | .. | Rs. 2/- per ton.              |
| Royalty .. ..                                | .. | .. | Rs. 2/8/- per ton.            |
| Loading at mine & unloading at factory .. .. | .. | .. | Re. 1/- per ton.              |
| Crushing .. ..                               | .. | .. | Rs. 20/- to Rs. 25/- per ton. |
| Bagging .. ..                                | .. | .. | Rs. 10/- per ton.             |
| Price of powder at factory ..                | .. | .. | Rs. 50/- per ton.             |

*Output*

Since 1945 more than 10,000 tons are reported to have been produced. The production figures, however, are available since 1950 only.

|         |    |             |
|---------|----|-------------|
| 1950 .. | .. | 1,860 tons. |
| 1951 .. | .. | 1,445 tons. |
| 1952 .. | .. | 2,609 tons. |

*Palitana*

Numerous small calcite stringers in traps are noticed by Mr. B. F. Mehta (8) in Palitana, particularly to the east of Thadach.

*Porbandar*

E. H. Adye (2) records a narrow calcite vein in traps at 1½ miles N. by N. N. W. of Bhatakri, in Porbandar. The area is strewn with geodes of onyx, chalcedony and quartz.

Dr. B.C. Roy (13 & 14) noted some specimens of calcite, reported from Adwana and Bagwadar in the Porbandar *taluk*. The material is being used at the works of Messrs. Porbandar Industrial Products for preparing a white powder. Samples of calcite, said to originate from Bhetakadi and Bapodar, also in the Porbandar *taluk*, are ground to 100 mesh and sold at Rs. 50/- per ton at the works of Messrs. Saurashtra Minerals Ltd., in Porbandar. About 20 tons of power are produced daily for use as filler in rubber factories.

Mr. B. F. Mehta (6) records the following calcite veins in traps in Porbandar:—

- (1) A seven feet thick, E.-W. striking vein, two miles west of Adwana.
- (2) A three feet wide, E.-W. striking vein S. S. W. of (1), exposed for 50 feet at the surface.
- (3) An eight feet wide, N.-S. vein, about 400 yards east of (2).
- (4) A four feet wide, N.-S. vein in the Ranawao river, about a mile north of Bakharla.

*Wadhwan*

According to Mr. R. K. Taploo (5), numerous one to two feet wide calcite veins in traps occur near a stream one mile south of Korda in Wadhwan. The surface material is pinkish but becomes clearer at depth.

**FUTURE**

The calcite deposits in Kathiawar peninsula are unique of their kind in India, running over considerable distances and

persisting up to 30-50 feet in depth. The important deposits are found in Nawanager, Porbandar, Junagadh, Amreli and Bhavnagar.

In recent years a good trade has developed with the material from Nawanager and Porbandar, where it is ground to fine powder and marketed to Calcutta, Bombay and elsewhere for use in rubber, textiles, paper mills, glass works, tanneries, etc. This industry, very prosperous in wartime as a result of a scarcity of certain mineral powders, is at present facing keen competition from cheap fine mineral powders. This is due to increasing higher mining and production costs. Efforts should be made to encourage the existing industry as otherwise it may not survive for a long period.

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## CHAPTER XIV

### CHALK

#### GENERAL

Chalk is a white, earthy limestone, used in the manufacture of cements, whiting and crayons. Chalk powder is also used as fillers in rubber factories and in textile and paper mills. It represents a chemical precipitate of calcium carbonate and contains organic bodies such as marine shells, foraminifera, etc., and is chiefly found in shallow water deposits.

The price of finished chalk varies from Rs. 33/- to Rs. 55/- per ton at works.

#### DISTRIBUTION

##### *Porbandar*

Dr. B. C. Roy (2) reports that 11 parties are working, about three miles away from Ranawao Railway Station, in an area of some 500 acres, in a flat country, for winning white chalk from a 3-5 foot thick bed below seven feet of overburden of black soil and impure clay. The pits are being filled up with waste, dug out materials from time to time. The winter water table is about 11 feet below the surface. The sub-soil water is abundant, and the material is thus easily levigated, recovering about 50 per cent. of white material from the crude chalk. The production cost, according to the producers, is as follows:—

|  |    |                   |
|--|----|-------------------|
| Quarrying & levigation                           | .. | Rs. 12/- per ton. |
| Transport to Porbandar                           | .. | Rs. 4/- per ton.  |
| Royalty .. .. .                                  | .. | Rs. 4/- per ton.  |
| Crushing & bagging of levigated material .. .. . | .. | Rs. 8/- per ton.  |

The finished product (100-200 mesh) is used as filler in rubber factories, textile and paper mills, and in making of distempers, cos-

metics, drugs, etc. It is usually marketed in West Bengal, U.P., the East Punjab, Madhya Bharat, etc., but some quantities are also exported to Pakistan and East Africa. The price of the finished product varies from Rs. 40/- to Rs. 50/- per ton ex-works. The cost of material delivered at Calcutta for rubber factories is stated to be Rs. 105/- per ton, whereas whiting powder of a superior quality from France, Italy, Belgium and Japan is available at Calcutta for Rs. 125/- per ton.

The two principal producers, i.e., Messrs. Saurashtra Minerals Ltd., and Porbandar Industrial Products, are nowadays recovering altogether about 6,000-10,000 tons of finished chalk or whiting per annum working for a period of eight months only. The chalk bearing area, a flat terrain representing a *recent* deposit, is said to cover nearly five square miles, and thus at the present rate of consumption, the industry is likely to continue for an appreciable period. The open-cast quarrying for chalk is being carried out since a number of years, and in fact Mr. B. F. Mehta (1) noted some activities in field season 1942-43.

A sample of finished whiting powder, analysed by Messrs. Hughes and Davies, Bombay, gave the following results:—

|                                | <i>Per cent.</i> |    |            |
|--------------------------------|------------------|----|------------|
| CaCO <sub>3</sub>              | ..               | .. | 89.80      |
| MgCO <sub>3</sub>              | ..               | .. | 4.04       |
| SiO <sub>2</sub>               | ..               | .. | 4.26       |
| Al <sub>2</sub> O <sub>3</sub> | ..               | .. | 0.52       |
| Fe <sub>2</sub> O <sub>3</sub> | ..               | .. | 0.68       |
| SO <sub>3</sub>                | ..               | .. | <i>nil</i> |
| Moisture                       | ..               | .. | 0.50       |
| Alkalies, etc.                 | ..               | .. | 0.20       |
| Total                          | ..               | .. | 100.00     |

Mr. B. F. Mehta (1) recorded a deposit of white chalk, in the small hillocks, about a quarter mile south of Bordi Sultanpur (21°44' : 69°52'), in the Ranawao *mahal*, in Porbandar. Here the bed is three feet thick and occurs below a two feet band of coarse grit, covering an area of half a square mile.

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## CHAPTER XV

### CLAYS

#### GENERAL

Clays are earthy substances of fine texture consisting mainly of hydrous aluminium silicates and specks of rock fragments, with colloidal matter and variable impurities such as quartz, mica, lime, magnesia, iron oxide, etc.

The clay minerals are usually kaolinite, nacrite, halloysite, montmorillonite and beidellite. The clay particles are extremely fine, commonly 0.002 mm. in diameter, and can remain suspended in water. Their granularity is determined by sieve tests.

The essential properties to be determined in assessing the quality of clays are plasticity, transverse strength, shrinkage during drying and firing, and fusibility. The clays are sometimes mixed to yield a suitable grade of plasticity. Clays having high shrinkage, but otherwise found suitable, can be blended with suitable varieties so as to get a desired degree of shrinkage.

Low grade clays fuse at 800° to 1,000° C., but the refractory clays generally do not fuse below 1,300° to 1,400° C., the temperature being denoted in terms of Seger or Pyrometric cones, each cone indicating a certain temperature range. Fusible clays may be vitrified, i.e., form a glassy material by fusion, below 1,300° C. The refractory clays, however, do not vitrify below 1,600° C.

Colloidal silica increases plasticity, but otherwise quartz lowers plasticity and shrinkage although rendering clay rigid and refractory. Coarse silica, however, is objectionable and should be removed in firebrick industry. Alumina is useful in making clay refractory. Felspar and iron decrease the melting point and act as a flux. Iron in any form colours the clay product buff, red or brown and should not exceed one per cent. if white-burning clay is desired. Lime, magnesia, alkalies (soda and potash) and titania have fluxing effects. Titanium also produces colouration in the fired clays.

### CLASSIFICATION, USES AND PRICES

Clays are generally classified into a number of types, namely, kaolins or china-clays, ball clays, fire-clays, stone-ware clays, potter's clays, brick clays, Fuller's earth, bentonite and lithomarge.

*Kaolins.*—They are residual, pure, white clays of limited occurrence. They invariably need washing, screening and filtering before use, particularly in the manufacture of high-grade pottery, i.e., in chinaware, glazed porcelain, insulators, etc., or as a filler in textile, paper and other industries. Other uses are in soap making, paint mixing and in rubber manufacture. The cotton mills import large quantities of china-clay in view of the poor quality of the Indian materials. With greater care in the methods of clay washing, the Indian producers should be able to compete with the imported materials. The price of china-clay nowadays varies from Rs. 40/- to Rs. 75/- per ton f.o.r. loading Station, depending on the quality of the material.

*Ball clays.*—These are good quality, plastic, refractory clays and are generally high in alumina. They are of sedimentary origin and are of restricted distribution. This type is mixed with other clays to give any desired degree of plasticity and bonding qualities. It generally burns white and is employed in the manufacture of white wares.

*Fire-clays.*—They are bedded, sedimentary rocks and are common in the Gondwana formation. They are either plastic or non-plastic. Their high refractoriness and absence of harmful impurities make them most suitable for the manufacture of varied types of refractories, firebricks, ceramic wares, etc. Some of the grey or dark varieties of clays often burn white. They are sent in raw state to the firebrick manufacturers. The price of fire-clay is usually Rs. 8/- per ton at loading Station.

*Stone-ware clays.*—They include semi-refractory or dense-burning clays, fire-clays, generally burning buff, and are used in the manufacture of stoneware and pottery.

*Potter's clays.*—They are common, impure, residual clays, earths and silt, used by village potters for making domestic pottery and utensils, the quality of the finished product depending on their colour, porosity and strength.

*Brick clays.*—These are residual or sedimentary, low grade, plastic clays, commonly burning brown or red, and are used for bricks, tiles, sewer pipes, etc. Soft or crushed shales are also employed for such purposes.

*Fuller's earth.*—It denotes a type of bleaching clay which has the property of absorbing colouring matters from oils, fats and greases. Its chemical composition, not differing from that of other clays, does not signify its absorptive power. It is generally non-plastic and commonly disintegrates in presence of water. The deposits of Fuller's earth are dealt with in Chapter XVII.

*Bentonite.*—Chemically it contains 5-10 per cent. alkaline earths and alkalies and 3 per cent. ferric oxide. Some varieties swell in water, whereas others do not, and the latter types possess bleaching properties like Fuller's earth. The former types are used as drilling mud, for reconditioning moulding sands, and in the preparation of cosmetics, medicines, etc. Bentonite is at present sold at Rs. 38/- per ton at loading Station.

*Lithomarge.*—The lateritic formation sometimes contains bands or pockets of a ferruginous clay known as lithomarge. It usually contains higher alumina and lower silica than kaolin. It is white in colour when free from ferric oxide, but it is otherwise red, brown or variegated in appearance. It does not remain in suspension in water even when finely ground. It is used as a substitute of kaolin, but not for all the requirements for which kaolin is employed.

## DISTRIBUTION

### *Bhavnagar*

The clay deposits in Bhavnagar were examined by Mr. M. M. Oza (11) during field season 1950-51. The following details are taken from his Progress Report:—

Just north of Malanka ( $21^{\circ}44'$  :  $72^{\circ}11'$ ), in the stream bed, a yellow coloured siliceous clay occurs in large quantities, below an overburden of five feet. When dry it crumbles between fingers and one can feel the presence of sand grains. The quarries are opened in the stream bed so as to avoid removal of large overburden. The clay is a variety of moulder's clay and is used for the construc-

tion of moulds for workshop and factory use. The annual production of clay is about 650 tons. Its working cost is reported to vary from Rs. 20/- to Rs. 25/- per ton. The material is being shipped to Bombay.

Blue and yellow clays, locally known as *chandani*, are present in the bed of the river Maleshari, a little south of Adhevada (21°43' : 72°9'). Such clays are also found in the bed of the stream right up to Malanka and Akvada (21°44' : 72°14') and about two furlongs north of Tagadi (21°41' : 72°10'). The bluish variety is free from silica and is quite plastic. At Chitra (21°45' : 72°7') two feet of reddish and yellow clays occur under five feet of soil. The annual production of blue and yellow plastic clays at Malanka is 50 tons, the working cost being reported to vary from Rs. 20/- to Rs. 25/- per ton. The clays are being sent to Bombay by boat.

A bluish white clay, locally known as *bhutada*, is quarried at Budhel (21°41' : 72°9') and Thoradi (21°39' : 72°12'). It is a soft clay, absolutely free from silica grains and any gritty materials. When freshly dug the material is quite moist and plastic. When exposed it becomes dry and friable. The clay may be of refractory type. At Thoradi this clay occurs under an overburden of 10 to 12 feet. At Budhel the material occurs under seven feet of soil and dirty white clay, the thickness of the *bhutada* being three to four feet. The annual production at Budhel and Thoradi is stated to be 560 tons and 150 tons, respectively. The working cost is said to vary from Rs. 25/- to Rs. 30/- per ton. The material is being sold at Bombay and Ahmedabad and is used in lining boilers.

### *Junagadh*

Mr. S. Krishnaswamy (4) sunk 15 trial pits in a zone 3,400 feet long and 100 feet wide, up to an average depth of 10 feet, with a view to prospecting the Gaj clay deposits in Panchala (20°19'30" : 70°8'15") in Junagadh. The clays are grey to buff in colour and are partly iron-stained and gypseous. They are highly plastic but some decrepitate badly on heating. Hence they are not likely to be useful for pottery. Washing might improve the clays and render them suitable for sizing in cloth and paper mills. Detailed physical examination would be necessary to assess their value. The following analyses of clays, carried out in the Geological Survey laboratory, are given below:—



*Analyses**(Per cent)*

|                                      | (1)   | (2)         |
|--------------------------------------|-------|-------------|
| SiO <sub>2</sub> .. ..               | 58.34 | 60.52       |
| Al <sub>2</sub> O <sub>3</sub> .. .. | 21.15 | 23.51       |
| Fe <sub>2</sub> O <sub>3</sub> .. .. | 3.95  | 5.69        |
| CaO .. ..                            | 0.85  | 5.60        |
| MgO .. ..                            | 1.55  | 1.08        |
| TiO <sub>2</sub> .. ..               | 1.10  | <i>n.d.</i> |
| Loss .. ..                           | 12.54 | -           |
| H <sub>2</sub> O .. ..               | -     | 2.84        |
| Alkalies .. ..                       | -     | 0.96        |

Mr. S. Krishnaswamy (5) investigated the following varieties of lithomargic clays, best exposed along *nala* beds and banks, around Kadiali (21°0'45" : 71°31'30"), in the Babriawad *pranth*, Junagadh:—

- (1) Greyish-white or grey clays occurring in some abundance to the north-east, east and south of the village.
- (2) Red and buff clays in abundance to the S. S. E. and south-east of the village, suitable for use as mineral pigments.
- (3) Pink or light pink coloured clays in small lenticular deposits, possibly suitable for the manufacture of acid jars.

The total reserve in the proved area is estimated at 2,71,000 tons, on the basis of 27 cubic feet of the clay making one ton. The probable quantity available in the easterly extensions of the deposit is believed to be about 2,84,000 tons. An additional reserve of 19,000 tons has been estimated from the areas along the Dowlia and other smaller *nalas* to the south of Kadiali. The average thickness of the clays varies between three and four feet.

The clays are being excavated and beneficiated by a crude method of levigation by (1) The Saurashtra Indian Sizing, Clay Refining and Colouring Works, and (2) Sattar and Dawood Pottery Works. The washed clays are used as sizing material in the inferior grades of textiles or paper manufacture. They are not considered suitable as a refractory or as fire-clay. The clays contain high lime

and magnesia, and as such no vitrified wares could be manufactured, as the product would be porous and liable to shrinkage.

*Analyses*

(Per cent)

|                                |    |    | (1)   | (2)   |
|--------------------------------|----|----|-------|-------|
| SiO <sub>2</sub>               | .. | .. | 41.56 | 41.54 |
| Al <sub>2</sub> O <sub>3</sub> | .. | .. | 44.58 | 39.50 |
| Fe <sub>2</sub> O <sub>3</sub> | .. | .. | 1.62  | 0.68  |
| CaO                            | .. | .. | 3.70  | 1.44  |
| MgO                            | .. | .. | 1.74  | 1.40  |
| H <sub>2</sub> O               | .. | .. | 6.13  | 15.23 |
| Alkalies                       | .. | .. | 0.80  | 0.20  |

Analysts:—1. Geological Survey of India.  
2. J. F. Davies of Bombay.

Dr. B. C. Roy (6) reports that while sinking a new well in the Gaj formation, in the premises of the Kathiawar Industries Ltd., near Chorvad Road Railway Station, a grey plastic clay was struck at a depth of 10 feet from the surface. The clay is stained by iron solutions and is not likely to improve at depth, as the Gaj beds are predominantly limonitic. Indications of grey clays (Gaj) are also seen in the debris from some wells in Virodar (20°55'30" : 70°37') and Gorakhmudi (20°54'20" : 70°34'40"). A new well excavation just to the north of Mangia (20°53' : 70°35') also struck similar clays; they are plastic but invariably iron-stained. A sample of clay from Mangia, analysed in the Geological Survey laboratory, gave the following analysis:—

|                                |    |       |    | Per cent. |
|--------------------------------|----|-------|----|-----------|
| SiO <sub>2</sub>               | .. | ..    | .. | 51.560    |
| Al <sub>2</sub> O <sub>3</sub> | .. | ..    | .. | 16.830    |
| Fe <sub>2</sub> O <sub>3</sub> | .. | ..    | .. | 6.500     |
| MnO                            | .. | ..    | .. | 0.050     |
| TiO <sub>2</sub>               | .. | ..    | .. | trace     |
| P <sub>2</sub> O <sub>5</sub>  | .. | ..    | .. | 0.008     |
| CaO                            | .. | ..    | .. | 7.420     |
| MgO                            | .. | ..    | .. | 3.620     |
| Loss                           | .. | ..    | .. | 13.280    |
|                                |    |       |    | <hr/>     |
|                                |    | Total | .. | 99.268    |

Dr. Roy (6) further records an occurrence of lithomargic clay associated with lateritic rocks capping the traps, near Char ( $21^{\circ}15' : 70^{\circ}12'30''$ ) in Keshod *mahal*. Here a few pits are put down to a depth of 10-15 feet from the surface. The maximum depth up to which the clay extends has yet to be ascertained by further excavations as none of the pits has explored the bottom of the clay. The clay-bearing strip measures some 200 yards by 100 yards, and is likely to contain over 10,000 tons of greyish-white clay, within the depth examined. The deposit is not uniform throughout; the better quality fine clay occurs as lenticular bands of  $2\frac{1}{2}$ -3 feet in thickness. A sample of lithomarge from Char, analysed in the Geological Survey laboratory, gave the following analysis:—

|                                |    |    |    |    | <i>Per cent.</i> |
|--------------------------------|----|----|----|----|------------------|
| SiO <sub>2</sub>               | .. | .. | .. | .. | 40.60            |
| Al <sub>2</sub> O <sub>3</sub> | .. | .. | .. | .. | 40.55            |
| Fe <sub>2</sub> O <sub>3</sub> | .. | .. | .. | .. | 2.03             |
| MnO                            | .. | .. | .. | .. | <i>trace</i>     |
| TiO <sub>2</sub>               | .. | .. | .. | .. | 1.90             |
| P <sub>2</sub> O <sub>5</sub>  | .. | .. | .. | .. | 0.02             |
| CaO                            | .. | .. | .. | .. | <i>trace</i>     |
| MgO                            | .. | .. | .. | .. | 0.65             |
| Loss                           | .. | .. | .. | .. | 13.70            |
| Total                          |    |    |    |    | 99.45            |

#### *Madhya Saurashtra*

Recently Dr. B. C. Roy (7) and Mr. C. Karunakaran (10) investigated the known fire-clay deposits in Madhya Saurashtra. The following notes are based on their reports:—

*Hasanpur* ( $20^{\circ}37' : 70^{\circ}58'$ ).—The clay bed is 16-17 feet thick, carbonaceous and black, and is useful for refractory bricks. It occurs beneath an overburden of reddish clay 12 feet thick which is sometimes used for building bricks. The quarries are not being worked at present.

*Rafaleshwar* ( $20^{\circ}47' : 70^{\circ}54'$ ).—The quarries show a dark grey, carbonaceous clay, four to five feet thick, overlain by impure, reddish clay 12 feet thick. The clay is used mainly for the manufacture of refractory bricks and sanitary wares. Several pits have been made in this region and the clay appears to exist as a horizontal bed extending more or less uniformly over an area of about half a square mile.

Dr. H. Crookshank (9) quotes the following analyses of dry fire-clay from Morvi, presumably from Rafaleshwar or Udepur quarries. No. 1 refers to a black fire-clay fusing at cone 29, whereas No. 2 is a grey fire-clay fusing between cones 30 and 31.

| <i>Analyses</i>                |       |       |       |
|--------------------------------|-------|-------|-------|
| <i>(Per cent)</i>              |       |       |       |
|                                |       | (1)   | (2)   |
| SiO <sub>2</sub>               | .. .. | 60.70 | 59.55 |
| Al <sub>2</sub> O <sub>3</sub> | .. .. | 22.81 | 25.31 |
| Fe <sub>2</sub> O <sub>3</sub> | .. .. | 1.24  | 1.36  |
| CaO                            | .. .. | 1.00  | 1.00  |
| MgO                            | .. .. | 1.01  | 0.94  |
| Alkalies                       | .. .. | 1.58  | 0.36  |
| TiO <sub>2</sub>               | .. .. | 1.80  | 1.65  |
| H <sub>2</sub> O               | .. .. | 10.80 | 9.90  |

*Ratidevli* (22°37':70°56').—The quarries are situated about four miles W. S. W. of Wankaner and show a clay bed 10-18 feet thick overlain by about four feet of sandstone. The area was worked a few years ago but was subsequently abandoned on account of lack of sufficient demand for the material. The usual excavation cost and transport charges to Wankaner are stated to be Rs. 7/- and Rs. 3/- per ton respectively.

*Udepur* (22°44' : 70°54').—The clay is black, plastic and carbonaceous, often containing carbonised twigs and leaf impressions. It burns white and is used in the pottery works at Morvi for manufacturing refractory bricks. The clay bed is three to five feet thick, sometimes up to eight feet thick, with a six feet thick overburden of an upper layer of impure clay and a lower layer of sandstone. The clay bed appears to be irregular, forming several separate lenses over an area of about two square miles.

*Wankaner*.—A greyish white, plastic fire-clay, 1½ feet thick, underneath a 2-3 feet thick layer of sandstone, is exposed in a new pit in the flat country, about 1½ miles east of Wankaner Railway Station. The clay is stained red at places and is underlain by 2-3 feet thick red shales. The clay is reported to burn cream-white at 1,300° C.

#### *Nawanagar*

Dr. B. C. Roy (7) states that a type of impure clay near Gaga, partly stained yellow, is used for cement manufacture by the new Digvijay Cement Works at Sika.

*Porbandar*

According to E. H. Adye (1), the altered alkaline felspar rocks of Babia Dungar, Kari Dhar and Jaderra Dhar in Porbandar, containing unlimited quantity of kaolin, might be used for recovering china-clay or kaolin for the manufacture of porcelain.

Dr. B. C. Roy (7) reports that the Porbandar Cement Works use the creek clay adjoining their works, about 25 tons daily, for the manufacture of cement. Its price delivered at works is about Rs. 7/- per 100 c.ft. An analysis of the clay, supplied by the Associated Cement Co., is given below:—

|                                |    |    |    |       | <i>Per cent.</i> |
|--------------------------------|----|----|----|-------|------------------|
| SiO <sub>2</sub>               | .. | .. | .. | ..    | 43.56            |
| Al <sub>2</sub> O <sub>3</sub> | .. | .. | .. | ..    | 17.62            |
| Fe <sub>2</sub> O <sub>3</sub> | .. | .. | .. | ..    | 6.52             |
| CaO                            | .. | .. | .. | ..    | 9.02             |
| MgO                            | .. | .. | .. | ..    | 4.52             |
| Alkalies                       | .. | .. | .. | ..    | 1.82             |
| Loss                           | .. | .. | .. | ..    | 16.94            |
|                                |    |    |    | Total | .. 100.00        |

*Sayla*

According to Mr. J. M. Master (2), a greyish clay is present in some quantity about a mile south of Raniput in Sayla State. It is suitable for pottery and is supplied intermittently for some potteries at three *annas* per cart load.

The recent 500-foot bore for coal near Khakrathal has shown the existence of several beds of clays at various depths (10). Six beds of black clay, varying from 4 to 38 feet in thickness, have been encountered within the total length bored. A 10-foot thick, white, plastic clay is struck below 149 feet, and a 4-foot thick, grey, plastic clay at 284 feet from the surface.

*Wadhwan*

Mr. R. K. Taploo (3) noted small pockets of a gritty, greenish-white clay in association with sandstones in Wadhwan area.

*Zalawad*

According to Sir Cyril S. Fox (8), large quantities of clays suitable for pottery and firebricks occur at Rajpur, Talavdi, Kankavati (23°4' : 71°22'), Dholi, South Kuntalpur, etc., in Dhrangadhra. Some clays are reported to be suitable for making ordinary firebricks for boiler seatings, flues, etc. Some varieties on levigation are expected to yield high-grade clay suitable for the manufacture of porcelain. An average sample of a pottery clay from Dhrangadhra, analysed and tested by Messrs. R. V. Briggs and Co. Ltd., Calcutta, gave the following results:—

| <i>Analysis—</i>                            |    |    |    |    | <i>Per cent.</i> |
|---|----|----|----|----|------------------|
| SiO <sub>2</sub> (free)                     | .. | .. | .. | .. | 39.39            |
| SiO <sub>2</sub> (combined)                 | .. | .. | .. | .. | 25.79            |
| Al <sub>2</sub> O <sub>3</sub>              | .. | .. | .. | .. | 20.17            |
| Fe <sub>2</sub> O <sub>3</sub>              | .. | .. | .. | .. | 1.36             |
| TiO <sub>2</sub>                            | .. | .. | .. | .. | 1.90             |
| CaO   | .. | .. | .. | .. | 0.05             |
| MgO   | .. | .. | .. | .. | 0.99             |
| K <sub>2</sub> O                            | .. | .. | .. | .. | 1.20             |
| Na <sub>2</sub> O                           | .. | .. | .. | .. | 0.77             |
| Loss  | .. | .. | .. | .. | 8.30             |
| <i>u. d.</i>                                | .. | .. | .. | .. | 0.08             |
| Total                                       |    |    |    | .. | 100.00           |
| <i>Plasticity (in % of original clay) —</i> |    |    |    |    |                  |
| Water held at liquid limit                  | .. | .. | .. | .. | 53               |
| Water held at plastic limit                 | .. | .. | .. | .. | 20               |
| Atterburg Number                            | .. | .. | .. | .. | 33               |

The clay bearing localities in the Umia beds (Jurassics) in the Zalawad district, where good quality clay suitable for ceramic purposes occurs, were recently examined by Dr. B. C. Roy (7) and Mr. C. Karunakaran (10). The following details are taken from their reports:—

*Amrapur* (22°36' : 71°51').—A shallow quarry for clay is situated at a short distance to the south-east of the village. The clay formation is bounded on the north by overlying horizontal sandstone and on all other sides by fields in which clay does not extend. The clay is a grey, plastic, slightly micaceous variety and occurs as a horizontal bed beneath an overburden of soil four to

six feet thick. The quarry is about 150 yards in length and 50 yards in width. The major part of the available clay has been already worked out. About one thousand tons are now left. This would be exhausted in two years at the present rate of excavation of about 500 tons per year. The clay burns less white and is also less plastic than that obtained from other quarries in Zalawad area. It is being used in the manufacture of stoneware jars.

*Bagagela*.—Located about two miles from Than, at Bagagela ( $22^{\circ}36' : 71^{\circ}16'$ ), the clay pits are being worked by six parties including Than pottery and comprise a 500-foot long N.-S. strip along a low cliff near a temple. A black, plastic fire-clay, 7-8 feet thick, occurs below a 15 feet overburden of sandstone followed underneath by 2-3 feet thick grey shale, the beds dipping very gently towards west. Thin partings of coaly shale, up to 3-4 inches thick, are present in the fire-clay bed. The present quarrying cost of the clay works out at one *Rupee* per ton, but the progressive increase of the overburden towards the hill would augment the cost later on. A part of the clay bed, hitherto exposed on the eastern cliff slope with a thin cover, has been worked out during the last 15 years or so. The clay is delivered at the Than pottery at Rs. 5/- per ton. Its f.o.r. price at Sihor pottery is Rs. 13/- per ton.

Earlier analyses of clay from Bagagela, carried out at the Pottery Department of Sir J. J. School of Arts, Bombay, are given below:—

|                                |    |    | Grey clay  | White clay |
|--------------------------------|----|----|------------|------------|
| SiO <sub>2</sub>               | .. | .. | 64.5       | 61.4       |
| Al <sub>2</sub> O <sub>3</sub> | .. | .. | 24.0       | 25.5       |
| Fe <sub>2</sub> O <sub>3</sub> | .. | .. | 1.5        | 1.5        |
| CaO                            | .. | .. | 2.0        | 1.7        |
| MgO                            | .. | .. | <i>nil</i> | <i>nil</i> |
| Loss                           | .. | .. | 8.5        | 8.1        |
| Total                          | .. | .. | 100.5      | 98.2       |

*Bhagat Talavdi* ( $22^{\circ}35' : 71^{\circ}35'$ ).—A clay bed about four feet thick but of very limited extent outcrops in the fields south of the village. The clay is similar to that obtained at Bagagela but is inferior in quality. The deposit is being worked at present in a small way.

*Rampurda* (22°39' : 71°24').—About half a mile west of the village there are several shallow pits, which display a band of clay about two feet thick, overlain by four feet of mottled, purple clay and two feet of brown sandstone. The formation has a dip of 5° S. S. W. The clay is a black, plastic, refractory variety but the quantity available does not appear to be large.

*Vagadia* (22°37' : 71°20').—A clay band about seven feet thick, overlain by two to four feet thick sandstone and soil, occurs adjacent to the Sayla pottery. It has been worked by several small pits over an area of 500 square yards. The clay is white, slightly gritty and non-plastic and is considered to be generally unsuitable for pottery.

*Than*.—The open-casts in the plains near Than Railway Station, known as Kerwari mines, are being worked by Than pottery and show a 4-5 feet thick bed of a black, plastic fire-clay, underneath a 6-8 feet thick overburden of black soil. It is delivered at Rs. 5/- per ton at the pottery. Earlier analyses of Than clay, carried out at the Pottery Department of Sir J. J. School of Arts, Bombay, are given below:—

*White clay*

|                                   | 1            | 2            | 3            | 4           | 5           |
|-----------------------------------|--------------|--------------|--------------|-------------|-------------|
| SiO <sub>2</sub> ..               | 56.0         | 55.20        | 63.5         | 68.4        | 62.0        |
| Al <sub>2</sub> O <sub>3</sub> .. | 24.0         | 25.93        | 25.0         | 18.0        | 21.6        |
| Fe <sub>2</sub> O <sub>3</sub> .. | 2.0          | 0.60         | 1.0          | 2.0         | 2.0         |
| CaO ..                            | 6.0          | 3.10         | 2.0          | 3.1         | 4.3         |
| MgO ..                            | nil          | nil          | nil          | nil         | nil         |
| Loss ..                           | 12.0         | 13.80        | 9.0          | 8.4         | 10.0        |
| <b>Total.</b>                     | <b>100.0</b> | <b>99.66</b> | <b>100.5</b> | <b>99.9</b> | <b>99.9</b> |

*Black clay*

|                                   | 1           | 2            |
|-----------------------------------|-------------|--------------|
| SiO <sub>2</sub> ..               | 72.0        | 52.20        |
| Al <sub>2</sub> O <sub>3</sub> .. | 15.0        | 27.24        |
| Fe <sub>2</sub> O <sub>3</sub> .. | 2.5         | 3.55         |
| CaO ..                            | 3.0         | 4.50         |
| MgO ..                            | trace       | nil          |
| Loss ..                           | 6.9         | 12.20        |
| <b>Total.</b>                     | <b>99.4</b> | <b>99.70</b> |



*Velala* (22°37' : 71°17').—Grey coloured refractory clay occurs about half a mile north-west of the village, over an area of about 200 square yards. The clay bed is two to three feet thick underlying variegated sandstones and mottled clay with a total thickness of 5-10 feet. Several old pits have exposed the formation. The clay appears to be of limited extent and the quarries are now abandoned.

*Test Results of Clays from Saurashtra, investigated in the Pottery  
Department of Sir J. J. School of Arts, Bombay, from 1909 to 1914.*

| Place.                            | Plasticity.       | Colour before firing. | Colour after firing. | Temperature. | Remarks.   |
|-----------------------------------|-------------------|-----------------------|----------------------|--------------|--|
| Kerwari<br>(Than)                 | } Good plasticity | Grey                  | Yellowish buff       | 1,030°C.     | A suitable clay for flooring, tiles and fire-clay goods. |
| Lakthar                           |                   |                       |                      |              |  |
| "                                 | Good plasticity   | Black                 | White                | 1,130°C.     | A good ball clay.  |
| "                                 | Slightly plastic  | Black                 | Fairly white         | "            | A sandy clay, useful for all purposes.                   |
| "                                 | Fairly plastic    | Reddish grey          | Buff                 | "            | A good fire-clay, useful for flooring tiles.             |
| "                                 | Good plasticity   | Dark grey             | White                | "            | A good black clay.                                       |
| "                                 | Slightly plastic  | Grey                  | Buff                 | "            | A sandy clay.  |
| Dwarka                            | Very plastic      | Yellow grey           | Red                  | "            | Cracking on drying. Can be used for red ware.            |
| Bhavnagar<br>Tagdi<br>(Bhavnagar) | } Fairly plastic  | Yellow                | Red                  | 1,070°C.     | Yellow ochre.  |
|                                   |                   |                       |                      |              |  |

## LIST OF POTTERIES IN SAURASHTRA

| Names.   | Types of wares produced.  |
|--|---|
| Parshuram Pottery Works Co. Ltd.,<br>Morvi .. .. .       | { Stoneware jars, stone-<br>ware pipes, acid jars,<br>firebricks and special<br>forms of fire-clay goods. |
| Parshuram Pottery Works Co. Ltd.,<br>Than .. .. .        | { Ordinary and decorative<br>crockerly, sanitary wares,<br>stoneware jars, earthen-<br>wares & toys.      |
| Parshuram Pottery Works Co. Ltd.,<br>Wankaner .. .. .    | { Glazed tiles, firebricks<br>and stoneware jars.   |
| Parshuram Pottery Works Co. Ltd.,<br>Dhrangadhra .. .. . | { Commercial crockerly.   |
| Khodiyar Pottery Works Ltd., Sihor                       | { Sanitary wares, stoneware<br>jars, commercial croc-<br>kery, toys, firebricks &<br>porcelain wares.     |
| Digvijay Tiles & Potteries Ltd.,<br>Jamnagar .. .. .     | { Commercial crockerly.   |
| Digvijay Tiles & Potteries Ltd.,<br>Vagadia .. .. .      | { Firebricks & stoneware<br>jars.   |
| Kathiawar Industries Ltd., Chorwad ..                    | { Commercial crockerly,<br>stoneware jars & fire-<br>bricks.  |

## RAW MATERIALS FOR POTTERIES

Fire-clay or ball clay for the potteries is obtained within the State. China-clay is obtained from Idar and Baroda. Quartz and felspar are brought from Ajmer-Merwara. Gypsum for moulding

is available locally, but supplies are also drawn from Rajasthan. The industry is dependent on Rajpipla agate for use in ball mills. The monthly requirements of the various raw materials at Than Pottery and their f.o.r. prices at Than are tabulated below:—

| Name of mineral.       | Monthly consumption. | F.o.r. price at Than.     |
|------------------------|----------------------|---------------------------|
| Fire-clay or ball clay | 150-200 tons         | Rs. 5/- per ton at works. |
| China-clay ..          | 60 "                 | Rs. 140/- per ton         |
| Quartz ..              | 60 "                 | Rs. 35/- " "              |
| Felspar ..             | 60 "                 | Rs. 35/- " "              |
| Gypsum ..              | 10 "                 | Rs. 50/- " "              |
| Agate ..               | 5 "                  | Rs. 112/- " "             |

#### FUTURE

In view of the widespread distribution of potter's clays and brick clays, in river alluvium, silt, surface earth, etc., no special surveys are considered necessary.

No china-clays or kaolins, strictly speaking, are worked in Saurashtra, although lithomarge is won from time to time in a number of places for industrial use. The main drawbacks of any industry based on lithomarge are the following:—

- (1) Wide variation of quality within short distance, even within one deposit, with consequent wide variation in the quality of the products.
- (2) The deposits are scattered in different areas and no single occurrence is large enough to sustain major levigation units, and therefore clay from various quarries will have to be transported to the central levigation units.
- (3) The winning for clay and levigation are not done systematically, the main idea being to work intermittently depending on the order secured, at a minimum cost. The consumers are thus never assured of an adequate supply of a proper quality.

The Gaj formation contains thick beds of plastic clays, which, however, are not likely to be used in potteries due to iron-staining and occasional gypseous nature. Such clays after washing might be useful in sizing and other purposes.

The best quality plastic and refractory clays in Saurashtra, associated with the Jurassics (Umias), are found in Dhrangadhra, Morvi, Than, Sayla, Wankaner, etc. Some of the fire-clays from this source yield refractories matching in quality with imported materials. In Saurashtra the ceramic industry based on such clays came into being about a quarter of a century ago, with the setting up of a factory in Morvi. There are at present eight ceramic works in the State producing porcelain, china wares, stoneware pipes, tiles, refractory bricks, sanitary wares, etc. The industry can be further improved, and the possibility of manufacturing special, high quality wares will have to be explored.

Nowadays the western countries beneficiate the clays by removing the harmful mineral constituents, particularly when exceptionally high quality products are desired, by various processes, i.e., centrifuging, floatation and bleaching. In Saurashtra as elsewhere in India, only some form of levigation is resorted to when refined china-clay or lithomarge is desired.

The present tendency to utilise only high quality clays is very harmful from the viewpoint of conservation, and steps should be taken to process the low grade clays or blend them with the high-grade materials. Ways and means should be found to work and recover the marginal grades, either abandoned in the workings or thrown away as mine dumps. In other words, all grades of clays should be worked and blended whenever possible.

At present the quarries are worked in a haphazard fashion, digging here and there and throwing dumps anywhere, thus rendering unworkable as much clay as is extracted. This wasteful method of extraction of clay is not only dangerous at times but is also detrimental to the future industry, and steps should be taken to work the clay deposits in a systematic and scientific manner, either by open-casts or underground mining, under technical supervision, particularly in areas where the water table is very high.

Although the reserves of high-grade fire-clays in Saurashtra appear to be large, we do not yet know their actual potentialities, and efforts should be made to get as much information as possible

by detailed exploratory works. Some of the deposits are nearing exhaustion. A programme of boring is recommended to locate all the clay beds, beginning with known areas, and their qualities should be determined with a view to classifying them.

The present clay quarries are situated in low ground often in the vicinity of rivers so that the overburden is minimum. Since all the clay beds appear to be practically horizontal, it would appear that the overburden in the higher regions would be correspondingly thicker and might often prove too thick for economic exploitation of the clays. Sites for sinking new prospecting pits, accordingly, may be located in the lower portions of the plains in the vicinity of streams.

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## CHAPTER XVI

### COAL

#### GENERAL

Apart from its principal use as fuel for heat and power, coal is converted into coke for metallurgical purposes, yielding a variety of by-products for chemical industries.

Coal seams may vary from an inch to hundreds of feet in thickness and are associated with sandstones, shales, etc. In India, coal is associated with Gondwana and Tertiary formations. The extraction of coal is done by open-casts or underground mining. Proximate analyses of coal, indicating the percentages of moisture, volatile matter, carbon and ash, and the coking property, are necessary to assess its value.

The industrial development of India has been based on the country's resources of coal. The most important coalfields in India are in West Bengal and Bihar, but coalfields of varying size are also located in Madhya Pradesh, Orissa, Hyderabad, Kashmir, Rajasthan and Vindhya Pradesh. About 90 per cent. of India's output is used for steam raising and domestic needs, and the rest is used in the production of hard coke for metallurgical purposes. The Indian reserves of all workable coals within 1,000 feet are estimated at 20,000 million tons; the reserves of coking coals have been calculated at 2,000 million tons.

#### DISTRIBUTION

The subject of coal in Saurashtra is fully dealt with by Dr. J. A. Dunn (4), and the following particulars are taken from his paper and unpublished information in the files of the Geological Survey.

#### *Sayla*

*Khakrathal*.—A 15-18 inch bed of coal, between carbonaceous shales, was struck many years ago in a well 500 yards west of this village ( $22^{\circ} 39' : 71^{\circ} 17'$ ), at a depth of 14 feet, the beds probably dipping gently north-west. The coal is extremely variable in quality and is high in ash content. The coal analysed as follows:—

|                            | 1                | 2                | 3                | 4                | 5                |
|----------------------------|------------------|------------------|------------------|------------------|------------------|
|                            | <i>Per cent.</i> | <i>Per cent.</i> | <i>Per cent.</i> | <i>Per cent.</i> | <i>Per cent.</i> |
| Moisture ..                | 4.55             | 4.83             | 5.71             | 8.82             | 7.90             |
| Volatile matter ..         | 17.86            | 16.87            | 22.90            | 19.00            | 19.30            |
| Fixed carbon ..            | 63.06            | 63.22            | 42.07            | 26.45            | 41.86            |
| Ash ..                     | 14.63            | 15.08            | 29.32            | 45.73            | 30.94            |
|                            | 100.00           | 100.00           | 100.00           | 100.00           | 100.00           |
| Colour of ash ..           | Light brown.     | Reddish-brown.   | Reddish-brown.   | Yellowish-brown. | ..               |
|                            | Non-coking.      | ..               | ..               | ..               | Non-coking.      |
| Calorific value, B.T.U. .. | ..               | 10863            | 7749             | 5175             | ..               |

Analysts:—Nos 1 & 5 — Geological Survey of India.  
Nos. 2, 3 & 4 — Dhrangadhra Chemical Works.

Another well sunk long ago just south of the village met with a 2-foot seam of coal between carbonaceous shales at a depth of 15 feet, the beds probably dipping slightly northwards. A 10-foot bore from the well bottom struck carbonaceous shale. The following analysis, carried out in the Geological Survey laboratory, is given below:—

|                    | <i>Per cent.</i>   |
|--------------------|--------------------|
| Moisture ..        | 1.10               |
| Volatile matter .. | 11.80              |
| Fixed carbon ..    | 58.98              |
| Ash ..             | 28.12              |
|                    | 100.00             |
|                    | <i>Non-coking.</i> |

A bore was subsequently drilled up to 78 feet near the above well and struck a 2-foot 6-inch coal at 18 feet 6 inches, a 2-foot coal at 61 feet 6 inches and a 2-foot 2-inch coal at 73 feet. The specimens



of coal from the lower seams, analysed in the Geological Survey laboratory, gave the following results:—

|                       | 1           | 2            |
|-----------------------|-------------|--------------|
|                       | At 62 feet. | At 73 feet.  |
|                       | Per cent.   | Per cent.    |
| Moisture .. ..        | 0.50        | 7.52         |
| Volatile matter .. .. | 5.22        | 24.32        |
| Fixed carbon .. ..    | 10.04       | 50.04        |
| Ash .. ..             | 84.24       | 18.12        |
|                       | 100.00      | 100.00       |
|                       | Non-        | Non-         |
|                       | coking.     | coking.      |
| Colour of ash ..      | Wood-brown. | Pinkish buff |

In view of the uncertainties about the actual location and authenticity of information about this bore, the Government of Saurashtra drilled a 500-foot calyx hole about one mile south of Khakrathal in 1949-50, under the supervision of the Geological Survey of India. The hole met with an 18-inch coal seam at a depth of 45 feet below the surface, and struck artesian water at a depth of 65 feet. The formations, according to Mr. C. Karunakaran (6), are recorded below:—

| Strata.                         | Thickness<br>in feet. |
|---------------------------------|-----------------------|
| Coarse, buff sandstone. .. ..   | 14                    |
| Black, arenaceous clay. .. ..   | 10                    |
| Coarse, grey sandstone. .. ..   | 6                     |
| Arenaceous clay. .. ..          | 3                     |
| Coarse, grey sandstone. .. ..   | 5                     |
| Black clay. .. ..               | 7                     |
| Coal. .. ..                     | 1½                    |
| Soft, arenaceous clay. .. ..    | 6½                    |
| Variegated sandstone. .. ..     | 60                    |
| Argillaceous sandstone. .. ..   | 4                     |
| Black clay. .. ..               | 32                    |
| Plastic, white clay. .. ..      | 10                    |
| Coarse, gritty sandstone. .. .. | 40                    |

*Contd.*

| Strata.                    |    |    | Thickness<br>in feet. |
|----------------------------|----|----|-----------------------|
| Coarse, grey sandstone.    | .. | .. | 8                     |
| Sandstone with clay. ..    | .. | .. | 48                    |
| Black clay. .. ..          | .. | .. | 9                     |
| Coarse, gritty sandstone.  | .. | .. | 20                    |
| Grey, plastic clay. ..     | .. | .. | 4                     |
| Grey sandstone. ..         | .. | .. | 3                     |
| White sandstone with clay. | .. | .. | 4                     |
| Black clay. .. ..          | .. | .. | 4                     |
| Sandstone with clay bands. | .. | .. | 5                     |
| Impure clay. ..            | .. | .. | 33                    |
| Variegated sandstone. ..   | .. | .. | 51                    |
| Black clay with vitrain.   | .. | .. | 38                    |
| Buff sandstone. ..         | .. | .. | 31                    |
| Black clay. .. ..          | .. | .. | 5                     |
| Variegated sandstone.      | .. | .. | 18                    |
| Carbonaceous clay. ..      | .. | .. | 8                     |
| Coarse grey sandstone.     | .. | .. | 4                     |
| <b>Total.</b>              |    |    | <b>504</b>            |

As a sequel to the recent bore at Khakrathal, the Government of Saurashtra drilled other holes in the Umia sandstones in the neighbouring region for water supply. Judging from the data available, although imperfectly recorded, none encountered any seams of coal.

*Ranipat.*—An old 25-foot deep well about two miles north-west of Khakrathal, at Ranipat ( $22^{\circ}41' : 71^{\circ}15'$ ), struck a bed of five feet thick carbonaceous shale, below current bedded horizontal sandstones.

*Velada.*—Mr. J. M. Master (5) noticed carbonaceous shales in a stream bed to the west of the village, dipping four degrees towards west, the shale thinning out within a few hundred yards to the south.

#### Morvi

Numerous bores have been sunk in Morvi State, down to a depth of 100 to 400 feet, but none is reported to have come across

any coal seam. A little coaly shale is sometimes found in some quarries for carbon shales at Udeypore, about seven miles south of Morvi town.

### *Wankaner*

*Wankaner City*.—Sunk in 1907 for water by Mr. Edger Lake, just east of the city, a 602-foot bore struck minor streaks of coal in a formation consisting mainly of sandstones with some shales. Record shows (1) a 3-foot 3-inch seam of carbon shale with streaks of coal at 329 feet, (2) a 3-foot 6-inch bed of dark grey shale with “strings” of coal at 419 feet, (3) a 10-inch seam of coal in dark grey and black shale at 559 feet, and (4) “strings” of coal in grey shale bands in sandstone between 590 and 602 feet.

*Rajthali*.—Also put down in 1907, a 400-foot bore a quarter of a mile south of the village, seven miles east of Wankaner city, struck a 2-foot seam of coal at about 400 feet from the surface. The coal was not analysed. The sandstones in the locality are current bedded, and are horizontal or tilt gently towards north-west.

### *Gogha*

A 1,016-foot bore at Gogha, south of Bhavnagar, struck methane at 847 feet and a little coal at 279 feet and between 290 and 292 feet. According to Dr. J. A. Dunn, although the formation drilled through has been assigned a Tertiary age, a part of it probably represents Gondwanas.

### *Wadhwan*

A bore hole at Wadhwan Camp in Gondwanas sunk to a depth of 1,001 feet is reported to have encountered a coal seam, about one foot in thickness, between 841 and 851 feet.

### *Lakhtar*

*Than*.—F. Fedden (1) reported “stringers” of coal at this locality as early as 1884.

A 2-foot thick coaly shale with thin layers of vitrain overlying two feet of carbonaceous shale is exposed about three quarters of a mile north of Than Railway Station. Two pits made some distance

to the south, now under water, are reported to have met with a poor quality coal. The beds although horizontal at the outcrop, further south dip gently at two degrees towards south. The analysis are given below:—

|                 | 1                  | 2                   | 3                |
|-----------------|--------------------|---------------------|------------------|
|                 | Coal & coal shale. | Thin bright layers. | Coal frag-ments. |
|                 | Per cent.          | Per cent.           | Per cent.        |
| Moisture ..     | 1.93               | 1.33                | 2.56             |
| Volatile matter | 12.41              | 16.97               | 15.24            |
| Fixed carbon    | 61.42              | 73.95               | 67.42            |
| Ash ..          | 24.24              | 7.75                | 14.78            |
| Sulphur ..      | 1.03               | -                   | -                |
|                 | 101.03             | 100.00              | 100.00           |

Non-coking.

Analysts:—Nos. 1 & 2—Messrs. Lindley & Weighell, Bombay.  
No. 3—Geological Survey of India.

An 18-inch seam of carbonaceous shale was struck in a 33-foot well below sandstones intruded by a thin dolerite, about one mile south of Than.

*Tarnetar.*—An outcrop of 20-foot thick carbon shale overlain by ferruginous sandstones is exposed in hillocks close to this village. A poor quality coal, two-foot thick, was found in an old well at a depth of 12 feet, about a quarter of a mile to the north-west. A new well, north-east of Tarnetar, 20-foot deep, did not strike any coal, the formations being carbon shales and sandstones intruded by thin dolerite.

*Dhrangadhra*

*Railway Station.*—An eight-inch bore, 514-foot deep, sunk in 1938 to the east of the Railway Station, struck a 30-inch seam at 329 feet below white clay and shale. The analyses are given below:—

|   | 1           | 2          |
|---|-------------|------------|
|   | Per cent.   | Per cent.  |
| Moisture .. ..                              | 7.08        | 5.50       |
| Volatile matter .. ..                       | 35.10       | 21.70      |
| Fixed carbon .. ..                          | 38.92       | 20.96      |
| Ash .. ..                                   | 18.90       | 51.84      |
|   | <hr/>       | <hr/>      |
|   | 100.00      | 100.00     |
| Colour of ash .. ..                         | white       | ..         |
|   | Non-coking. | Non-coking |
| Calorific value—9158 B. T. U.               |             |            |
| Analysts:—No. 1—Dhrangadhra Chemical Works. |             |            |
| No. 2—Geological Survey of India.           |             |            |

*Salt Siding.*—A 4-inch bore, 360-foot deep, sunk in 1937, about 800 feet north of the Railway Station bore, is reported to have met with good coal at 325-329 feet. This seam is correlated with the seam encountered in the above mentioned bore.

*Alkali Works.*—Here a 501-foot bore, 8½-inch in diameter, sunk in 1927 about 1,000 feet east of the Railway Station bore, encountered black shale at 492-494 feet.

*Ginning Factory.*—Located about one quarter of a mile to the W. N. W. of the Railway Station bore, a 789-foot bore, 8-12 inch in diameter, met with thin seams of coal between 640 and 644 feet and between 775 and 789 feet, and carbon shale at 293-313 feet, 607-617 feet and 711-732 feet.

*Lake View.*—Here, about one mile W. S. W. of the Railway Station bore, an eight-inch bore, 500-foot deep, was sunk in 1937-38. According to the records, black shale in white clay is found between 470 and 472 feet.

*Moti Bag.*—A 4-inch bore, 300-foot deep, was put down here in 1935. A carbon shale, passed at 275 feet, analysed as follows:—

|                        | Per cent.   |
|------------------------|-------------|
| Moisture .. ..         | 6.72        |
| Volatile matter .. ..  | 16.20       |
| Fixed carbon .. ..     | 11.08       |
| Ash .. ..              | 66.00       |
|                        | <hr/>       |
|                        | 100.00      |
| Colour of ash — brown. | Non-coking. |

*Satapur.*—In 1924, a 14-inch bore, 548-foot deep, was sunk here, about eight miles N. N. W. of Dhrangadhra city. A thin coal in white sandstone is recorded between 312 and 342 feet, and a black shale in sandstone between 447 and 538 feet.

*Halvad.*—Here, a 500-foot bore is reported to have struck coaly material in yellow clay between 262 and 265 feet.

#### FUTURE

The old bore holes in Morvi, Wankaner, Dhrangadhra, Lakhtar, Sayla, Wadhwan, Gogha, etc., have demonstrated that no economically important coal seams are present in the Gondwanas of Saurashtra. The recent bores at Khakrathal and elsewhere have confirmed the absence of payable seams. Further exploratory bores might show local thickening up to say five feet at places, but unless the seams cover extensive areas and are at least 3-4 feet thick, and second grade in quality, no profitable mining is visualised. The coal is very variable in quality with high ash content and is at the best second grade.

The existence of coal in the Deccan traps which occupy a major part of the State is ruled out. The presence of workable coal seams in Gondwanas under the traps is hypothetical, and judging from the test bore at Bhusawal in Bombay (2 & 3), and the absence of payable seams in Saurashtra, the question of deep drilling in traps is not likely to be taken up in Saurashtra in the near future.

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## CHAPTER XVII

### FULLER'S EARTH

#### GENERAL

Fuller's earth is a variety of non-plastic clay which has the power to filter and decolour oils, fats and greases. The chemical composition gives no indication of decolourising power, and only actual test can prove its usefulness for such a purpose. When not naturally active, artificial activation by acid treatment is done. The clays most suited for activation generally possess a high silica-alumina ratio, viz., roughly 1 : 5 to 1 : 4. Typical analyses of some foreign clays which can be activated to a better degree than Indian clays are given below:—

|                                |    | <i>Per cent.</i> |        |        |        |
|--------------------------------|----|------------------|--------|--------|--------|
|                                |    | Type 1           | Type 2 | Type 3 | Type 4 |
| SiO <sub>2</sub>               | .. | 72.95            | 58.12  | 58.72  | 57.32  |
| Al <sub>2</sub> O <sub>3</sub> | .. | 12.65            | 15.43  | 16.00  | 13.57  |

Fuller's earth is chiefly used in refining petroleum, vegetable oil and animal fat. Its use in oil refining, however, is being replaced by activated bentonite clay. It is partly dried, ground and screened before use. Except in case of vegetable oil, it can be reused about 20 times by heat treatment.

Fuller's earth is available from Bikaner, Jaipur, Jodhpur, Jaisalmer, Bhavnagar, Nawanagar, Jubbulpore and Mysore.

Crude Fuller's earth is nowadays priced at Rs. 163/- per ton at loading Stations.

#### DISTRIBUTION

##### *Bhavnagar*

According to Dr. B. C. Roy (1), the cliff slopes and low grounds about 2½ miles west of Lakhanka (21°31'30" : 72°17'30") in Bhavnagar, comprise lithomargic clay which is being shipped to Bombay for manufacturing activated Fuller's earth. The clay is partly



white, soft and grit free, and is associated with variegated or lavender coloured clays. It is at times slightly green when freshly dug.

Mr. Chotalal Ratilal Patel, working in a 200-foot x 200-foot plot, has recently removed 250 tons of material working to a depth up to 20 feet. Messrs. Selective Chemicals Ltd., of Bhavnagar, who are shortly going to manufacture six tons of activated Fuller's earth per day, have applied for a mining lease of a 12-acre plot in this area. The material will have to be transported to Bhavnagar over a distance of 20-25 miles.

The exposed clay bearing strip roughly runs N.-S. for two furlongs and is one furlong wide, but the deposit appears to be much more extensive. The clay is exposed up to a depth of 10-20 feet but its actual thickness is possibly more at places. The area is promising and needs some detailed prospecting. The unwashed clay, analysed by Mr. R. J. Mehta of Messrs. Selective Chemicals Ltd., gave the following results:—

|                                |    |    |       |    | <i>Per cent.</i> |
|--------------------------------|----|----|-------|----|------------------|
| SiO <sub>2</sub>               | .. | .. | ..    | .. | 58.04            |
| Al <sub>2</sub> O <sub>3</sub> | .. | .. | ..    | .. | 15.81            |
| Fe <sub>2</sub> O <sub>3</sub> | .. | .. | ..    | .. | 3.10             |
| MgO                            | .. | .. | ..    | .. | 4.12             |
| CaO                            | .. | .. | ..    | .. | 1.19             |
| Na <sub>2</sub> O              | .. | .. | ..    | .. | 1.62             |
| K <sub>2</sub> O               | .. | .. | ..    | .. | 0.75             |
| H <sub>2</sub> O               | .. | .. | ..    | .. | 14.95            |
|                                |    |    |       |    | —                |
|                                |    |    | Total | .. | 99.58            |

Messrs. Bombay-Sewree Chemicals Manufacturing Co. Ltd., who manufacture Fuller's earth on a large scale, state that the materials from Bhavnagar and Kutch are the best types for their purpose. They quote the following analyses of materials from Bhavnagar and Kutch.

|                                | <i>Per cent.</i> |        |        |
|--------------------------------|------------------|--------|--------|
|                                | Type 1           | Type 2 | Type 3 |
| SiO <sub>2</sub>               | .. 46.02         | 44.74  | 39.00  |
| Al <sub>2</sub> O <sub>3</sub> | .. 24.06         | 25.66  | 36.60  |
| Fe <sub>2</sub> O <sub>3</sub> | .. 7.44          | 6.12   | 2.48   |

*Nawanagar*

Dr. B. C. Roy (1) reported large quantities of Fuller's earth, in association with ochres and iron-ore, in the lateritic zones in Nawanagar, particularly around Nandana ( $22^{\circ}8' : 69^{\circ}20'$ ), Ran ( $22^{\circ}10' : 69^{\circ}20'$ ), Mewasa ( $22^{\circ}13'30'' : 69^{\circ}21'$ ), Habardi ( $22^{\circ}13' : 69^{\circ}25'$ ), Virpur ( $22^{\circ}15' : 69^{\circ}21'30''$ ), etc. The material could find a ready market in Bombay, where similar material from Bhavnagar is being utilised for manufacturing activated Fuller's earth.

## FUTURE

Of late the lithomargic clays from Bhavnagar are being used in Bombay for the manufacture of activated Fuller's earth. Similar material is available in large quantities in the lateritic zones, particularly in Nawanagar, Junagadh, etc. Some of the known lithomarge deposits are described in Chapter XV on clays. Apart from the need at Bhavnagar for the manufacture of activated Fuller's earth, the demand in Bombay is bound to increase considerably in view of the setting up of an oil refinery in Trombay Island. Consequently, the occurrences within Saurashtra could be successfully exploited.

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## CHAPTER XVIII

### GEMSTONES

#### GENERAL

The cardinal properties of gemstones are rarity, durability, colour, transparency, lustre and brilliance. The important gemstones are diamond, emerald, ruby, sapphire, topaz, etc. Semi-precious stones are the various types of quartz or secondary silica, beryl, garnet, lapis lazuli, spinel, tourmaline, zircon, etc. The precious or semi-precious stones are identified by their physical and optical characters, i.e., colour, hardness, specific gravity, refractive index, pleochroism, etc. The stones are cut or faceted before marketing.

A number of artificial and imitation stones, e.g., synthetic ruby and sapphire, glass imitations (paste) and composite stones are manufactured nowadays. They are distinguishable from natural stones by expert examination.

India recognised the value of gemstones from very ancient times. Numerous precious stones have been obtained for centuries in India, where the best diamonds in the world were won. Nowadays some quantity of diamonds is obtained from time to time. The well known diamond bearing localities are in South India and Madhya Bharat. Sapphire is produced in Kashmir. Some emerald is won from Rajasthan and Ajmer-Merwara.

#### DISTRIBUTION

##### *Bhavnagar*

According to Dr. B. C. Roy (6), agate-bearing Gaj conglomerate beds up to 30-50 feet thick, striking roughly N. N. E.-S. S. W., form a series of hills, about  $2\frac{1}{2}$  miles west of Lakhanka ( $21^{\circ}31'30''$  :  $72^{\circ}17'30''$ ) in Bhavnagar. Pebbles of agate, chalcedony, flint, jasper, etc., derived from the conglomerate are strewn all along the hill slopes. Big pebbles, if available in large quantities, should be suitable for ball mills, whereas the small pebbles of good quality could be used as semi-precious stones. A considerable quantity of pebbles is envisaged in the locality.

Mr. M. M. Oza (5) noted an agate-bearing ferruginous conglomerate, about 15 feet in thickness, in a N.-S. ridge from Badi to Chhaya, a distance of nearly six miles. The conglomerate bed is almost horizontal and forms the top of the ridge. The formation encloses rolled pebbles of agate, flint and quartz. Agate pebbles are also strewn over on both the flanks, especially on the western flank. The size of the pebbles is variable, but generally small. The large pebbles may be useful in ball mills for grinding ceramic clays and paint materials. At present the material is not used at all.

Agate-bearing ferruginous conglomerate is also mentioned by Mr. Oza in a stream half a mile south-west of Rampur, where the following section is visible:—

|                      |          |
|----------------------|----------|
| Soil cover .. .. .   | 2 feet.  |
| Conglomerate .. .. . | 30 feet. |
| Blue clays .. .. .   | 5 feet.  |
| Brown grits .. .. .  | 3 feet.  |

#### *Junagadh*

Milky white chalcedony and agates as geode materials in traps are reported by Mr. S. Krishnaswamy (4), along the south-eastern borders of the Gir forest in Junagadh, close to Junagadh-Dedan border and near Khambha ( $21^{\circ}9' : 71^{\circ}17'30''$ ). He also records a sporadic occurrence of rock crystals in geodes to the north-west of Patsar ( $20^{\circ}55'30'' : 71^{\circ}1'$ ), and pebbles of agates and chalcedony in a *nala* between Hemal ( $20^{\circ}55' : 71^{\circ}19'$ ) and Sokhra ( $20^{\circ}52'45'' : 71^{\circ}19'30''$ ).

#### *Morvi*

F. Fedden (1) records the presence of moss-agate, in association with amythistine quartz and clear rock crystal, forming a large irregular vein in a vesicular trap at Khijaria,  $2\frac{1}{2}$  miles west of Tankara, in Morvi State. This was hitherto mined in a desultory fashion for many years, as a result of a demand by the lapidaries in Cambay for making cheap rings, brooches, etc.

#### *Nawanagar*

In former Nawanagar State, E. H. Adye (2) noticed the following occurrences of semi-precious stones:—

(1) Geode materials containing chalcedony, moss-agate, onyx, etc., particularly near Beraja, Nawagam, Latipur, Jiwapur, Badanpur, Thoriali, Timbri, Vijarkhi, Khokhri, Baolidar, Bori, etc.

(2) Spheroidal siliceous geodes, including amethyst and onyx at times, near Chaora (near Wanthali Railway Station), Chapra (five miles S. W. by E. S. E. of Kalawad, on the roadside mound  $\frac{3}{4}$  mile west of Nawagam), near Jalansar (five miles S. W. by S. S. W. of Kalawad), Bhangor, Parevala (east of Rajkot), Bhaiati Khakhria (three miles north-east of Kalawad), etc.

(3) Chalcedony, agate and jasperoid conglomerates of varying size, both *in situ* and as erratic materials, near Veratia on the river Moti Phuljar and between Parddhari and Latipur. Big size blocks are embedded in the silt in Ladak Vola *vokala*, one mile south-east of Veratia, in the *nalas* east of Virpur, at Nana Nagajal, and on the terraced banks of the Dhudala *vokala* and a tributary of the river Und.

#### *Wankaner*

Dr. B. C. Roy (6) noted a silicified green cherty rock, at times banded and brecciated, in association with flint, jasper, chalcedony, etc., up to 30-40 feet wide, on the top of hill  $\Delta$  490, about  $2\frac{1}{2}$  miles west of Wankaner ( $22^{\circ}37' : 70^{\circ}59'$ ). It is intrusive into the Deccan traps and runs for over half a mile along an E.-W. to E. S. E.-W. N. W. strike.

According to Mr. V. R. R. Khedker (3), green flint boulders and pebbles, resulting from siliceous veins in traps, are scattered in an area of over one square mile, near Amarsar, four miles west of Wankaner city. A few thousand tons of material are estimated to be present. Small pieces of agate and amethyst are also reported in traps from a village in the extreme south-west corner of the former Wankaner State.

#### FUTURE

The chief precious stones like diamond, ruby, sapphire, emerald, topaz, etc., are not known to occur in Saurashtra. Amongst the semi-precious stones, varieties of quartz, amethyst, rose quartz, chalcedony, agate, onyx, opal, etc., are common in the traps, in the rivers that drain the trap country, and in the Gaj conglomerates.

The detrital pebbles and gravels of agates, dislodged from weathering of traps, subsequently rounded by water action and concentrated in beds of gravels in the river valleys, have been worked into ornaments by the lapidaries of Cambay.

There is, however, no industry in Saurashtra for cutting and polishing the semi-precious stones. Attempts should be made to locate large geodes in the amygdaloidal traps and to work the agate-bearing Gaj conglomerates, with a view to the recovery and use of such stones. In spite of an existing trade in imitation and synthetic stones from abroad, there is always a good market for natural stones, and suitable areas in the State might be exploited on small cottage industry basis. The possibility of utilising the agate pebbles in ball mills for grinding ceramic and paint materials should be explored in view of rapid expansion of such industries in India.

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## CHAPTER XIX

### GLASS-MAKING MATERIALS

#### GENERAL

Although there has been considerable development in the manufacture of glass in India, there is a large scope for further expansion, in view of the considerable imports of glass and glass-ware in this country.

The chief raw materials for glass manufacture are silica, soda, lime or limestone, borax, etc. Manganese dioxide, nickel oxide and selenium are used as decolourisers. Among the colouring agents for coloured glass, manganese, cobalt, chromates, nickel and selenium are used. A cheap fuel is essential in glass industry, and Indian coals are suitable for this purpose. There is no dearth of refractory materials needed for the building of furnaces.

The main ingredient silica in the glass batch should be very pure, containing above 99 per cent.  $\text{SiO}_2$  and less than 0.02 per cent. iron oxide if colourless glass is to be manufactured. In any case the iron oxide content must not exceed one per cent. Some amounts of alkalis and alumina in the sand, within reasonable limits, are permissible. For manufacturing flint glass, the  $\text{Fe}_2\text{O}_3$  and  $\text{TiO}_2$  contents should not usually exceed 0.025 per cent. Inferior sands containing high iron content, however, could be utilised in making green bottle glass. The sand grains should be of equal size, averaging 0.4 mm. in diameter. Sands of high degree of purity as specified above are rare in India, although materials suitable for the manufacture of clear glass bottles and laboratory ware are available in plenty.

#### DISTRIBUTION

##### *Dhrangadhra*

Mr. C. Karunakaran (6) examined the following reported occurrences of glass-sands in Dhrangadhra during field season 1950-51. The material is consumed in sodium silicate factories and glass industries in Saurashtra.

*Dhrangadhra* (23°1' : 71°23').—Some of the numerous quarries near this town indicate white sandstone suitable for yielding glass-sand. The rock is fairly hard and will need crushing before use. There is no regular quarrying exclusively for glass-sand. The outcrops of pure white sandstone, however, are limited.

*Rampurda* (22°39' : 71°12').—The horizontally disposed white sandstone near this village and south of Dudhai (22°41' : 71°12') is found in an area of about a thousand square yards. The material from shallow pits contains small amounts of white clay which may be washed out after crushing.

*Surajdeval* (22°30' : 71°13').—A band of friable, pure white sandstone striking W.N.W.-E.S.E., covers a strip one mile long and 300 feet wide, between this village and Waori (22°31' : 71°17'). It is at present worked by many shallow pits less than four feet deep. The pure sandstone appears to persist to greater depths. Percolation of water through the numerous joints and fissures has discoloured the stone along narrow zones, which should be avoided while quarrying. The material is pulverised at the site, packed in jute bags, and despatched to the Railway Station about half a mile away.

Sir Cyril S. Fox (4) is of opinion that the Dhrangadhra sandstone bears close resemblance to the Songir sandstone in Baroda which is considered suitable for glass-making, although the ferric oxide in Dhrangadhra stone is a little high. He quotes the following recent analysis of an average sample of the white Dhrangadhra sandstone carried out by Messrs. R. V. Briggs & Co., Calcutta.

|                                |    |    |    |       | <i>Per cent.</i> |
|--------------------------------|----|----|----|-------|------------------|
| SiO <sub>2</sub>               | .. | .. | .. | ..    | 91.38            |
| Al <sub>2</sub> O <sub>3</sub> | .. | .. | .. | ..    | 4.58             |
| Fe <sub>2</sub> O <sub>3</sub> | .. | .. | .. | ..    | 0.34             |
| TiO <sub>2</sub>               | .. | .. | .. | ..    | 0.40             |
| CaO                            | .. | .. | .. | ..    | 0.34             |
| MgO                            | .. | .. | .. | ..    | 0.32             |
| Na <sub>2</sub> O              | .. | .. | .. | ..    | 0.46             |
| K <sub>2</sub> O               | .. | .. | .. | ..    | 0.05             |
| Loss                           | .. | .. | .. | ..    | 2.04             |
| <i>n. d.</i>                   | .. | .. | .. | ..    | 0.11             |
|                                |    |    |    | Total | 100.00           |



*Morvi*

Mr. J. M. Master (2) reports that the Umia sandstone near Udeypur in Morvi is a fairly good material which is used for making bottles, jars, etc., by the glass factory at Morvi.

*Nawanagar*

E. H. Adye (1) notes that the crushed wastage of massive quartz reef in Alech hills, in case it is worked for gold, could be used as a glass-sand and abrading powder where it is not stained excessively with iron oxides or pyrites.

*Wadhwan*

Mr. R. K. Taploo (3) refers to a type of porous quartzitic sandstone, near Wadhwan, suitable for the manufacture of low quality glass and glazing in pottery.

**FUTURE**

The Jurassic sandstones in Dhrangadhra are large sources of friable and fairly good materials suitable for the manufacture of common types of glassware. Carefully selected bands may be suitable for the preparation of better quality glass.

There is only one glass factory in Saurashtra, manufacturing the commoner types of glassware, using obsolete furnaces and equipments. It is located in Morvi and is not equipped to manufacture scientific or high quality glassware. The present industry is largely dependent on silica from Dhrangadhra and Morvi. Soda is available from Mithapur and Dhrangadhra. Indigenous lime is available in plenty. Manganese-ore from Panch Mahals should serve the needs of the industry. The industry is possibly drawing the present supplies of manganese-ore from Madhya Pradesh. The chemicals like borax, nickel oxide, selenium, etc., are imported. The industry has increased considerably in recent years and is likely to develop further, provided the supply of raw materials, refractories, coal and oil is assured.

Many Indian glass works, located in large cities, have to depend on raw materials and refractory goods, involving long distance haulage, whereas Morvi is ideally located with regard to all the

raw materials and could easily export glass to Bombay through Navlakhi port. The difficulty of fuel could be offset by installation of modern oil fired furnaces.

Research on the various raw materials and methods of manufacture of glass would augment the production and improve the quality of goods. Washing, desliming and acid treatment usually improve the low grade sandstones. Attention is drawn to the recent technique of attrition grinding which is reported to yield a high quality glass-sand from a low grade sandstone (5). As the most important factor in glass manufacture is the supply of sand free from iron, the question of washing and possibly magnetic separation will have to be seriously considered.

Examination of sand stretches along the coastal areas might be useful in locating materials suitable for the manufacture of glass.

The prospect of utilising nepheline syenite from Mount Girnar in the manufacture of glass should be explored.

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## CHAPTER XX

### GOLD

#### GENERAL

The Indian output of gold is almost entirely derived from reef gold from the Kolar gold fields in Mysore. The mining and extraction of gold at Kolar are done most efficiently by the latest technical methods. Some of the mines are being worked at great depths, the deepest one reaching a depth of 9,554 feet. Some auriferous reefs in Madras, Bihar and Bombay were worked many years ago, but the activities have ceased. The working of the auriferous veins in Hutti in Hyderabad ceased in 1922, but the mines have recently re-opened and started production. Small quantities of alluvial gold are recovered from U. P., Bihar, Orissa and Madras.

#### DISTRIBUTION

##### *Junagadh*

La Touche (1) mentions that small quantities of gold are reported to occur in the sands of the Sourekha river emanating from the Mount Girnar ( $21^{\circ}32' : 70^{\circ}35'$ ). Mr. S. Krishnaswamy (3), however, could not detect any gold in the sands, although he carried out panning of the sands right from the source down to its confluence with the Uben river near Wadhavi ( $21^{\circ}34' : 70^{\circ}26'$ ).

##### *Nawanagar*

E. H. Adye (2) reports a large quartz reef in rhyolitic and associated rocks in the ridge about  $3\frac{1}{2}$  miles S. S. E. of Satapur in the Alech hills, in Nawanagar. It is 30 feet wide and is seen at intervals for over two miles in an E. N. E.-W. S. W. direction. It shows pyrite inclusions and is said to be auriferous. It is massive at the W. S. W. end and milky white at the E. N. E. end.

According to Dr. H. Crookshank (4), who visited the area, the so-called auriferous rock is a silicified rhyolite looking like chert. The cherty band strikes N. E.-S. W. and is 3-4 feet up to 30 feet wide. It runs for four miles in a discontinuous fashion and dips

steeply towards south-east. Generally only a few grains of gold are reported in this rock. The recent exploratory trenches at intervals across the deposit for a distance of 200 yards have shown 10 dwts. of gold per ton over a thickness of six feet in one locality. Higher values are reported from cores down to a depth of about 150 feet.

Dr. Crookshank's observation was primarily based on the information given by the sponsoring company. He conceded that the deposit holds promise but that it was yet to be proved. He recommended the sinking of an incline or shaft for the sampling of the auriferous rock and opined that it was necessary to prove the continuance of gold in depth for at least 500 feet before undertaking mining operations. Unlike auriferous quartz veins having a well defined border, a silicified crush zone would have an ill-defined margin and as such gold might extend in rhyolite far away from the centre of the zone.

Dr. B. C. Roy (5) recently examined part of the cores from two 150-foot bores in the Alech hills, about one mile apart. The cores show a brecciated and silicified, banded, cherty rock, generally grey or green in colour. Besides minute traces of pyrites, no gold could be detected in the cores. Some core samples analysed in the Geological Survey laboratory showed only *traces* of gold.

#### FUTURE

It is not unlikely that several occurrences of alluvial gold are present in certain localities in the State, but no large scale operation involving modern dredging plant is visualised. Roughly three grains of gold per cubic yard over several hundred acres in a shallow valley, and an adequate water supply, are essential for successful exploitation by modern dredging methods.

The auriferous chert in Alech hills is believed to hold promise, but then the area needs detailed prospecting on the lines indicated for proving the gold deposit. The exploratory measures carried out by the Alech Gold Mining Syndicate have not been thorough, and more detailed work must be done before undertaking mining operations.

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## CHAPTER XXI

### GYPSUM

#### GENERAL

Pure gypsum ( $\text{CaSO}_4, 2\text{H}_2\text{O}$ ) contains 46.6 per cent.  $\text{SO}_3$ , 32.5 per cent.  $\text{CaO}$  and 20.9 per cent. water. Its specific gravity is 2.3. It is scratched by a knife or the finger nail, as its hardness ranges from 1.5 to 2 (Moh's scale). The transparent, colourless variety is known as selenite. Anhydrite is a calcium sulphate lacking in water. Gypsum is usually white or grey, but pink, yellow or brown varieties are also present.

Gypsum occurs in regular beds or lens, horizontal or gently inclined, sometimes in association with rock salt, limestone and shales, varying from a few feet up to several hundred feet in thickness. It also occurs as platy crystals in marine silts along the sea coasts subject to periodic incursion by sea water.

The mineral is ground to a powder before use. It is calcined in kilns at  $300^\circ$  to  $350^\circ\text{F}$ . to remove the water of hydration, and screened before being sold for use as calcined gypsum or plaster of Paris.

The principal Indian deposits are in Trichinopoly, Bikaner, Jaisalmer and Jodhpur. Other sources are in United Provinces, Sirmur, Rewa, Kashmir, Kutch and Saurashtra. The country will eventually need large quantities of gypsum for the fertiliser factories in Sindri and Alwaye.

Lump gypsum *f.o.r.* Makrana is priced at Rs. 8/- per ton. The price of Nawanagar gypsum delivered at Sika is quoted at Rs. 24/- to Rs. 28/- per ton. Gypsum from Rajputana is sold at Rs. 30/- and Rs. 38/- per ton at Sika and Porbandar respectively.

#### USE

Uncalcined gypsum is used as a retarder in the manufacture of Portland cement. After calcining it is used in the preparation of plaster of Paris. It is also used for the manufacture of Keene's

*cement*, ammonium sulphate and sulphuric acid. Other applications are for making crayons, in paints, and in the manufacture of paper. The value of gypsum as a mineral fertiliser is also well known.

#### DISTRIBUTION

##### *Bhavnagar*

The gypsum bearing clays are seen within a radius of 10 miles from the city of Bhavnagar. They are buried under a thick soil cover in the north, but the overburden in the south varies from five to ten feet in thickness. The mineral does not form regular layers or beds but occurs as platy crystals embedded sporadically in Gaj clays, seldom exceeding two to three per cent. of the entire bulk of clays. The deposits are not very encouraging, but some detailed pittings, proposed to be undertaken by the State Government, will throw more light on their workability. The Associated Cement Company is reported to have prospected the area some years ago, but the results are not known. The particulars of the known gypsum deposits, as recorded by Mr. M. M. Oza (9), are given below:—

*Chitra* (21°45' : 72°7').—This village is situated three miles south-west of Bhavnagar. About a furlong north of the village some gypsiferous clays are exposed below five to ten feet of black soil. Fibrous as well as tabular varieties of gypsum are found associated with yellow and grey clays. Gypsum is very intimately mixed with clays and has to be sorted out from them.

*Adhevada, Malanka and Akvada*.—Just to the east of the Tramway bridge gypsiferous clays are exposed in the Maleshari river section near Adhevada (21°43' : 72°9'). As one follows the river downstream towards Malanka (21°44' : 72°11'), gypsiferous clays are also found in the river bed. Further downstream, a small outcrop of gypsiferous clays is met with on the southern bank of the stream, just west of Akvada (21°44' : 72°14'). A section at this place shows yellow gypsiferous clays overlain by an overburden of soil. Beyond Akvada gypsiferous clays disappear under soil and alluvium. Gypsum is sparingly distributed in these localities.

*Budhel* (21°41' : 72°9').—A furlong east of Budhel Railway Station there is a small stream, on the bank of which some quarries

have been opened for gypsum. The gypsiferous clays occur below five feet of overburden. The gypsum crystals are so sparingly distributed that the enterprise had to be given up.

*Tagadi* ( $21^{\circ}41' : 72^{\circ}10'$ ).—About two furlongs north of Tagadi, yellow and grey clays with fibrous gypsum are exposed in a *nala* below the culvert on the Bhavnagar-Gogha road. The gypsiferous clays can be traced for about a couple of furlongs downstream, disappearing under soil and alluvium. The quantity is so small that the crystals after sorting had to be rejected by some earlier worker.

*Bhutesar* ( $21^{\circ}41' : 72^{\circ}13'$ ).—Gypsum is reported to occur in the stream bed about one mile west of Bhutesar under an overburden of about 10 to 12 feet, but no gypsum could be seen on the spot.

#### *Dhrangadhra*

At Khuda ( $23^{\circ}8' : 71^{\circ}24'$ ), platy, transparent, selenite crystals, two feet long in exceptional cases, are found in a dark, plastic, bluish clay, within a depth of 5-16 feet, above the brine sand horizon. According to Mr. J. M. Master (2), here about 100,000 *maunds* of gypsum may be available per square mile. This is equivalent to 3,500 tons per square mile, i.e., one pound per three square feet. Sir Cyril S. Fox (4) believes that this quantity is too small to be worked economically.

#### *Junagadh*

Mr. S. Krishnaswamy (3) records small but workable quantities of gypsum from the following localities in Junagadh:—

(1) One furlong south of Balanivav ( $20^{\circ}57' : 71^{\circ}24'$ ).—The gypseous clays in Gaj formation lie in a strip two furlongs in length and half a furlong in width, the average thickness of the clays being 18 inches. About 24,000 tons could be won from the locality.

(2) Near Panchala ( $20^{\circ}19'30'' : 70^{\circ}8'15''$ ).—The gypsum bearing clays in Gaj formation occur in a strip, over 4,000 feet long and 50 feet wide, the average thickness of the clays being about 18 inches. Here about 3,200 tons could be excavated.

(3) Near Kadiali ( $21^{\circ}0'45'' : 71^{\circ}31'30''$ ).—Gypsum is found underlying the alluvial formations and overlying the Gaj beds. A few hundred thousand tons are anticipated.



Mr. D. R. S. Mehta (7) reports selenite veins and crystals in a bluish and yellowish bed of Gaj clay to the west of Lunsapur (20°55': 71°25') in Jafrabad area in Junagadh. The clay covers a strip one mile long and half a mile wide, and seems to persist up to a depth of 15 feet from the surface. The yield roughly varies from one to 10 *maunds* per 1,000 cubic feet in richer patches, there being a progressive decline in the yield at depth.

Mr. B. F. Mehta (6) noticed small, tabular gypsum crystals distributed sporadically in Gaj clay and alluvium in a *nala* section one mile south-east of Kagvadar (20°53': 71°23'), 6½ miles north-east of Jafrabad.

Messrs. Kathiawar Industries Ltd., at Jafrabad, are at present recovering gypsum from brine by keeping it at a concentration of 12°-20° Beaume and exposing to solar evaporation, the reported output being 2,000 tons and 3,000 tons in 1950 and 1951 respectively (6). The material was utilised by their pottery works at Chorwad, and by Messrs. Fertilizers and Chemicals, Travancore, and Associated Cement Company at Porbandar. The firm at Jafrabad intends to augment the production of gypsum to 11,000 tons per year by putting into use a larger number of pans. The price of the gypsum delivered at Porbandar Cement Works is Rs. 33/- per ton. The chemical analysis of Jafrabad gypsum and that of Jodhpur gypsum are given below for comparison:—

|  | Jafrabad<br>gypsum.<br><i>Per cent.</i> | Jodhpur<br>gypsum.<br><i>Per cent.</i> |
|--|---|--|
| Moisture .. .. .                       | 3.30                                    | 5.00                                   |
| Loss .. .. .                           | 21.40                                   | 19.95                                  |
| SiO <sub>2</sub> .. .. .               | 6.24                                    | 6.14                                   |
| Fe <sub>2</sub> O <sub>3</sub> .. .. . | 0.60                                    | 0.10                                   |
| Al <sub>2</sub> O <sub>3</sub> .. .. . | 1.50                                    | 0.86                                   |
| CaO .. .. .                            | 30.09                                   | 32.47                                  |
| MgO .. .. .                            | 0.86                                    | 0.79                                   |
| SO <sub>3</sub> .. .. .                | 39.10                                   | 39.37                                  |
| Alkalies .. .. .                       | 0.21                                    | 0.32                                   |
|  | <hr/>                                   | <hr/>                                  |
| Total .. .. .                          | 100.00                                  | 100.00                                 |

Analyst:—Associated Cement Co. Ltd.

*Nawanagar*

E. H. Adye (1) referred to haphazardly worked gypsum in Gaj beds in Jamnagar, and stated that the total pits, even if worked to full capacity, would not cover quarrying cost and freight charges. The price then prevalent was reported to be *annas* eight per ton only. Two types of gypsum are recognised, namely, impure fibrous veins running vertically, horizontally and obliquely, and fairly pure, high quality gypsum in the form of lenticular plates and irregular lumps, horizontally disposed and embedded between the laminae of the clay. The following localities are particularly mentioned:—

- (1) About two miles north of Virpur.
- (2) Along Kardhoria *vokala*, about 1½ miles S.S.W. of Ran and on the way to Nandana.
- (3) Along Khubadi *nala*, one mile N.N.E. of Bhatia.

Mr. D. R. S. Mehta (7 & 8) recently investigated the recorded occurrences of gypsum in Nawanagar by sinking a number of pits and 30 bores, and gave some idea about their potentialities. The following notes are taken from his reports:—

*Ran* (22°10' : 69°20').—This is the richest deposit in Saurashtra. Selenite veins varying from mere streaks to three inches in thickness and segregations up to one foot six inches long and four inches in thickness and width, are found sporadically in a bluish plastic clay (Gaj), near the junction of Gaj beds and laterite. The clay bed is generally visible in a 3½-mile long and one-mile wide strip. The clay bed appears to be over 20 feet thick and lies below a 4-foot thick overburden of black soil in the flat portions of the area. The average yield of gypsum is two tons per 1,000 cubic feet of clay. On this basis, about 3,776,000 tons are likely to be present generally within 30-50 feet.

The gypsiferous clay is likely to be present in the area further to the west, in the higher portions of the area, underlain by limestone. A sample of selenite, analysed in the Geological Survey of India laboratory, gave 1.09% SiO<sub>2</sub>, 0.90% R<sub>2</sub>O<sub>3</sub>, 32.28% CaO, trace: MgO, 45.92% SO<sub>3</sub>, 19.16% H<sub>2</sub>O, trace: CO<sub>2</sub>, total. 99.35%.

The deposit at Ran can supply 500 tons of gypsum per day to the Sindri Fertilizer Project for a period of 20 years, by taking up large scale mining by sluicing, hydraulicking or dredging or by a combination of such methods.

*Virpur* ( $22^{\circ}15' : 69^{\circ}20'$ ).—Located about eight miles north of Ran the selenite veins are associated in a marl bed covering an area of  $2\frac{1}{2}$  miles by half a mile, the total thickness of the marl bed being over 10 feet, underlying four feet of soil. The veins, platy or fibrous, range from mere streaks to three inches in thickness. On the assumption of about one ton of gypsum per 1,000 cubic feet of selenitic marl, here nearly 490,000 tons of material are visualised. The presence of gypsum bearing clay beds at further depths, below limestone bands, would augment the reserves considerably.

*Bhatia* ( $22^{\circ}6' : 69^{\circ}17'$ ).—The selenitic strip west of this locality, consisting of a marly clay, is about two miles long and varies from 200 yards to one mile in width, the mineral being particularly seen in the neighbourhood of Gaj beds and laterite. The soil overburden varies usually from one foot to two feet, the thickness of the clay being over 12 feet. On the basis of 0.25 ton of gypsum per 1,000 cubic feet of clay, roughly 175,000 tons of material are anticipated. This selenitic clay is likely to persist below the limestone (Gaj) to the north and west of the area.

Minor deposits of selenite in Gaj beds are also present in other localities. On the basis of 12 feet thick selenitic clay, containing possibly 0.25 ton of gypsum per 1,000 cubic feet of clay, about 135,000 tons of material are estimated from the following places:—

- (1) One mile north-east of Bhatia.
- (2) One mile north-west of Nandana ( $22^{\circ}7'30'' : 69^{\circ}17'30''$ ).
- (3) One mile west of Gurgat ( $22^{\circ}11'30'' : 69^{\circ}11'30''$ ).
- (4) Near Kuranga Railway Station ( $22^{\circ}4' : 69^{\circ}10'30''$ ), Okha district, Baroda.

The deposits in Nawanagar are near metre gauge railhead, thus involving transshipment of gypsum at Viramgam broad gauge system, but despatch by sea route (Dwarka or Okha) to Calcutta and thence to Sindri by rail, would probably be more economical.

Recently Dr. B. C. Roy (10) examined the important gypsum deposits in Nawanager. The following notes are taken from his report:—

The former Government of Nawanager leased out certain areas for gypsum to the Associated Cement Company and the Digvijay Cement Company. After the integration of former States, a dispute has arisen between the two concerns. The Digvijay Cement Company is now working nine months in a year in a leased out area of 900 acres around Ran, Nandana and Virpur. The work is being carried out in a desultory fashion in a series of pits and burrow holes up to 10-20 feet deep, in the low grounds or *nalas*, sub-soil water being generally struck at a depth of 20 feet. The higher adjoining grounds, consisting mostly of a limestone cover, also contain gypsum underneath in the clays, where the cost of winning will be more. The Digvijay Cement Company has excavated altogether about 10,000 tons since 1948, but the total output of the Associated Cement Company is not known.

Below some five feet of soil cover, the Gaj clays usually yield varying amounts of selenitic gypsum in the form of veins or segregations. The present output is about 6-7 *maunds* per 100 cubic feet, i.e., roughly two tons per 1,000 cubic feet. At Virpur a big horizontal patch of gypsum, 50 feet x 50 feet x 1 foot, was recently struck at a depth of 10 feet.

The gypsum from Ran is delivered to the Digvijay Cement factory at Sika at Rs. 28/- per ton, as per following schedule:—

|  |                     |
|--|---------------------|
| Quarrying cost .. ..   | Rs. 15/- per ton.   |
| Transport to Bhatia Railway Station and loading in wagon .. .. | Rs. 9/- per ton.    |
| Freight (Bhatia to Sika) .. ..                                 | Rs. 4/12/- per ton. |

The gypsum from Virpur is delivered at Sika at Rs. 24/- per ton, as per schedule given below:—

|  |                    |
|--|--------------------|
| Quarrying cost .. ..                   | Rs. 15/- per ton.  |
| Transport to Pindara port .. ..        | Rs. 1/4/- per ton. |
| Pindara to Sika by country craft .. .. | Rs. 8/- per ton.   |

The price of Jodhpur gypsum *f.o.r.* Sika works out at Rs. 30/- per ton, inclusive of railway freight of Rs. 22/- to Rs. 23/- per ton.

Mr. D. R. S. Mehta's estimates of gypsum reserve in Nawanager include the resources in the arable land, forming a large part of the area, where no gypsum could be recovered, and therefore the potential reserve would be much less. Apart from the feasibility of the proposed mining scheme, by bringing sea water over a distance of 8-12 miles by canals or pipes in case of Ran and Nandana, the most serious drawback of the proposal is that the saline water would waste the arable land of the area. Judging from the present output from all localities as 30 tons per day, employing some 300 workers (150 male excavators and 150 women helpers) daily, the maximum production capacity from the entire Jamnagar area would probably be of the order of 100 tons per day, over some years, but not for 20 years, particularly as a large part of the mineral lies in cultivable land.

A feasible method of large scale mining would probably be piling up of the gypsiferous clays by mechanical excavators, tractors, etc., and subsequent separation of gypsum by sun-drying. Mining by sluicing, hydraulicking, etc., would make the plastic clays more sticky, instead of loosening the gypsum crystals.

#### *Porbandar*

Mr. D. R. S. Mehta (7) recently investigated the recorded selenitic gypsum deposits in a marsh in Meda creek, north-east of Miani (21°49': 69°26') in Porbandar. Gypsum occurs as sporadic plates and needles in a yellowish calcareous clay, underlain by 2-3 feet of soil and silt, the average yield being 0.18 ton per 1,000 cubic feet of clay. The gypsum bearing strip is stated to be two miles long and half a mile wide, the area being inundated by saline water during monsoon, with the possibility of periodic replenishment of the mineral.

According to Mr. B. F. Mehta (5), the source at Miani yielded about 2,000 tons every year for the cement company at Porbandar, the mineral being sold in 1942-43 at Rs. 12/8/- per ton.

Dr. B. C. Roy (10) states that the price of gypsum from Miani delivered at Porbandar Cement Works is nowadays about Rs. 35/- per ton. He further records that gypsum, reported to occur at Keshav in the Porbandar *taluk*, is used by Messrs. Porbandar Industrial Products at Porbandar.

**FUTURE**

The recent work of the Geological Survey has shown the existence of large quantities of gypsum in Nawanagar, where the reserves have been roughly estimated at 4,700,000 tons. The deposit at Ran, most important in Saurashtra, is considered reasonably suitable for part requirements of the Sindri Fertilizer Project, and it is believed that the area is likely to supply at the rate of 500 tons per day for a period of some 20 years. It is stated that the deposits in Nawanagar could be economically worked by one or a combination of the following methods, i.e., (1) ground sluicing, (2) hydraulicking, and (3) dredging.

In view of certain observations noted by the author, with regard to the deposits in Nawanagar, it seems that their prospects although valuable have been overestimated.

The separate recovery of gypsum from Rann alluvium, containing roughly one pound per three square feet, is not economically feasible. The material could be won in a small way as a by-product at the brine pits of Kharaghoda, Khuda and other areas in the Rann. If projects for recovering brine by construction of canals and dredging operations materialise, the winning of gypsum as a by-product might be economically possible.

The deposits in Porbandar and Junagadh are not likely to be commercially workable in view of the isolated and sporadic nature of the mineral.

The Gaj clays around Bhavnagar are reported to contain two to three per cent. of gypsum. Probably the quantity is much less in general. There is a factory at Bhavnagar manufacturing plaster of Paris, chalk sticks, crayons, etc., but the concern failed to obtain an adequate supply of local gypsum at regular intervals and is now entirely dependent on foreign source and supplies from Kutch available at a cheaper rate.

The efforts of Messrs. Kathiawar Industries Ltd. in producing 2,000-3,000 tons of gypsum annually from brine at Jafrabad are commendable, and further augmentation of their output would be of general help to the industry.

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## CHAPTER XXII

### IRON-ORE

#### GENERAL

India has extensive deposits of iron-ore and is second to none from the viewpoint of reserves of high quality ore. The rich deposits are located in Bihar, Orissa, Madhya Pradesh, Mysore and Madras, the total known reserves being calculated at 10,200 million tons. The Bihar deposits are the most important and are reported to hold a reserve of 8,000 million tons. The high-grade ores contain 60-68 per cent. of iron, low sulphur and variable percentages of phosphorus.

The country's iron and steel industry is well established. The ore produced is smelted for reduction to pig iron and for the manufacture of steel. The iron-ore from the Tata Iron and Steel Company's mines is taken to the smelters at Jamshedpur, whereas that from the Indian Iron and Steel Company's mines is railed to the smelters at Kulti and near Asonsol in West Bengal. The smelters of the Mysore Steel Works are located at Bhadravati.

The production of iron-ore in India in recent years has been of the order of 2.5 million tons a year. The total annual capacity of the blast furnaces of the Indian pig iron producers is roughly two million tons. About 75 per cent. of the Indian pig iron is used in the preparation of steel. As a result of the increasing requirements of the country, the prospect for an expansion of the existing industry and erection of new iron and steel works is bright, particularly in view of India's enormous resources of iron-ore and ores of manganese, chromium, titanium and vanadium.

#### DISTRIBUTION

##### *Bhavnagar*

Some of the lateritic deposits in the 20-mile long laterite belt, in Bhavnagar area, according to Mr. M. M. Oza (6), are fairly rich in iron, often passing into hematite and red ochres.



*Dhrangadhra*

Sir Cyril S. Fox (5) noted a ferruginous sandstone with veins and segregations of hematite, two miles south of Rampura in Dhrangadhra. At Kuntalpur ( $22^{\circ}46'30''$ :  $71^{\circ}20'30''$ ), two miles further south, the ore was smelted locally many years ago as could be judged from 10-15 feet high slag heaps.

*Junagadh*

Mr. S. Krishnaswamy (4) recorded the following occurrences of iron-ore in the former Junagadh State:—

(1) Low grade lateritic iron-ore occurring as small pellets and nuggets, about  $1\frac{1}{2}$ -2 furlongs north-west of Char and 3-4 furlongs west of that village, and about half a mile south of Nunarda.

(2) Some abundance of impure hematite, associated with felspar porphyry dykes in traps, from a point about a mile north-west of Chhelena ( $20^{\circ}55'$ :  $71^{\circ}16'$ ), extending north-eastwards for a mile and a half up to Lor ( $20^{\circ}58'$ :  $71^{\circ}18'$ ). Some 'float-ore' is also reported from the fields near the occurrence.

(3) Some iron-ore from the lateritic plateau to the west and south-west of Balanivav and also between Balanivav ( $20^{\circ}57'$ :  $71^{\circ}24'$ ) and Kagwadar ( $20^{\circ}58'$ :  $71^{\circ}25'30''$ ).

*Nawanagar*

E. H. Adye (2) referred to rich hematitic and limonitic iron-ore, mostly in lateritic rocks, in Nawanagar, in a number of places, besides evidences of abandoned iron-smelting near Asota, Khambhalia, Bharana, Morpur, Ranpur and elsewhere. He recommended a revival of the iron-smelting industry, starting with a blast furnace at Asota Mota or Bhatia. The following localities are reported to contain iron-ore:—

(1) A low ridge and the adjoining fields, about  $1\frac{1}{2}$  miles south of Samelia Bet and two and one third miles W.N.W. of Asota Mota, showing rich iron-ore in abundance.

(2) Conical hillock and the vicinity,  $1\frac{1}{2}$  miles W. by W.N.W. of Asota Mota.

(3) The northern end of a N.N.W.-S.S.E. ridge, two miles W.S.W. of Habardi,

(4) The south-west end of a ridge at Maha Devia, with rich iron-ore.

(5) Near Tamba Talav, 1½ miles E.S.E. of Nandana, showing good ore in abundance.

(6) At Khokhra Dhar, a long low ridge near Lamba, containing large quantity of ore.

(7) A hillock two miles E.S.E. by E. of Bhatia, showing large quantity of rich ore.

(8) Cheque Dhar, 2½ miles east of Wadwala in the Alech hills.

(9) Highly ferruginous dykes, three and one third miles S.S.E. of Jam Jodhpur.

Dr. B. C. Roy (7) recently examined some of the lateritic iron-ore in Nawanagar. According to him, soft and earthy iron-ore, at times hard, is present in very large quantities, particularly around Nandana (22°8': 69°20'), Ran (22°10': 69°20'), Mewasa (22°13'30": 69°21'), Habardi (22°13': 69°25'), Virpur (22°15': 69°21'30"), Asota Mota (22°16': 69°25'). etc. It might be possible to develop a foreign market for it, possibly to Japan, if large supplies of a good quality ore could be steadily maintained. The area is partly held under a prospecting lease by a certain concern. Analyses of samples by Messrs. Hughes & Davies, Bombay, are given below:—

*Analyses*

*Per cent.*

|                                |    | Asota<br>Mota | Asota<br>Mota | Mewasa | Nandana | Habardi |
|--------------------------------|----|---------------|---------------|--------|---------|---------|
| Fe <sub>2</sub> O <sub>3</sub> | .. | 76.17         | 74.83         | 96.31  | 70.58   | 63.49   |
| Al <sub>2</sub> O <sub>3</sub> | .. | 5.31          | 9.24          | 1.07   | 13.29   | 11.38   |
| SiO <sub>2</sub>               | .. | 6.46          | 9.14          | 0.19   | 2.65    | 11.62   |
| TiO <sub>2</sub>               | .. | 0.38          | 0.50          | 0.16   | 1.00    | 0.28    |
| MnO                            | .. | trace         | trace         | trace  | 0.13    | trace   |
| CaO                            | .. | nil           | nil           | nil    | 2.23    | nil     |
| MgO                            | .. | nil           | nil           | nil    | trace   | 0.22    |
| SO <sub>3</sub>                | .. | nil           | nil           | nil    | 0.12    | nil     |
| CO <sub>2</sub>                | .. | n.d.          | n.d.          | n.d.   | 1.60    | n.d.    |
| P <sub>2</sub> O <sub>5</sub>  | .. | 0.55          | 0.23          | 0.01   | 0.04    | 0.16    |
| H <sub>2</sub> O               | .. | 11.13         | 6.06          | 2.26   | 8.36    | 12.85   |
| Total                          | .. | 100.00        | 100.00        | 100.00 | 100.00  | 100.00  |

The total iron content of ore (Fe), calculated from the above analyses, varies between 44.44 and 67.42 per cent.

### *Porbandar*

F. Fedden (1) recorded an ancient industry in iron-smelting, to some extent, in many parts of Porbandar. The following localities are particularly mentioned:—

(1) Near Bakharla, not far from Porbandar, a number of ancient 5-15 feet deep pits for iron-ore in the lateritic rocks are present.

(2) At Palakra, further north of Porbandar, evidence for ancient iron-smelting is noticed.

E. H. Adye (3) noted the following occurrences of iron-ore in Porbandar:—

(1) Ancient excavations in laterite, fairly rich in iron-ore, for iron-smelting, in slightly elevated patches to the west of Chorkhada Dhar, and  $1\frac{1}{4}$  miles south by S.S.W. of Ranawao town.

(2) Numerous small, shallow pits in lateritised conglomerate and massive laterite, west of Bakharla, the material from which, a rich hematitic iron-ore, was utilised for ancient smelting. Here was a flourishing iron-smelting centre which was abandoned a century ago due to cheapness of imported iron. The ore from the lateritic belt, of which Bakharla forms a small outlier, in the opinion of Adye, might be used by erecting small blast furnaces.

(3) Segregations of magnetic iron-ore in the altered granophyre of Babia Dungar in Porbandar. According to Adye they might be profitably crushed for iron-smelting, using the residue in pottery.

### *Sayla*

F. Fedden (1) referred to very large iron-slag heaps at Kantrori, near Sara, indicating large scale iron-smelting. The iron-stone bands near the top of the Umia group are believed to be the source of ore.

## FUTURE

Judging from ancient slag heaps, there seems to have been some iron-smelting in parts of Saurashtra. The cause of extinction of the ancient industry may be attributed to cheapness of imported metal and to the scarcity of fuel.

The ferruginous laterites, containing 25-40 up to 60 per cent. iron, are spread over parts of the State, at the contact of the Deccan traps with the Tertiary beds. Large quantities of ore are available in Nawanagar, Porbandar, Junagadh and Bhavnagar. These might prove to be economically workable deposits in the distant future, under favourable conditions of mining, beneficiation and transport, with the availability of cheap electrical power. At present it might be possible to develop an export industry, provided a steady supply of good quality ore could be assured for a reasonable period.

The raw materials from Saurashtra for any projected iron and steel industry within the State, cannot, under any circumstances, compete with the rich and extensive iron-ore deposits of Bihar, Orissa, Madhya Pradesh, Mysore and Madras. Most of the deposits in Saurashtra are widely scattered and comprise essentially low grade ores, the reserves being nowhere sufficient for a modern iron and steel works. The setting up of an industry in Saurashtra based on ore and coke from other States of the Indian Union is not likely to be an economical proposition.

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## CHAPTER XXIII

### LEAD-ORE

#### GENERAL

The commercially important lead-ores are galena ( $\text{PbS}$ ), cerussite ( $\text{PbCO}_3$ ) and anglesite ( $\text{PbSO}_4$ ). Galena is sometimes associated with zinc and silver sulphides, and rarely with arsenic, antimony, etc. The lead-ores occur as cavity fillings and replacements of limestones and dolomites by hydrothermal solutions. When associated with zinc ores or other complex ores, various methods of jigging, tabling or floatation are adopted for concentrating the lead-ore.

Although small deposits of lead-ore are known to occur in several localities in India, the only promising deposit is at Zawar in Rajasthan, where an ore-dressing plant has been recently installed for concentrating both lead and zinc ores. As the almost entire need of India with regard to this vital metal is met from foreign imports, the success of the Zawar lead-zinc mines will go a long way towards the supply of this strategic, non-ferrous metal in this country.

#### USES

Lead-ore is chiefly used for the extraction of metallic lead by smelting. Lead forms important alloys with other metals and is also used for making pipes, sheet lead and shots, and in the preparation of pigments like white lead and red lead.

#### DISTRIBUTION

##### *Junagadh*

The unusual occurrence of a metalliferous vein with galena in Saurashtra was first discovered by F. Fedden (1) in 1884. According to him, it is associated with copper pyrites and occurs very sparingly in a quartz vein in the traps at a site called Banej Nes ( $21^{\circ}3'$ :  $70^{\circ}53'$ ) in the Gir forest. The vein was seen to vary in thickness from two to six inches where exposed. Fedden believed that there was no promise of a workable quantity of ore being found in the area.

The area was visited in 1943-44 by Mr. S. Krishnaswamy (2), who carried out some prospecting work by sinking a few pits. About 44 tons of rock were excavated, yielding about 0.5 lbs. of galena. He also reported that the deposit of galena at Banej Nes has no economic significance.

Mr. C. Karunakaran (3) examined the recent pits for lead-ore around Banej Nes during field-season 1950-51 and reported several shallow pits and trenches in the area between Banej Nes on the west and the Machundri river about three miles to the east. Out of these, only five pits are said to have struck a quartz vein bearing galena speckled with chalcopyrite. Two trial pits are situated on the western bank of the river Dhamelio, a tributary of the Machundri river. One pit, about 35 feet long, 4 feet wide and 15 feet deep, shows the quartz vein increasing in width from about two inches at the surface to about five inches at the bottom of the pit. Galena with specks of chalcopyrite occurs sporadically in the vein. The second pit, about 10 feet long, 3 feet wide and 8 feet deep, indicates disseminations of galena and specks of chalcopyrite and malachite. The third pit near the hillock locally known as Bhuro Katro is 5 feet long, 2 feet wide and 6 feet deep, the exposed quartz vein with specks and crystals of galena being less than three inches in width. The two other pits are located about two miles north-east of the other pits and show specks of galena. Mr. Karunakaran concluded that no payable ore-body is present in the Banej Nes area.

Dr. B. C. Roy (4) examined the recent pits for lead-ore in the Gir forest in 1952. The Government of Saurashtra recently granted prospecting licenses to five parties for prospecting lead-ore in the Gir hills, and a mining lease is being given to Messrs. Sun Mining Syndicate. According to Dr. Roy, galena, chalcopyrite, bornite, tetrahedrite and malachite are disseminated in a vein quartz, a few inches up to one foot wide, visible at intervals for some considerable distance along a N.-S. to N.N.E.-S.S.W. strike. The fact that the mineralised area lies in a zone of fault-breccia, which may have an important bearing on the occurrence of ore, was not recognised by Fedden or recent workers. The fault-rock, possibly an acid intrusion, is up to 50 feet or more in width and forms the core of a hill range. It is suggested that this zone be prospected by driving adits at several localities. Although the meagre, exploratory works to date do not show optimistic indications, the area deserves further attention by detailed prospecting, particularly in the zone of fault-breccia.

Some vein quartz material containing galena was recently sent by Messrs. Saurashtra Trading Syndicate of Rajkot for analytical work to the Indian Institute of Science, Bangalore. Judging from certificates issued by Dr. M. R. Aswathanarayana Rao of the Institute, some of the samples show traces of cerium (less than 0.02 per cent.) and beryllium (less than 0.1 to 0.59 per cent.). A specimen of lead-ore, analysed by one of the prospecting concerns, showed 9.2 ozs. of silver per ton and gave the following results:—

|                                      | <i>Per cent.</i>                          |
|--------------------------------------|---|
| PbS .. ..                            | 94.32                                     |
| SiO <sub>2</sub> .. ..               | 4.44                                      |
| Fe <sub>2</sub> O <sub>3</sub> .. .. | 0.43                                      |
| Al <sub>2</sub> O <sub>3</sub> .. .. | 0.33                                      |
| ZnS .. ..                            | 0.48                                      |
|                                      | <hr style="width: 10%; margin: 0 auto;"/> |
| Total.                               | 100.00                                    |

#### FUTURE

The recent prospecting by several parties for lead-ore in the Gir forest has been mostly superficial work. While conceding that the shallow test pits have not given any promising results, it must be pointed out that none of the parties has so far carried out any explorations in the well marked zone of fault-breccia, which might have an important bearing on the mineralisation.

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## CHAPTER XXIV

### LIMESTONE

#### GENERAL

A pure limestone contains 56 per cent. CaO and 44 per cent. CO<sub>2</sub>. It may be argillaceous, ferruginous or siliceous, depending on the nature of impurities such as clay, ferruginous matter or silica. Generally a rock containing between 10 and 40 per cent. MgCO<sub>3</sub> is called dolomitic limestone. Dolomites are composed of equal molecular proportions of calcium and magnesium carbonates, namely 54.35 per cent. CaCO<sub>3</sub> and 45.35 per cent. MgCO<sub>3</sub>. Limestone and dolomite are bedded sedimentary rocks, whereas their metamorphic derivatives are termed crystalline limestone (marble) or dolomite (marble).

Limestone is usually sold at Rs. 7/- to Rs. 12/- per ton at the quarries. The price of limestone chips from Aditania quarries, delivered at Porbandar Cement Works, varies from Rs. 5/- to Rs. 6/- per ton.

#### USES

Limestone is commonly used as building stone, depending on its durability, appearance, workability and price. Large quantities of limestone are burnt for the preparation of lime for mortar and plaster; one hundred tons of pure limestone yield 56 tons of lime. The purity is not an essential factor for such use. Lime is also used as fertilizer in agriculture, for water purification, paper mills, tanning, sugar refining, etc.

It is employed as a flux in the iron and steel industry. For this purpose the limestone may not be very low in magnesia and iron. Silica and alumina are the chief impurities to be avoided. In smelting a high alumina iron-ore, the presence of a certain amount of silica is permissible.

Some quantity of lime is needed in the making of glass. The limestone must be pure but some free quartz and alkalis are permissible. Magnesia and iron are undesirable. Low alumina

content is essential. The other uses of lime are in the manufacture of paper, in tanning and in water purification.

In chemical industries very pure limestone is needed, particularly in the manufacture of bleaching powder. It is also used for the manufacture of calcium carbide and calcium cyanamide. For use in chemical industries absence of quartz is preferred although it is not considered very harmful, but high percentages of iron and alkalis are not allowed. The iron should be preferably below 0.20 per cent., and the combined impurities (silica, alumina, etc.) must be less than 1 to 2 per cent.

The principal use of limestone nowadays is in the manufacture of Portland cement. The limestone need not be necessarily low in silica and alumina, which are in any case added in the form of clay, but they should not exceed certain proportions. Raw materials containing MgO in excess of 4 per cent. should not be used. The iron percentage in the limestone should not normally exceed 2 per cent. The presence of alkalis does not matter, as they are driven off in the flue gases. The chemical composition of Portland cement usually varies between the following limits:—

|                                   | <i>Per cent.</i> |
|-----------------------------------|------------------|
| SiO <sub>2</sub> ..               | 17 - 25          |
| Al <sub>2</sub> O <sub>3</sub> .. | 4 - 10           |
| Fe <sub>2</sub> O <sub>3</sub> .. | 0.1 - 5          |
| CaO ..                            | 60 - 67          |
| MgO ..                            | 0 - 4.5          |
| SO <sub>3</sub> ..                | 1 - 2.5          |
| Alkalis ..                        | 0.3 - 2          |
| Loss ..                           | 0 - 3            |
| Insolubles ..                     | 0 - 0.5          |

#### DISTRIBUTION

The miliolite limestone deposits in the Kathiawar peninsula have been recorded by F. Fedden, whereas the occurrences in Nawanagar and Porbandar have been dealt with exhaustively by E. H. Adye. It is not possible to enumerate all such deposits here.

The recent work of the Geological Survey has proved the existence of high-grade limestone, occurring in parts of Saurashtra. The earlier works do not give any idea of the qualities of the de-

posits, and as such the recent data would throw more light on their workability and utilisation.

#### *Amreli*

Portions of miliolite limestone in the coastal areas around Kodinar and Okhamandal are suitable for the manufacture of cement. The miliolite limestone is being extensively used for this purpose in Dwarka and Porbandar. Similar material is present practically all along the coastal tracts of Saurashtra.

The limestone from Adivi, Dholasa and Harmaria in Kodinar is reported to contain an average 93%  $\text{CaCO}_3$ , 1.2%  $\text{MgCO}_3$ , 1.6%  $\text{Al}_2\text{O}_3$  and  $\text{Fe}_2\text{O}_3$ , 3%  $\text{SiO}_2$  and 0.3% combined water (11). The material used at Dwarka Cement Works has usually the following composition:—51.3%  $\text{CaO}$ , 2.5%  $\text{SiO}_2$ , 0.7%  $\text{Al}_2\text{O}_3$ , 0.6%  $\text{Fe}_2\text{O}_3$ , 1.4%  $\text{MgO}$  and 42.5% loss.

Coral limestone is present along the coastal margin of Okhamandal. The deposits near Mithapur alone, about 5-10 feet thick, are reported to contain five million tons (11). The material is very good in quality and is used by the Tata's Mithapur Works. The limestone analyses as follows:—95.94%  $\text{CaCO}_3$ , 2.22%  $\text{SiO}_2$ , 0.16%  $\text{Fe}_2\text{O}_3$ , 0.60%  $\text{Al}_2\text{O}_3$ , 0.12%  $\text{NaCl}$  and 1.07%  $\text{H}_2\text{O}$ .

#### *Bhavnagar*

K. P. Sinor (4) reported quarrying for miliolite limestone at Piperla, Sanosra (Sanosara), Chogat ( $21^\circ 49' 30'' : 71^\circ 55'$ ), Methla ( $21^\circ 10' : 72^\circ 4'$ ), Naip ( $21^\circ 6' : 71^\circ 55' 30''$ ), Gujarda ( $21^\circ 2' : 71^\circ 46' 30''$ ), Khared and Nesvad, in the former State of Bhavnagar. A yellow clayey limestone in association with a thin fossiliferous limestone in Gaj beds is also noted by him near Oonchdi ( $21^\circ 15' : 72^\circ 5'$ ).

#### *Gondal*

There are extensive miliolite limestone deposits in Gondal, particularly quarried around Jar, Patanwao, Zinjuda, Upleta, Paneli, etc. The chips are used in chemical works at Kharaghoda, Dhrangadhra, Ahmedabad, etc.

*Junagadh*

Dr. B. C. Roy (13) recorded high-grade miliolite limestone around Chorwad Road Railway Station ( $21^{\circ}3' : 70^{\circ}20'$ ), Kinderwa ( $21^{\circ}0' : 70^{\circ}21'30''$ ), Adri Road Railway Station ( $20^{\circ}59' : 70^{\circ}22'$ ), Dari ( $20^{\circ}57' : 70^{\circ}22'$ ), Veraval ( $20^{\circ}54' : 70^{\circ}25'$ ), Savni ( $20^{\circ}57'30'' : 70^{\circ}29'$ ), Patan ( $20^{\circ}53' : 70^{\circ}27'$ ), Lati ( $20^{\circ}52' : 70^{\circ}29'$ ), Gorakhmudi ( $20^{\circ}54'20'' : 70^{\circ}34'40''$ ), Prachi ( $20^{\circ}55'20'' : 70^{\circ}39'$ ), Sutrapara ( $20^{\circ}51' : 70^{\circ}31'30''$ ), Warodra ( $20^{\circ}49' : 70^{\circ}34'$ ) and other places in Junagadh State. The purer bands of limestone are homogeneous, fine grained or compact and are white, pale yellow or grey in colour. Their thickness varies between one and three feet.

With a view to getting an idea of the quantity and quality of the material available, Dr. Roy carried out a detailed examination of the deposits in Gorakhmudi, a type area, by sinking a number of shallow test pits. The deposits occur along a strip about one mile long and two furlongs wide, along the Veraval-Prachi highway, but are not continuous or uniformly distributed throughout. There are nine patches of limestone, the thickness varying from one to three feet. It is estimated that there are about 300,000 tons of good grade limestone within a depth of five feet from the surface

Analyses of samples collected by Dr. Roy from various localities in Junagadh, carried out in the Geological Survey laboratory, gave the following results:—

*Analyses**(Per cent)*

|                                  | 1     | 2     | 3     | 4     | 5     | 6     | 7     |
|----------------------------------|-------|-------|-------|-------|-------|-------|-------|
| SiO <sub>2</sub>                 | 0.68  | 1.04  | 0.65  | 0.58  | 0.96  | 1.02  | 1.06  |
| Al <sub>2</sub> O <sub>3</sub> & |       |       |       |       |       |       |       |
| Fe <sub>2</sub> O <sub>3</sub>   | 0.82  | 1.20  | 1.20  | 0.72  | 1.00  | 0.88  | 0.84  |
| CaO                              | 53.85 | 53.58 | 53.66 | 53.32 | 53.58 | 53.66 | 53.32 |
| MgO                              | 0.57  | 0.78  | 0.67  | 1.08  | 0.72  | 0.82  | 0.88  |
| Loss                             | 43.60 | 43.22 | 43.38 | 43.68 | 43.46 | 43.44 | 43.48 |
| Total.                           | 99.52 | 99.82 | 99.56 | 99.38 | 99.72 | 99.82 | 99.58 |

## Analyses - contd.

(Per cent)

|                                  | 8     | 9     | 10    | 11    | 12    | 13    | 14    |
|----------------------------------|-------|-------|-------|-------|-------|-------|-------|
| SiO <sub>2</sub>                 | 1.12  | 0.74  | 0.60  | 0.92  | 1.02  | 0.80  | 1.00  |
| Al <sub>2</sub> O <sub>3</sub> & |       |       |       |       |       |       |       |
| Fe <sub>2</sub> O <sub>3</sub>   | 0.52  | 0.82  | 0.98  | 1.20  | 0.78  | 0.60  | 0.62  |
| CaO                              | 53.86 | 54.01 | 54.15 | 53.58 | 53.48 | 54.13 | 54.05 |
| MgO                              | 0.65  | 0.47  | 0.47  | 0.38  | 1.08  | 0.43  | 0.46  |
| Loss                             | 43.48 | 43.60 | 43.70 | 43.42 | 43.46 | 43.60 | 43.48 |
| Total.                           | 99.63 | 99.64 | 99.90 | 99.50 | 99.82 | 99.56 | 99.61 |

- Localities:—
- (1) Dari.
  - (2) Chanduwao.
  - (3) Chamboda.
  - (4) Lati.
  - (5) Nawapara.
  - (6) Sutrapara.
  - (7) Warodra.
  - (8) Virodar near Prachi.
  - (9) Kinderwa.
  - (10) Chorwad Road.
  - (11) Gorakhmudi (pit No. 4).
  - (12) Gorakhmudi (pit No. 3).
  - (13) Gorakhmudi (pit No. 2).
  - (14) Gorakhmudi (pit No. 1).

According to Mr. S. Krishnaswamy (8), extensive miliolite limestone deposits are present in the coastal areas between Kodinar in the west and Nagesri in the east, the thickness varying from a few feet up to 100 feet. A sample of limestone from Una, about six furlongs east of Rajpura (20°46' : 71°7'), analysed in the Geological Survey laboratory, gave the following results:—

|                                | Per cent. |    |    |    |       |
|--------------------------------|-----------|----|----|----|-------|
| SiO <sub>2</sub>               | ..        | .. | .. | .. | 2.54  |
| Al <sub>2</sub> O <sub>3</sub> | ..        | .. | .. | .. | 0.32  |
| Fe <sub>2</sub> O <sub>3</sub> | ..        | .. | .. | .. | 0.32  |
| CaO                            | ..        | .. | .. | .. | 52.16 |
| MgO                            | ..        | .. | .. | .. | 0.93  |
| Loss                           | ..        | .. | .. | .. | 41.72 |

Mr. J. M. Master (6) reports frequent occurrence of miliolite limestone along the southern border of the Gir forest, at the foothills of Mount Girnar, and near Talala ( $21^{\circ}3'30''$  :  $70^{\circ}35'$ ) and Malia.

Mr. B. F. Mehta (9) noticed miliolite limestone attaining a thickness of over 50 feet in the quarries at Dhunphuliya and Shapur in the Vanthli mahal, Junagadh.

The miliolite limestone deposits near Jafrabad ( $20^{\circ}52'$  :  $71^{\circ}22'$ ) in the Gohilwad district were recently investigated by Mr. B. F. Mehta (10). The following note is taken from his report.

Buff coloured miliolite limestone with a northerly regional dip of about 30 degrees, intercalated with soft sandstones, occurs in an area of nearly four square miles within the limits of Babarkot ( $20^{\circ}52'$  :  $71^{\circ}24'$ ), Bhakodar ( $20^{\circ}54'$  :  $72^{\circ}27'$ ) and Vand ( $20^{\circ}54'$  :  $71^{\circ}25'$ ), to the east of the Jafrabad creek. To the south-west of Jafrabad there is a similar occurrence covering an area of about five square miles between Jafrabad and Balana ( $20^{\circ}51'$  :  $71^{\circ}17'$ ). More than half of these areas is covered by sand dunes of nearly 50-100 feet in height; besides, a major portion of the remaining tract is under cultivation. Whereas only the top two to six feet of the limestone in the former area and about four to six feet of the top limestone in the latter area are of a hard and compact type, the underlying strata are of a softer and indifferently cemented calcareous sandstone. About 43 million tons of the material may be available from the area to the east of Jafrabad and about 21 million tons from the south-west of Jafrabad. Analyses of the representative samples show that the material is suitable for cement manufacture. However, the limestone generally does not attain such purity as is required in the manufacture of soda ash. The analyses carried out in the Geological Survey laboratory are tabulated below:—

|                                   | 1      | 2     | 3     | 4     | 5     | 6     |
|-----------------------------------|--------|-------|-------|-------|-------|-------|
| SiO <sub>2</sub> ..               | 13.72  | 3.02  | 7.52  | 2.36  | 14.20 | 4.48  |
| Al <sub>2</sub> O <sub>3</sub> .. | 4.55   | 1.49  | 1.06  | 0.72  | 2.93  | 0.66  |
| Fe <sub>2</sub> O <sub>3</sub> .. | 4.05   | 0.81  | 1.14  | 0.68  | 2.07  | 1.94  |
| MgO ..                            | 1.68   | 0.62  | 0.86  | 0.28  | 0.86  | 0.51  |
| CaO ..                            | 39.54  | 51.76 | 49.62 | 51.63 | 43.63 | 51.15 |
| Loss ..                           | 36.52  | 41.84 | 38.60 | 42.44 | 35.46 | 40.72 |
| Total. ..                         | 100.06 | 99.54 | 98.80 | 98.65 | 99.15 | 99.46 |

## Localities:—

- (1) Quarry, west of Jafrabad.
- (2) Two miles west of Jafrabad.
- (3) One mile south of Mitiala.
- (4) Masankoidi.
- (5) Vararup.
- (6) East of Babarkot.

The extensive deposits of sand dunes would be useful in cement manufacture for blending with limestone, and their utilisation would mean a saving in the cost of quarrying and crushing. A sample from a dune to the north-west of Babarkot, analysed in the Geological Survey laboratory, gave the following results:—

|  | <i>Per cent.</i> |
|--|------------------|
| SiO <sub>2</sub> .. .. .               | 16.62            |
| Al <sub>2</sub> O <sub>3</sub> .. .. . | 4.47             |
| Fe <sub>2</sub> O <sub>3</sub> .. .. . | 3.93             |
| MgO .. .. .                            | 3.80             |
| CaO .. .. .                            | 36.80            |
| Loss .. .. .                           | 32.40            |
| Total ..                               | 98.02            |

*Limbdi*

Mr. R. K. Taploo (7) reports impure limestone at Panri (22°32' : 72°47'), and near Mojhidar (22°28' : 72°48'), Acharda (22°28' : 72°50') and Chalala (22°24' : 72°50') in Limbdi.

*Morvi*

According to Dr. H. Crookshank (12), calcareous bands, veins and concretions are present in all geological formations in Morvi. Good quality material, suitable for chemical purpose or cement manufacture, is reported to be small. The Sub-Recent formations usually contain large quantities of impure material.

*Nawanagar*

F. Fedden (1) and E. H. Adye (2) referred to the various deposits of miliolite limestone in the former Nawanagar State. The localities are too numerous to be enumerated here.

The miliolite limestone from Gop area is used by the new Digvijay Cement Company at Sika for the manufacture of cement.

### Porbandar

F. Fedden (1) and E. H. Adye (3) described the various well developed miliolite limestone occurrences in the State of Porbandar. The localities are too numerous to be given here.

Dr. B. C. Roy (14) recently inspected the famous miliolite limestone quarries for building materials at Aditania ( $21^{\circ}43' : 69^{\circ}44'$ ), altogether 318 in number, covering an area of over one square mile, and worked by some 42 parties. There is a 5-mile long railway siding to the quarries from Ranawao Railway Station. The quarries are located at an elevation of 296 feet above sea-level, and have supplied since a long time materials for frontages, columns, balustrades, etc., in palaces, temples and public buildings, not only in Saurashtra but also in Calcutta, Bombay, Karachi, Madras and Rangoon. The thickness of limestone, overlying the Deccan traps, varies from five feet up to over 100 feet. The quarries are generally taken down to a depth of 30-40 feet, the deepest open-cast (Dhoba) being nearly 100 feet in depth. The quarry waste (chips) is used by the Associated Cement Company at Porbandar and by Ta'a's Mithapur Chemical Works, their monthly need being roughly 5,000 tons and 6,000 tons respectively. The price of chips delivered at Porbandar Cement Works is Rs. 5/- to Rs. 6/- per ton.

### Analysis

|                                |    |    |       |    | Per cent. |
|--------------------------------|----|----|-------|----|-----------|
| SiO <sub>2</sub>               | .. | .. | ..    | .. | 3.97      |
| Al <sub>2</sub> O <sub>3</sub> | .. | .. | ..    | .. | 1.77      |
| Fe <sub>2</sub> O <sub>3</sub> | .. | .. | ..    | .. | 0.65      |
| CaO                            | .. | .. | ..    | .. | 51.76     |
| MgO                            | .. | .. | ..    | .. | 0.63      |
| Alkalies                       | .. | .. | ..    | .. | 0.13      |
| Loss                           | .. | .. | ..    | .. | 41.09     |
|                                |    |    |       |    | <hr/>     |
|                                |    |    | Total | .. | 100.00    |

Analyst:—Porbandar Cement Works.



*Wankaner*

Infra and inter-trappean limestones, up to 50-60 feet in thickness, are noted by Mr. V. R. R. Khedker (5) in trap areas in Wankaner State, but details about the exact localities are not stated. The limestone is reported to contain about 80 per cent.  $\text{CaCO}_3$ . Some Sub-Recent limestone bands are also reported to occur in Wankaner.

## FUTURE

Saurashtra is endowed with fairly rich sources of limestone and their qualities appear to be suitable for various industrial uses. The limestone is being used to some extent for lime-burning and in the manufacture of cement at Dwarka, Porbandar and Sika, apart from local use as building materials. It is desirable to utilise this in other varied spheres of industrial application.

It has been noticed that high-grade limestone is sometimes used for lime for building purposes. Such practice should be discontinued, and in fact all selected bands of high-grade limestone deserve to be conserved for the chemical industries or for the manufacture of high quality lime for other industrial uses. The recent work of the Geological Survey has proved the existence of exceptionally pure limestone, suitable for chemical purposes, in coastal areas around Veraval.

As the various limestone deposits in the State have been indicated, and a fair idea of their quality and quantity is known, it is now up to the industrialists to locate by detailed prospecting the appropriate grades according to their need. Limestone forms an important link in the chain of integrated mineral industries and thus deserves careful attention in any future planning within the State.

The possibilities of developing a cement industry, utilising the deposits in Jafrahad, have been discussed. The proposed factory at Jafrahad will have a capacity of 1,000 tons per day and is expected to meet the requirements from other States.

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## CHAPTER XXV

### MINERAL PIGMENTS

#### GENERAL

There are three types of mineral pigments, namely, natural mineral pigments, pigments obtained by calcination or sublimation of natural minerals, and chemically treated pigments.

Ochres are naturally coloured mineral pigments, usually with ferric (red) and hydrated ferric (yellow) oxides, used for the manufacture of paints and for colouring ceramic goods, cement, linoleum, rubber, wood, etc. They are generally dried, ground and sieved before marketing. Levigation and calcining often improve the quality. The oxide pigments have a good covering power, and are cheap, durable and inert. A variety of tints, including siennas and umbers, are provided by the lateritic rocks.

Gypsum, talc, baryte, whiting, white clay (*whites*), green earth or ochre (*greens*), black shale or slate, etc., also represent natural pigments. The chemically treated paints are derived from minerals containing lead, zinc, barium, titanium, etc.

For marketing, the mineral pigments are graded according to quality, with a corresponding variation in price. Certain physical tests are usually carried out to determine their colour, particle size, tinting strength, hiding power (opacity), oil absorptive power, etc. The pigments are crushed and ground to minus 300 mesh before use, the imported "Persian red" having an average grain size of 0.80 to 0.85 microns.

A number of paint manufacturers have been well established in India since the first world war. The principal recorded output of ochres is from Madhya Pradesh, Madras, Mysore, Sandur, Vindhya Pradesh, Rajasthan and Madhya Bharat. Some production is also maintained in Saurashtra.

Levigated red ochre is priced at Rs. 100/- per ton and yellow ochre powder at Rs. 90/- to Rs. 150/- per ton. The price of red oxide lump (97%) is Rs. 60/- at loading Station.

## DISTRIBUTION

*Bhavnagar*

Dr. B. C. Roy (7) reports that the lateritic rocks, consisting of extensive deposits of yellow ochre and some red ochre, constitute the tops of low cliffs, about  $2\frac{1}{2}$  miles west of Lakhanka ( $21^{\circ}31'30''$  :  $72^{\circ}17'30''$ ) in Bhavnagar. The yellow ochreous bed is 5-15 feet thick, forms a horizontal layer, and overlies 10-20 feet of lithomarge constituting the low grounds and cliff slopes.

Mr. M. M. Oza (10) noted an occurrence of red ochre and hematite about one mile west of Alapur ( $21^{\circ}35'$  :  $72^{\circ}14'$ ). Ferruginous red clays are also reported near Tagadi ( $21^{\circ}41'$  :  $72^{\circ}10'$ ) and south of Thoradi ( $21^{\circ}39'$  :  $72^{\circ}12'$ ). Lavender coloured earth is particularly mentioned about one mile west of Khadsalya ( $21^{\circ}34'$  :  $72^{\circ}14'$ ). All these outcrops are in association with lateritic rocks in Bhavnagar.

*Dhrangadhra*

Sir Cyril S. Fox (5) referred to red ochres from near Ankevalia Mota ( $22^{\circ}51'$  :  $71^{\circ}27'$ ) in Dhrangadhra, in a 10-foot deep well, in association with bedded sandstones. He also noted some exposures of red ochre at Raigadh (? Ravliavadar) in great abundance, and near Baisahebgarh.

The red ochre deposit between Soladi ( $23^{\circ}1'$  :  $71^{\circ}24'$ ) and Rajpur ( $23^{\circ}1'$  :  $71^{\circ}25'$ ), in the Zalawad district, was recently investigated by Mr. C. Karunakaran (9), by sinking 20 trial pits at the cost of Saurashtra Government. It occurs as a horizontal bed overlain by ferruginous sandstone. Denudation of the sandstone capping has exposed the ochre over an area of nearly three quarters of a mile. Undenuded remnants of sandstone capping fringe the ochre outcrop on all sides. The ochre is an original clay deposit which has been coloured bright red by impregnation of ferric oxide which has leached down from the overlying ferruginous sandstone.

The deposit is situated a little more than a mile away from Rajpur on the Dhrangadhra-Halwad railway line. The ochre has been found on testing to be nearly grit free but any necessary levigation could be easily carried out at the site where abundant water would be available from shallow wells. All the 20 pits spaced

at regular intervals over the area were carried down to the water table, generally about 15 feet below the surface. Two of the pits were continued down to a depth of 20 feet and the ochre was found to persist to this depth. The base of the ochre bed was nowhere reached and prospecting work had to be stopped on account of water trouble.

The ochre consistently persists down to a depth of at least 15 feet in all the pits, proving its existence throughout the area investigated. The total quantity available in this area ( $\frac{1}{4}$  square mile) to a depth of 15 feet is at least one million tons. Traverses made over the adjoining tract to the west beyond the agricultural land showed that the ochre continues in this area. Good exposures are available where the ground is intersected by shallow streams. The ochre exists continuously over the whole of this additional tract. This would raise the potential reserves of ochre to at least three million tons.

An average sample was made of the 20 samples collected and tested. This yielded the following results:—

(1) *Fineness tests:* 35 gms. of the material was ground and sieved through 200 mesh.

Residue left in the sieve: 23.5%.

Residue after two re-grindings: 4.96%.

Grit present is negligible.

In carrying out the following tests a sample of red ochre which has already been proved satisfactory for paint manufacture was used as the standard for comparison. The standard sample, B-1/No. 1,094/1852, was obtained from the British Paints, India. All the tests were carried out on the test sample and the standard sample separately.

(2) *Colour:* According to the I.S. 5-49 and also B. S. 381. C.  
Standard sample ..... Venetian red.  
Test sample ..... No. 444. Terra cotta.

(3) *Oil absorption:* On mixing both samples with the requisite quantity of linseed oil to attain proper consistency, it was found that the test sample was superior to the standard sample.

(4) *Opacity or hiding power:* The test sample was slightly inferior to the standard sample.

(5) *Tinting strength:* White lead was used as the extender and the staining power of the sample compared favourably with that of the standard taking into consideration the lighter shade of the former.

Chemical analysis of the test sample, carried out in the Geological Survey of India laboratory, gave the following results:—

|   | <i>Per cent.</i> |    |       |        |
|---|------------------|----|-------|--------|
| Fe <sub>2</sub> O <sub>3</sub> & Al <sub>2</sub> O <sub>3</sub> | ..               | .. | ..    | 17.30  |
| CaO   | ..               | .. | ..    | 2.65   |
| MgO   | ..               | .. | ..    | 0.79   |
| Loss  | ..               | .. | ..    | 14.00  |
| Insolubles  | ..               | .. | ..    | 65.26  |
|   |                  |    | Total | 100.00 |

Red ochre, identical in appearance and quality to that described above, was further examined by Mr. C. Karunakaran (9) at the following places in Dhrangadhra:—

*Chorvirda* (22°35' : 71°23').—The ochre occurs as a horizontal deposit, overlain and underlain by sandstone, and outcrops to the north of the village. Part of the bed has been completely denuded away exposing the basal sandstone. The ochre bed varies in thickness from two to five feet, and extends over a tract approximately 200 square yards.

*Khod* (22°30' : 71°22').—Red ochre occurs as a horizontal bed on the surface on either side of the railway line where it passes north of the village. Shallow pits have shown that the bed is at least five feet thick and extends over an area of about 40,000 square yards.

#### *Junagadh*

Dr. B. C. Roy (6) reports clays of variegated colours of lateritic origin in the vicinity of Barula (21°2' 30" : 70°24' 20"), Danderi (21°1' 40" : 70°25'), Shimerwao (21°0' 40" : 70°29') and Bhetali

(20°57' 30" : 70°35') in Junagadh. The deposits are worked for local colour wash and do not have any commercial importance.

According to Dr. Roy (6), the soft, yellow clays in Gaj beds in Junagadh, after washing, may be found suitable for the manufacture of paints. Extensive deposits occur around Chorwad Road Railway Station (21°3' : 70°20'), Savni (20°57' 30" : 70°29'), Palasli (20°54' : 70°41') and other localities.

#### *Morvi*

Dr. H. Crookshank (8) found low grade ochres in Jurassic clays in Morvi, but none is reported to be of good quality and in large quantities.

#### *Nawanagar*

Adye (1) refers to a red bole bed more than one foot thick, covering a considerable distance at Verawal, five miles S. E. by E.S.E. of Gop hill, Nawanagar. Other such deposits are also recorded in sufficient quantity, at the following places:—

- (1) West of village Ran, on the west sloping bank of Ranuka *vokala*.
- (2)  $\frac{1}{4}$  mile S.S.W. of Tungi, at the base of Tungi Dhar, 23 miles south-west of Jamnagar.
- (3) North-east of Katkōla, five miles north of Wansjalia Railway Station.

Good quality yellow ochre in plenty is also reported by Adye, two miles south-west of Hariawar and three miles S. S. E. of Ran, in Nawanagar.

According to Dr. B. C. Roy (7), a two-foot thick red bole bed is seen in a raised ground below five feet of trap, between 7 and 8 milestones from Jamnagar on the Bed-Sika road. Judging from an open quarry and a nearby *nala* section, large amount of red ochre would be available, but the material would need dressing and levigation before use.

Dr. Roy further states that coloured clays, variegated earths and yellow and red ochres are present in almost inexhaustible

amounts in the lateritic terrain in Nawanagar area, particularly around Nandana, Ran, Mewasa, Habardi, Virpur, etc. Properly levigated material should find a ready market. At present there are a few factories manufacturing paints in Jamnagar.

#### Porbandar

Adye (2) records a bright yellow ochre of excellent quality from a well shaft, one mile E. by E.S.E. of Palakra in Porbandar. It is concealed below a 15-foot thick soil overburden in the adjoining terrain. It is a fine-textured friable marl, presumably occurring in considerable quantity, and much favoured for making distempers or conversion into a light red pigment by calcination. Another occurrence is reported near Hathiani temple,  $\frac{1}{4}$  mile E. S. E. of Sakhpur.

Mr. B. F. Mehta (3) examined a six to eight-inch thick impersistent band of yellow ochre, partly red in patches, covered by soil, dipping very gently eastwards, about 200 yards south-west of Bharware in the Adwana *mahal*, Porbandar. It occurs in a small hillock near a stream bank, below seven feet from the surface, possibly covering an area of a quarter of a square mile. The ochre is worked by numerous pits. It is dried, sieved and baked to give deeper shades of colour. It is sold at Rs. 40/- per ton at Porbandar.

Dr. B. C. Roy (7) reports that the material from Bharware is being treated for manufacture of paints at Porbandar by Messrs. Porbandar Industrial Products Ltd., their annual consumption being reported to be about 1,000 tons. The following figures, supplied by the firm, are of interest:—

|                                      |                   |
|--------------------------------------|-------------------|
| Cost of excavation and levigation .. | Rs. 7/- per ton.  |
| Transport to Porbandar .. ..         | Rs. 4/- per ton.  |
| Royalty .. .. .                      | Rs. 4/- per ton.  |
| Crushing of levigated ochre ..       | Rs. 10/- per ton. |
| Bagging charge .. .. .               | Rs. 8/- per ton.  |

#### Wadhwan

Mr. R. K. Taploo (4) noted good quality red ochre about 30 feet below the surface near Rampara in Wadhwan, but the pits hitherto filled up could not be examined. Over 500 *maunds* are said to have been won from here.



## Wankaner

Dr. B. C. Roy (7) recently reported on the following deposits of ochre in Wankaner area:—

*Ratidevli.*—A lavender coloured clay, 3-4 feet thick, below a 3-5 feet overburden of soil in a *nala* bank, about one mile from Ratidevli ( $22^{\circ}37' : 70^{\circ}56'$ ), on the cart track to Sajanpur, is being worked for manufacturing coloured clays at Wankaner. The clay is underlain by a bed of sandstone and is seen for nearly 100 yards along the bank. The excavation cost and carting to Wankaner are said to be Rs. 7/- and Rs. 3/- per ton respectively.

In a *nala* north of the village, a tributary of the river Asoi, is exposed a 5-foot bed of impure red ochre below 2-5 feet of soil cover. The ochre bearing strip measures about one furlong by 100 yards. The ochre at places shows patches of white, yellow or lavender coloured clays.

*Sajanpur.*—The yellow sandstone at Sajanpur ( $22^{\circ}40'30'' : 70^{\circ}54'$ ) was till recently being worked and levigated for manufacturing yellow ochre. The area is seven miles north-west of Wankaner.

*Panchasia.*—A bed of red ochre, 5-8 feet thick, partly variegated in colour, yellow, black or grey at places, below a 5-foot cover of soil, occurs in the banks of Ratawao *nala*, about  $1\frac{1}{2}$  miles north-west of Panchasia ( $22^{\circ}42' : 70^{\circ}54'$ ). It is seen continuously for some three furlongs along the banks and is intruded by a 10-foot wide basic dyke at one place. The ochre is underlain by sandstones.

*Wankaner City.*—Extensive deposits of impure red ochre are seen both upstream and downstream of the Machu river bridge and in the flat terrain around Wankaner ( $22^{\circ}37' : 70^{\circ}59'$ ). The right bank near the bridge shows the following section:—

|           |    |    |    |           |
|-----------|----|----|----|-----------|
| Sandstone | .. | .. | .. | 4 feet.   |
| Red ochre | .. | .. | .. | 8 feet.   |
| Sandstone | .. | .. | .. | 3 feet.   |
| Red ochre | .. | .. | .. | 10 feet.  |
| Sandstone | .. | .. | .. | 5-8 feet. |

At places selected material is worked for local manufacture of paints. The excavation cost is said to be Rs. 7/- per ton, and the

transport to factories works out at Rs. 3/- per ton. The grinding and bagging charges are stated to be Rs. 12/- and Rs. 8/- per ton respectively. The unlevigated red ochre is priced at Rs. 40/- to Rs. 45/- per ton at works.

Patches of friable, soft, yellow sandstone in the Machu river bed and banks are quarried for manufacturing yellow ochres by the factories at Wankaner, for about half a mile upstream of the bridge. Some of the workable patches are about 100 yards long along the bank and are 100 feet wide. A typical section is given below:—

|                              |               |
|------------------------------|---------------|
| Sandstone .. ..              | 5 feet.       |
| White or variegated clay ..  | 9 inches.     |
| Yellow, gritty sandstone ..  | 1½ feet.      |
| Yellow, friable sandstone .. | 1½ to 2 feet. |
| White clay .. ..             | 1½ feet.      |

The amount of yellow ochre recovered on levigation varies from 18-20 per cent. of the rock by weight. The total cost of excavation, transport to works, crushing and levigation is stated to be Rs. 70/- per ton. The expense on bagging works out at Rs. 10/- per ton. The finished material is sold at Rs. 100/- per ton ex-works. At Wankaner, the following firms manufacture paints, ochres, dis-temper, etc.:—

- (1) Mangal Minerals.
- (2) The Indian Colouring Factory.
- (3) The Parijat Paints Manufacturing Co.

*Gangiawadar.*—An extensive deposit of soft, friable, yellow sandstone occurs about 2-3 furlongs west of Gangiawadar (22°38' : 71°5') in the plains and at the foot-hills of a low hill range formed of sandstones with capping of Deccan trap. Judging from wells and pits, the ochreous bed appears to be 3-5 feet thick, underlying 3-10 feet of soil. The deposit forms an almost N. N. W.-S. S. E. strip of country, about one mile long, i.e., extending up to Kashiagarh (22°37' : 71°5'), and is 100 yards wide. Here about 50,000 tons of levigated yellow ochre could possibly be recovered within a shallow depth on the basis of 20 per cent. of ochre in rock. Abundant water would be available at a shallow depth for

levigation. A partial analysis of the yellow ochre, carried out at the Directorate of Industries, Government of Saurashtra, gave the following results:—

|  |    |    | <i>Per cent.</i> |
|--|----|----|------------------|
| Moisture at 105° - 110°C.                    | .. | .. | 0.57             |
| Total volatile content                       | .. | .. | 4.82             |
| Insolubles                                   | .. | .. | 80.35            |
| Iron oxide (Fe <sub>2</sub> O <sub>3</sub> ) | .. | .. | 14.30            |

#### FUTURE

At present a few firms are known to produce paints and varnishes in Saurashtra utilising local ochres, but there should be considerable scope for further development of the industry, judging from imports of paint materials. Although no recorded production of ochre is available, a large quantity of the material is won in many parts of the State for local consumption.

There is no dearth of red bole beds in the Deccan trap country, but the material cannot be used without levigation, thus adding to the cost of the products. The large varieties of coloured earths and ochres, if properly washed, should find a growing use as colouring media for the existing potteries within the State. The lateritic rocks would yield almost inexhaustible quantities of ochres.

The yellow or red ochres in Jurassic rocks are being used in a small way by the local paint manufacturers. The excellent yellow ochre deposit near Gangiawadar, where about 50,000 tons of levigated material could possibly be recovered, needs detailed prospecting for proving the reserve. This occurrence should draw the attention of paint manufacturers.

The easily accessible red ochre deposit in Dhrangadhra, with a possible reserve of at least three million tons, within a shallow depth of 15 feet, might be useful in future. The ochres being almost horizontally disposed or tilted gently, the working will have to be carried out by stripping the overlying sandstone or mining underground below the sandstone. As the water table is very high, there will be trouble of water unless the work is carried out under technical supervision. The material should be freed from grits by levigation and settling the products according to various grades of fineness. While the results of the tests appear favourable

it is to be noted that the colour is different from that of the standard used in the paint industry. Colour being a vital factor in paint manufacture it is likely that this ochre may not find much favour among paint manufacturers.

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## CHAPTER XXVI

### MINERAL WATERS

Bihar is perhaps the most endowed State with regard to mineral springs possessing medicinal and radio-active properties. There are also several such springs in parts of Saurashtra, where their curative values have long been recognised, but nowhere any attempt has been made to classify them and exploit these resources on modern lines. Most of these places are held sacred where pilgrims have facilities to bathe with the water of the springs led into suitable tanks. The springs possessing medicinal properties should be brought under Government control and developed as health spas.

There is a recorded mineral spring at Tulsī Sham ( $21^{\circ}3':71^{\circ}5'$ ) in the Gir forest. It is frequented by pilgrims and visitors. The water shows a temperature of  $124^{\circ}\text{F}$ ., emits a bad odour and is reported to have no medicinal value. The spring is located in Deccan trap. La Touche (1) quotes the following analysis:—

|   | <i>Per cent.</i> |
|---|------------------|
| NaCl .. .. .                            | 7.92             |
| Na <sub>2</sub> SO <sub>4</sub> .. .. . | 1.13             |
| CaSO <sub>4</sub> .. .. .               | 0.41             |
| CaCO <sub>3</sub> .. .. .               | 1.33             |
| SiO <sub>2</sub> .. .. .                | 1.08             |
|   | 11.87            |
| Total solids ..                         | 11.87            |

The up-to-date information based on a recent survey of the mineral springs in other parts of India by Dr. P. K. Ghosh (2) of the Geological Survey of India is under publication.

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## CHAPTER XXVII

### MINERAL WOOL

#### GENERAL

After visiting a working plant in the U. S. A. manufacturing mineral wool, Dr. M. S. Krishnan (1) in 1940 had drawn the attention to the possibilities of manufacturing mineral wool in India, and stressed the necessity for producing a cheap insulating material for building purposes in a tropical country.

The fine fibrous material produced by melting a suitable mineral matter and blowing by steam or air under pressure is known as mineral wool. Various types of mineral wool are manufactured and used, e.g., *glass wool* or *glass silk* from glass melts, *slag wool* from smelting of ores with or without fluxes, and *rock wool* from melted rock or mixture of rocks. In recent years the industry has made much progress, with great improvement in the manufacturing techniques in the U. S. A., where there are now over 50 plants producing mineral wool valued at \$79,094,000.

Glass, chinawares, sand, gravel, earth, slag, easily fusible rocks, shale and limestone are commonly used for the manufacture of mineral wool. With a view to ensuring an uniformity of products, the composition of the raw materials, temperature range, etc., need proper control and adjustment. It is said that to manufacture one short ton of rock wool, 3,000 lbs. of rock, 1,200 lbs. of coke, 3,000 lbs. of steam and 4,000 gallons of cooling water are required.

The raw materials are melted in cupolas, reverberatory or electric furnaces. The ordinary method of drawing into fibres consists of pouring the melt across a blast of air or steam, thus splitting the melt into small globules which are drawn into fibres. The melt is also at times poured in a rotating disc or wheel at high speed, whereas the droplets are thrown off as fibres and threads.

#### USES

The heat insulating property of mineral wool is due to the countless air cells between the fibres, the fibres with a diameter

of 2-10 microns being reported to yield the best insulators. Rock wool prevents heat transfer from buildings, steam pipes, boilers, furnaces, stoves, refrigerators, etc. Mineral wool is also employed in acoustic control in buildings, auditoria, theatres, etc. Rock wool blankets, quilts, mats and files deaden the noises from outside. Mineral wool is further used as a filter for air and for certain corrosive liquids, for packing acid containers, in fire-proof cement, as shock absorbers, etc.

Various forms of mineral wool are available on the market, e.g., *loose wool* (in building insulation), *granulated wool* (blowing into spaces in walls, roofs, etc.), *batts* (compressed wool with a binder and made into suitable shapes for spaces between floors, in roof, etc.), *blankets* (rectangular shaped, in which wool is sewn between wire-netting, metal, paper, etc.), *blocks* (made with a binder, e.g., asphalt, plaster and cement, for lining refrigerators, stoves, etc.), etc. A type of *insulating cement*, a mineral wool with a suitable binder such as clay, bentonite or cement, is also sold in the market for using around irregular objects.

#### FUTURE

Although no readily fusible rocks occur in Saurashtra, the limestone deposits could be utilised in manufacturing mineral wool, as a subsidiary industry to the well established Portland cement manufacturers and the ceramic industry in the State. The prospect will have to be determined after careful research and experiments in collaboration with the existing cement and ceramic industries.

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## CHAPTER XXVIII

### MOULDING SAND

#### GENERAL

Moulding sand, a mixture of sand and loam, is used by founders in making sand moulds to receive molten metal. It varies from 3 mm. down to clay in size, with angular to sub-angular grains. Dune sand mixed with required quantities of suitable clay is also used as foundry sand. Moulding sand should have the following properties:—

- (1) Refractoriness to withstand melting.
- (2) Cohesive or bonding property to take shape; as such some clay constituent is essential.
- (3) Porousness to permit escape of gases during casting.
- (4) Low in iron content.

#### DISTRIBUTION

##### *Bhavnagar*

Dr. B. C. Roy (1) reports that weathered Gaj sandstones in the bed of a river at Malanka ( $21^{\circ}43'30''$  :  $72^{\circ}13'$ ), six miles from Bhavnagar, are being worked by several parties for recovering a fine, yellow moulding sand. The sand *in situ* is found below 3-5 feet of river sand and is worked up to a depth of 35 feet provided pumping facilities are available. After removing thick grey partings of clay, the material is shipped to Bombay where it is sold @ Rs. 28/- per ton. The following figures furnished by the producers are of interest:—

|                                |                             |
|--------------------------------|-----------------------------|
| Excavation cost .. ..          | Rs. 4/ 0/- per ton.         |
| Transport to Bhavnagar port    | Rs. 4/ 8/- per ton.         |
| Royalty .. .. .                | Rs. 2/10/- per ton.         |
| Loading in country crafts ..   | Rs. 1/ 0/- per ton.         |
| Freight to Bombay .. ..        | Rs. 10/ 0/- per ton.        |
| Customs duty at Bhavnagar port | Rs. 1/ 4/- per ton.         |
| Customs duty at Bombay port    | Rs. 1/ 4/- per ton.         |
| <b>Total.</b>                  | <b>Rs. 24/10/- per ton.</b> |



## PRODUCERS

| Names.                          | Area.            | Probable annual output. |
|---------------------------------|------------------|-------------------------|
| Shashikant Ramesh Chandra & Co. | 127 ft. x 75 ft. | 1,000 tons.             |
| Pradibkumar B. Gohel & Co. ..   | 60 ft. x 50 ft.  | 800 tons.               |
| Champaklal Vithalji & Co. ..    | 50 ft. x 50 ft.  | 500 tons.               |
| Ramnklal Vithaldas Patel. ..    | 125 ft. x 75 ft. | 1,000 tons.             |

*Porbandar*

In the Jambuvanti cave near Aditania limestone quarries (21°43' : 69°44') in Porbandar, an ancient natural tunnel in limestone, 100-150 feet long and 20-25 feet deep, with four shafts, a fine, brown sand is present in some quantities. According to Dr. B. C. Roy (1), it is being used in small amounts as moulding sand by the Maharani mill at Porbandar. The sand may be about five feet thick, underlying miliolite sandstone, and seems to have been partly washed out by some underground stream.

## FUTURE

The most important moulding sand deposits are found in Bhavnagar. They are being regularly shipped to Bombay for use in foundries. The material is reported to be the best in India and as such they would be continued to be worked. As the sand represents weathered Gaj sandstones *in situ*, in the river bed, large reserve of material is visualised within the State. The present producers are capable of supplying about 3,000 tons annually.

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## CHAPTER XXIX

### NATURAL GAS

#### GENERAL

Natural gas is mostly associated with petroleum, but is also connected with buried organic remains in Tertiary sediments along the coastal areas. The essential constituent of natural gas is methane, although other hydrocarbons may be found. Natural gas from Texas and Utah contains helium.

In the U. S. A. it is used as a fuel for domestic and industrial purposes, and is led by pipe lines to consumers over thousands of miles. It is also liquefied for domestic purposes, processed to make natural gasolene, or burnt into carbon black for various industries.

#### DISTRIBUTION

##### *Kodinar*

In 1921 Captain Palmer (1) investigated the occurrence of natural inflammable gas met with in four out of seven bore-holes, varying from 76 to 185 feet in depth, at Jagatia, eight miles north-east of Kodinar ( $20^{\circ}47' : 70^{\circ}45'$ ), Amreli district. Judging from an examination of cores he opined that there are no further chances of striking gas by deep boring at Jagatia on account of the proximity of the Deccan trap, recorded at a depth of 185 feet 6 inches in bore-hole No. 3. No gas field of economic value was conceived as the gas was under no great pressure; the closed pressures were found to vary from 12.5 lbs. per square inch to practically *nil*.

##### *Gogha*

In 1930 Rao Bahadur M. Vinayak Rao drew attention to the wasteful escape of gas, issuing since 1920, from a bore-hole at Gogha, reported to be 1,016 feet deep. In view of the discovery of natural gas in this locality, Messrs. Chinoy & Co. of Bombay, in the hope of striking gas, sunk another bore in 1935 near Sonaria tank, about  $1\frac{1}{4}$  miles to the west of the old bore. Although gas was obtained at 841-845 feet and 957-960 feet, the quantity was



|   | 1 | 2   | 3    | 4    | 5 | 6 |
|---|---|-----|------|------|---|---|
| B.T.U. per cubic<br>foot (calcu-<br>lated) .. | ? | 870 | 857  | 837  | ? | ? |
| Specific<br>gravity ..                        | ? | ?   | 0.58 | 0.63 | ? | ? |

Sample 1, from Gogha bore-hole No. 3, was evidently contaminated by air at the time of collection; it was collected by Rao Bahadur M. Vinayak Rao and analysed by Professor C. Forrester, Indian School of Mines, Dhanbad.

Sample 2, from Gogha bore-hole No. 3, was collected and analysed by Dr. M. S. Patel, Industrial Chemist, Bombay Government.

Samples 3 and 4, from Gogha bore-hole No. 4, were collected and analysed by Mr. A. L. Chandavarkar on behalf of Messrs. Chinoy & Co.

Samples 5 and 6, from Jagatia wells, were analysed by Dr. H. E. Watson, Indian Institute of Science, Bangalore.

#### FUTURE

The presence of natural gas from bores in Baroda and Broach has been also established long ago. The discovery of gas fields at widely separated places on both sides of the Gulf of Cambay is of considerable importance, but as noted by previous observers, the gas cannot be considered as an indication of oil. The origin of the gas is attributed to buried organic remains in the Gaj sediments in the Gulf. On both sides of the Gulf new occurrences of gas may come to light in future.

The quantities of gas and pressure in Kodinar, Baroda (1) and Broach (7) are stated to be not sufficient to warrant any economic exploitation, possibly due to patchy distribution of gas sand as envisaged by Dr. Ghosh. There is evidently a concealed gas field of an appreciable extent at Gogha, where gas is still escaping undiminished. The field is believed to be 12 square miles in extent, but our knowledge in general with regard to the gas-content of the Tertiaries in Saurashtra and Gujerat cannot be increased without a programme of bore-hole sinking. The gas has no commercial

possibility as a fuel at Gogha, but may find a use as a source of carbon black. According to Dr. Watson, Indian Institute of Science, Bangalore, the helium content in a gas sample from the bore-hole at Gogha is of the order of 8 in 1,000 — too low a figure to be of any commercial importance.

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## CHAPTER XXX

### OIL

#### GENERAL

The origin of oil is attributed to organic matters buried in marine sediments or fresh water beds converted into natural hydrocarbons, which migrated into rocks of high porosity and permeability, and trapped or accumulated in the form of oil pools under certain structural conditions. Tertiary rocks form the principal source of oil, although formations ranging from Cambrian to Pliocene are also known to contain it to some extent.

Oil is recovered by drill holes up to 10,000 feet in exceptional cases and processed into gasoline, kerosene, fuel oil, etc., and other associated products like lubricants, asphalt, coke, wax, etc.

Assam is the only oil-producing centre in India. Oil bearing geological formations are also known to occur in Tripura, Kutch, Saurashtra, and along the foot-hills of the Himalayas, but so far no sources have been located in such areas. The Indian oil bearing source is Tertiary in age. Normally Indian output amounts to roughly 10 per cent. of her requirements, and the rest is met by foreign imports.

#### FUTURE

The presence of natural oil in the Deccan traps is highly improbable. The underlying Jurassics are also not likely to yield oil. The only chance of striking oil in the State is in parts of the coastal areas consisting of Tertiary rocks. The Geological Survey from time to time investigated the areas on opposite sides of the Gulf of Cambay in view of the occurrences of natural gas in Baroda, Kodinar, Gogha and Ankleshwar, but came to the conclusion that the gas cannot be considered as an indication of oil (see Chapter XXIX). It was further held that no evidence of structures for accumulation of oil was forthcoming. It is presumed that this view is also shared by Mr. R. Morrison, a geologist of the Burma Oil Company, who visited all localities yielding gas in 1933. The fact that the Burma Oil Company has not shown any interest in the area since Mr. Morrison's visit is significant.

During field season 1948-49, Mr. M. C. Poddar (1) made a rapid reconnaissance of the Tertiary beds in the Okhamandal area, Amreli district, with a view to studying the possibilities of the existence of natural oil. No direct indication of oil or gas is reported. The thickness of the Tertiaries is unknown due to almost horizontal disposition of the beds, but from the deep bore-hole records at Adatra (Okha port), it appears that the Tertiary beds overlying the traps in that region are only about 995 feet in thickness. From the above evidences, Mr. Poddar concluded that the Tertiaries of Okhamandal offer indifferent prospect for oil.

In recent years the Geophysical parties of the Geological Survey have commenced reconnaissance surveys by magnetic and gravity methods, in parts of the alluvial plains of Gujerat and Saurashtra, with a view to determining geological structures appertaining to the oil possibilities, and their results will be watched with interest.

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## CHAPTER XXXI

### REFRACTORY MATERIALS

#### GENERAL

The term refractory in a wider sense represents a material which has heat-resisting qualities. A refractory material withstands a temperature of 1,400°C. - 1,600°C. without fusing, resists chemical action with the materials being melted and does not spall under changes of temperature. The manufactured products are in the form of bricks and other standard or special shapes, e.g., retorts, muffles, tiles, crucibles, glass pots, saggars, etc. Refractory linings are needed in smelting ores, refining metals, making alloys, kilns, coke ovens, glass furnaces, etc. The refractory materials include china-clays, fire-clays, bauxite, chromite, magnesite, steatite, dolomite, silica, feldspar, kyanite, sillimanite and graphite. In Saurashtra only fire-clays, bauxite and silica (quartz, sand and sandstone) are present.

#### BAUXITE

The resources of aluminous laterite or bauxite in Saurashtra are detailed in Chapter XI. At present Bihar produces a limited amount of bauxite bricks.

#### FELSPAR

The occurrences of feldspar in Saurashtra have been dealt with in Chapter XXXIII.

#### FIRE-CLAYS

Fire-clays are the principal source on which a refractory and ceramic industry is based. The occurrences of such clays have been described in Chapter XV.

#### QUARTZ

Cherty quartz veins, associated with secondary silica, such as chalcedony, agate, jasper, etc., are not uncommon in the Deccan



traps. In view of their general impurity and owing to the availability of pure vein quartz from Ajmer and Bombay States, they are not likely to be utilised in the near future.

#### SAND

There is inexhaustible source of silica in the State in the form of ordinary river sand and coastal dune sand. Only the purer materials would be suitable for refractory purposes. The occurrence of moulding sand is described in Chapter XXVIII.

#### SANDSTONE

The soft, friable sandstones of the purer variety of Jurassic rocks (Umias) will yield large quantities of good materials. Some of the known localities are detailed in Chapter XIX, but further detailed examination for selection of materials for specific purposes will have to be undertaken.

#### FUTURE

At present a large ceramic industry has been built up in Saurashtra utilising the local source of fire-clays. The refractory goods find a ready market in the adjacent States. The resources of the State appear to be considerable, and it is hoped that in the future the industry will not only expand but will also export manufactured refractory goods. With the availability of cheap power, a variety of materials could be economically mined, crushed and converted into refractory goods in a number of suitable places.

## CHAPTER XXXII

### SALT

#### GENERAL

The Indian output is chiefly recovered from sea water along the coasts of Bombay, Saurashtra, Madras and Orissa. The salt lakes in Rajasthan and the sub-soil brine in the Rann of Kutch contribute nearly a third of the Indian production. Small quantities are obtained from West Bengal, Bihar, U.P. and Himachal Pradesh. With the various salt projects of the Government, India should be self-sufficient in the near future, the present import into this country being about 10 to 15 per cent. of her needs.

#### USES

In addition to its necessity in food, common salt plays an important role in the chemical industry, in the manufacture of a long range of compounds like sodium nitrate, salt cake, caustic soda and soda ash. Salt is also the raw material for the manufacture of hydrochloric acid. At present only a small fraction of the Indian output is utilised for industries.

#### PRODUCTION CENTRES

Most of the Saurashtra salt production is by the direct solar evaporation of sea water at a number of private owned factories. An appreciable quantity of salt is derived from subterranean brine in the Little Rann of Kutch. The following are the important salt producers in the Kathiawar peninsula:—

- |  |                               |
|--|-------------------------------|
| (1) Maharaja Salt Works Co. Ltd., Lavanpur.  | } Madhya Saurashtra district. |
| (2) Maharaja Salt Works Co. Ltd., Varsamedi. |                               |
| (3) Bharat Salt Works, Venasar.              |                               |
| (4) Maliya Salt Works, Maliya.               |                               |

- |   |   |                    |
|---|---|--------------------|
| (5) Digvijay Salt Works, Ltd., Jamnagar.                    | } | Halar district.    |
| (6) Halar Salt & Chemical Works, Jamnagar.                  |   |                    |
| (7) Nawanagar Salt & Chemical Works, Salaya.                |   |                    |
| (8) Nawanagar Salt & Chemical Industries, Jodiya.           |   |                    |
| (9) Salt and Allied Industries, Jamnagar.                   |   |                    |
| (10) Prabhat Salt Works Co., Jhinjhuda.                     |   |                    |
| (11) Jaylakshmi Salt Works, Ltd., Nagna.                    |   |                    |
| (12) Saurashtra Salt Manufacturing Co., Porbandar.          | } | Sorath district.   |
| (13) Saurashtra Chemical Co., Mangrol.                      |   |                    |
| (14) Junagadh Salt & Allied Chemical Works, Jafrabad.       | } | Gohilwad district. |
| (15) Kathiawar Industries Ltd., Jafrabad.                   |   |                    |
| (16) Bhavnagar Salt & Industrial Works Ltd., Bhavnagar.     |   |                    |
| (17) Khuda Salt Works, Khuda.                               | } | Zalawad district.  |
| (18) Mahalaxmi Salt Works, Khuda.                           |   |                    |
| (19) Gandhi Salt Works, Jesda.                              |   |                    |
| (20) Bajana Salt Producers Co-operative Society, Bajana.    |   |                    |
| (21) Dehgam Agaria Sahakari Mandali Ltd., Jesda.            |   |                    |
| (22) Ambika Salt Manufacturing Co-operative Society, Jesda. |   |                    |
| (23) Tata Chemicals Ltd., Mithapur, Amreli (Bombay).        |   |                    |
| (24) Kharaghoda Salt Works, Kharaghoda, Ahmedabad (Bombay). |   |                    |

#### KHARAGHODA SALT WORKS

Dr. M. R. Sahni (2) visited Kharaghoda salt works in 1943-44, and pointed out the necessity of preparing a detailed plan of the area and maintaining proper records of well sections and other data.

During subsequent field seasons Dr. B. C. Roy (3 & 4) inspected the work of the Survey party carrying out a survey of the Kharaghoda salt works, and recommended a number of experimental bores to ascertain the chances of obtaining good brine at moderate depths.

Brine of average density 17° Beaume occurs in lenticular sand patches at different levels within 15-40 feet from the surface and is tapped by sinking several hundreds of new wells or opening the older ones. The works comprise a N. W.-S. E. strip of Rann, about ten miles long and five miles wide. There is a great variation in the succession of strata in the wells, even in immediately adjacent areas. A general geological profile of the brine wells is given below:—

|                                 |    |    |    |            |
|---------------------------------|----|----|----|------------|
| Fine, fresh water silt          | .. | .. | .. | 3- 4 feet. |
| Bluish grey clay                | .. | .. | .. | 5-10 feet. |
| Brown sandy clay                | .. | .. | .. | 2- 6 feet. |
| Plastic bluish clay with gypsum | .. | .. | .. | 2-10 feet. |
| Dry sand                        | .. | .. | .. | 2- 6 feet. |
| Coarse, gritty sand, with brine | .. | .. | .. | 2- 6 feet. |

Dr. Roy further examined the following proposed alternatives for obtaining the brine, in preference to the present well and bucket arrangements:—

- (1) Working mobile pumps for drawing brine from groups of wells.
- (2) Sinking of tube wells.
- (3) Laying subterranean perforated pipes connected to a central pumping station.
- (4) Constructing percolation canals converging to a central pumping station.

The proposal for drawing brine from groups of wells by working mobile pumps is not recommended. The poor capacity of the wells, yielding 0.01 to 0.02 cusecs, is not favourable for uniform working with the aid of mechanically driven pumps. The use of hand operated pumps will be efficient and economical.

With a view to tapping all brine horizons at a shallow depth excavation up to a depth of 40 feet would be necessary for the construction of the proposed canals. The cost of construction and maintenance of a system of canals will be highly prohibitive. Besides, the underground currents of brine would be too feeble to feed the canals, and there is a possibility of the brine being weakened by sweet ground water.

The laying out of subterranean perforated pipes will not be a feasible or economical proposition in view of the marked irregularities of the brine horizons. Excavation up to a depth of some 40 feet and provision for pipe lines over long distances would be needed. Dilution of good brine with weak brine or sweet water currents is inevitable.

The most efficient and economical proposition for improving the methods would eventually be the sinking of hand operated tube wells, with provision for some mechanisation in case of those with fairly copious yield, and the construction of suitable permanent wells throughout the salt works. Sinking of one dozen tubewells and one dozen permanent wells is recommended as test measures. The possibilities of wind mills for lifting brine might be investigated.

The areas showing brine of weak, medium and high densities have been approximately delineated on a plan by Dr. Roy, and it is suggested that the future working should be normally restricted to areas yielding good brine.

#### KHUDA SALT WORKS

The geological formations at Khuda and the method of working of the brine wells there are essentially the same as that of Kharaghoda, but the brine at the former locality is usually tapped at a much shallower depth, the average density of the brine ranging between 12°B to 20°B. This is due to the fact that Khuda is much nearer to the sea than Kharaghoda. In fact the sea actually penetrates each year up to Khuda. The salt manufactured at Khuda, however, is said to be of much inferior type to Kharaghoda, due to lack of proper supervision. The Khuda area is said to be producing about 50,000 tons of salt annually during recent years; each year the salt works on an average work 300 wells and 225 pans.

*Average analyses of Kharaghoda and Khuda brines  
and comparison with sea brine.*

(After K. H. Vakil)

|                       | Rann brine       |                  | Sea brine        |
|-----------------------|------------------|------------------|------------------|
|                       | Kharaghoda       | Khuda            |                  |
|                       | <i>Per cent.</i> | <i>Per cent.</i> | <i>Per cent.</i> |
| Calcium carbonate ..  | 0.012            | 0.016            | 0.0221           |
| Calcium sulphate ..   | 0.440            | 0.421            | 17.4649          |
| Sodium chloride ..    | 14.668           | 16.038           | 17.2666          |
| Magnesium sulphate .. | 0.486            | 0.510            | 1.6016           |
| Potassium chloride .. | 0.414            | 0.275            | 0.4569           |
| Calcium chloride ..   | -                | -                | 0.0427           |
| Magnesium chloride .. | 4.636            | 4.647            | 1.9432           |
| Magnesium bromide ..  | 0.072            | 0.057            | 0.1836           |
| Total solids ..       | 20.728           | 21.964           | 21.9816          |
| Sp. gravity ..        | 1.167            | 1.173            | 1.161            |
| Degrees Beaume ..     | 20.5             | 21.3             | 20.0             |

#### FUTURE

The lines on which the future working of brine in Kharaghoda should be carried out have been indicated. The Khuda salt works or any other works depending on subterranean brine in the Rann areas could profitably follow the lines suggested in case of Kharaghoda.

Apart from the scope of further production of common salt from the coastal areas of Saurashtra, there is also considerable prospect of setting up of new alkali industries within the State, with a view to manufacturing soda ash, caustic soda, chlorine, bleaching powder, etc. The chief requirements which are needed in plenty are coal and cheap electrical energy. Recovery of such by-products like potassium chloride, magnesium chloride, etc., could be made from the bitterns available in the manufacture of salt by solar evaporation. Limestone suitable for the manufacture of bleaching powder and calcium chloride is available from the coastal areas of Saurashtra or elsewhere within the State. The new industry would possibly be located along the coast, e.g., at Jamnagar, Porbandar, Veraval, Jafrabad, etc.

In Saurashtra at present there are two important concerns manufacturing alkalies, i.e., the Tata's Mithapur (Okha) Works and Dhrangadhra Chemical Works. Besides, Messrs. Pioneer Magnesia Works Ltd., at Kharaghoda, manufacture magnesium chloride, magnesium sulphate, potassium chloride, etc., from the bitterns of salt works. They also manufacture calcium chloride by the process of interaction between lime and magnesium chloride or bitterns rich in magnesium chloride. The bitterns rich in sulphates may be eventually considered as a possible source of sulphur in India.

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## CHAPTER XXXIII

### MINERALS OF LITTLE OR NO VALUE

#### ALKALI SALTS

##### GENERAL

The saline efflorescence known as *reh*, so common in the soil in the drier parts of the Indian peninsula, is an important source of indigenous carbonate of soda. It is a mixture of sodium carbonate, sodium sulphate and sodium chloride. It is principally recovered in Bihar, U.P. and the East Punjab. The Indian output has averaged roughly 8,000 tons per year for many years. The material is used in making soap or as a fertilizer if containing nitre.

##### DISTRIBUTION

According to E. H. Adye (1), efflorescent alkaline salt or *reh* is present in limited quantity near Timbri,  $4\frac{1}{2}$  miles E.N.E. of Latipur, in Nawanagar.

Mr. S. Krishnaswamy (2) reports thin layers of *reh* soil on the salt pans and along some *nalas* in coastal areas of Junagadh, where it is at times collected for use as washing soda. The following localities are mentioned:—

- (1) Near Balanivav ( $20^{\circ}57' : 71^{\circ}24'$ ).
- (2) Between Nagesri and Mitiala.
- (3) Between Nanawara and Chikhli.
- (4) Near Bherai bunder ( $20^{\circ}58' 30'' : 71^{\circ}33'$ ).

Alkali salts are said to occur in the Sihor *taluk* and Valbhipur *mahal* in the Gohilwad district, at Bajana in the Zalawad district, and in Jodiya in the Halar district.

##### FUTURE

The deposits of alkali salts occur in limited amounts in parts of Saurashtra and are used for local use. No large scale industry is visualised.



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## BORAX

La Touche (1) referred to a reported occurrence of borax which was being won from the soil at some locality "four days' journey distant" from the vicinity of Limbdi ( $22^{\circ}34' : 71^{\circ}52'$ ), for export to Bombay.

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## COPPER-ORE

## GENERAL

The principal sulphide ores are chalcopyrite ( $\text{CuFeS}_2$ ), bornite ( $\text{Cu}_5\text{FeS}_4$ ), chalcocite ( $\text{Cu}_2\text{S}$ ) and covellite ( $\text{CuS}$ ). The oxidised ores comprise cuprite ( $\text{Cu}_2\text{O}$ ), tenorite ( $\text{CuO}$ ), malachite [ $\text{CuCO}_3, \text{Cu}(\text{OH})_2$ ], azurite [ $2\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2$ ] and chrysocolla ( $\text{CuSiO}_3, 2\text{H}_2\text{O}$ ). Copper is also sometimes present in native form in volcanic rocks. The copper-ore deposits found as lenses, veins or disseminations in igneous rocks constitute the world's chief source. A thin but extensive cupriferous black shale, containing 2-3 per cent. copper, has been worked in Mansfeld in Germany.

Occurrences of copper-ore are known in many parts of India, but with the exception of the Singhbhum deposits in Bihar, none has yet been proved to be of any economic significance. The Singhbhum copper bearing belt is about 80 miles in length and the mines are being worked by the Indian Copper Corporation Ltd., whose outputs of refined copper in recent years have been roughly 6,000 tons annually.

## DISTRIBUTION

La Touche (1) refers to an occurrence of copper-ore reported in the hills running south from Bhudli (?), and near Nawanagar ( $22^{\circ}28' : 70^{\circ}8'$ ).

Dr. H. Crookshank (2) noticed some trifle films of native copper in the trap debris from a new well south of Beh, 13 miles north-west of Khambalia in Nawanagar. He suggested a small expenditure on dewatering the well and prospecting, although conceding that the deposit might turn out to be an insignificant one.

Recently Dr. B. C. Roy (3 & 4) examined a reported occurrence of copper-ore at Moj dam. The 1,500-foot long excavations for the foundation of the dam, two miles south-east of Bhaivadar Railway Station, have exposed in the river bed the following section in descending order:—

|  |    |    |          |
|--|----|----|----------|
| Compact, green & bedded lava                   | .. | .. | 5' - 10' |
| Red, amygdaloidal lava, with<br>tuff & breccia | .. | .. | 5' - 8'  |
| Compact, reddish lava                          | .. | .. | 5' - 8'  |

The left and right abutments show a capping of miliolite limestone and sandstone, 16-20 feet thick. With the exception of the uppermost lava bed, the lower lava beds show sporadic but fairly abundant, small disseminations of filiform and platy native copper, rarely a few inches long or across, along joints and fissures (stained green due to chlorophaeite), in minor calcite veins, in infillings of various types of zeolites, and as replacements in tuff and breccia. It has been derived from localised hydrothermal solutions in the lavas by some reducing agent. The deposit bears a close analogy with similar occurrences of the world, and is only of mineralogical interest. A sample of native copper on analysis showed 95 per cent. of copper.

It is reported that the soil overlying the trap hills just south of Chogat ( $21^{\circ}50' : 71^{\circ}52'$ ), 12 miles from Sihor, contains 2 to 12 per cent. of copper. Dr. Roy (3) reports, however, that apart from some green stains and dark dendritic marking along the joints in a light grey, highly fissured trap, no trace of copper-ore was seen.

## FUTURE

Native copper is easily separable from the associated trap rock, and is economically mined in the U.S.A., where the ore containing one per cent. of metal in the rock is considered exploitable. The large scale excavations at the Moj dam-site have definitely proved that the native copper deposit has no economic significance. This remark probably applies also to the occurrence at Nawanager.

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## FELSPAR

## GENERAL

Although the feldspars form nearly 50 per cent. of igneous rocks, the commercial source is entirely drawn from the pegmatites in the mica belts of Bihar, Nellore, Rajasthan and Ajmer-Merwara. Chemically, they represent a series of aluminosilicates containing essentially potash, soda or lime. They are commonly white or pink, but green varieties also occur. Their specific gravities range from 2.56 to 2.76.

Felspar is mostly used in ceramics and glass industries to supply the desired alumina and alkali. Minor quantities are also needed in enamels. Both potash and soda feldspars are utilised, but the lime

rich felspars are undesirable. The mineral is crushed and ground before use.

The price of felspar is nowadays Rs. 30/- per ton, *f.o.r.* loading Station.

#### DISTRIBUTION

##### *Junagadh*

Mr. J. M. Master (1) noted felspar porphyry dykes near Tulsi Sham ( $21^{\circ}3' : 71^{\circ}5'$ ) and north of Goraori ( $21^{\circ}0' : 71^{\circ}2'$ ) in the Gir forest. They contain lath shaped or tabular orthoclase felspars embedded in a fine groundmass.

Mr. S. Krishnaswamy (2) recorded a small deposit of feldspathic syenite in the Kalichippri area, about a mile and a half W.S.W. of Goraknath peak ( $\Delta$  3,666). According to him, this would possibly yield enough felspar to be utilised in a small scale ceramic industry. Similar syenites are available between Malbela and Surajkhund (outer eastern Girnar valley) and also from parts of the Girnar massif and its western low spurs.

#### FUTURE

Although the resources of felspar in other parts of India are practically inexhaustible, being recoverable as a by-product in mica mining, no economically workable deposits are present in Saurashtra. The requirements of the ceramic concerns within the State are usually obtained from Ajmer-Merwara. The extraction of felspar from the feldspathic syenites and felspar porphyries in Junagadh is not likely to be a commercial proposition as the material could be had cheaply from the neighbouring States of Ajmer-Merwara, Rajasthan or Bombay.

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## ILMENITE

## GENERAL

Ilmenite is a titanium bearing iron-ore, containing up to 32 per cent. titanium. Titanium metal is an important alloying element. Ilmenite, however, is chiefly used in the manufacture of titanium dioxide - a perfect white paint with great opacity, covering power and resistance to corrosion.

The principal ilmenite deposit of India, indeed the world's largest source, is in the coastal sands of Travancore, from near Quilon to Cape Comorin and eastwards, a distance of nearly 100 miles. The reserves are calculated at 200 million tons. The Indian export, mainly to the U.S.A. and United Kingdom, is roughly estimated at 200,000 tons a year. Workable deposits have been recently located in the coastal areas of Ratnagiri in Bombay State.

The principal firms working the South Indian deposits, as agents to the Government of Travancore-Cochin, are (1) Messrs. F. X. Pereira & Sons Ltd., (2) The Associated Minerals Co. Ltd., (3) The Travancore Minerals Co. Ltd., and (4) Messrs. Hopkin and Williams Ltd. The beach sand is reported to contain 70 per cent. of ilmenite. The sand is treated for the separation of associated minerals like zircon, monazite, rutile, garnet, etc. Monazite is a phosphate of rare earths of the cerium group and is a raw material for the preparation of thorium nitrate, used in the gas mantle industry. It is one of the most important minerals used in the production of atomic energy. The recovery of monazite as a by-product is a most valuable adjunct to the ilmenite exploration.

With the setting up of a new factory in Travancore for the manufacture of titanium dioxide, the Indian materials will be consumed in the country, although some exports could be made for years to come.

The value of ilmenite from Travancore in 1949 was Rs. 15-6-0 per ton, but the material from Ratnagiri is being exported to Japan at a basic price of Rs. 55/- per ton *f.o.b.* port.

## DISTRIBUTION

Fedden (1) refers to a black sand consisting probably of magnetite and ilmenite derived from the traps, in two or three places on

the coast south of Gopnath Point, south-east of the Kathiawar peninsula.

Adye (2) records the presence of magnetite and ilmenite in the black sea sands near Ghandhri, Pindara and other localities in Nawanagar. They are also reported in minor amounts from the beds of Bari *vokala*, 1½ miles N.N.W. of Morpur in the Barda hills, and at Kund Jhar, ½ mile S.S.W. of Ghandhri.

#### FUTURE

So far no large deposits of ilmenite have been reported from Saurashtra, but a systematic search in the coastal areas might be profitably carried out. The recent discovery of large ilmenite deposits in the coastal sands of Ratnagiri, where the traps are very common as in Saurashtra, is very significant. As in Ratnagiri, monazite, zircon, etc., however, are not anticipated. As Saurashtra is principally constituted of the Deccan traps containing minute ilmenite crystals, their weathering and disintegration must have dislodged the ilmenite grains and deposited them along river courses and coastal areas.

#### BIBLIOGRAPHY

- |                 |   |
|-----------------|---|
| (1) Fedden, F., | The geology of the Kathiawar peninsula in Guzerat, <i>Mem. Geol. Surv. Ind.</i> , Vol. XXI, Pt. 2, p. 61, 1884. |
| (2) Adye, E.H., | Economic geology of Nawanagar State, p. 109, 1914.  |

#### MAGNESITE

##### GENERAL

Magnesite ( $MgCO_3$ ) is white, grey or yellow in colour, and has a specific gravity of 2.9 to 3. It has a hardness of about 4 on the Moh's scale of hardness.

The chief uses of magnesite after calcination are for refractory bricks and cements. It is also a raw material for the extraction of metallic magnesium and for the preparation of magnesium compounds.

The Indian deposits are rich and sufficient for her own needs as well as for some export, the important producing centres being in Mysore and Madras. Roughly 75 per cent. of India's output is utilised in the manufacture of refractory bricks, whereas the rest is exported.

#### DISTRIBUTION

Magnetite was reported from the laterite formation near Bhatia in Nawanagar State, but Dr. H. Crookshank (1) who recently searched for it could not find any such deposit in the locality. If present in large quantities, it would be valuable for the existing ceramic works in Saurashtra.

#### BIBLIOGRAPHY

- (1) Crookshank, H., Note on the economic geology of Nawanagar State; (unpublished).

#### MAGNETITE

##### GENERAL

Magnetite ( $\text{Fe}_3\text{O}_4$ ) is an important accessory constituent in the Deccan traps, and occurs as minute crystals discernible under the microscope. Other igneous and metalliferous rocks also contain small amounts of the mineral. When occurring in association with magnetite-quartzites in considerable quantities, the ore may be useful as a source of iron-ore. Magnetite grains are sometimes used as a substitute for "emery" as abrasives.

#### DISTRIBUTION

Fedden (1) records the presence of a black sand consisting mostly of magnetic iron-ore (magnetite?) derived from the traps in two or three localities on the shore south of Gopnath Point, south-east of the Kathiawar peninsula.

Adye (2) noted magnetite and ilmenite in the black sea sands near Ghandhri, Pindara and other localities in Nawanagar. They are also reported in minor amounts from the beds of Bari *vokala*,  $1\frac{1}{2}$  miles N.N.W. of Morpur in the Barda hills, and at Kund Jhar,  $\frac{1}{2}$  mile S.S.W. of Ghandhri.

Adye (3) also reported magnetic iron-ore segregations in the granophyre of Babia Dungan in Porbandar, and suggested that they

might be profitably crushed for iron-smelting, using the residue in pottery.

An unpublished report of Dr. Evans (1896) refers to a deposit of titaniferous magnetite to the south-west of Bawaka Madhi temple, in northern Girnar valley, on the south-east side of a *nala* flowing by that temple. According to Mr. S. Krishnaswamy (4), who re-examined this occurrence recently, the deposit is not so rich as was believed to be, whereas another locality found by him to the south of Kohlibeda hill in Husnapur (north Girnar) valley is stated to be relatively richer, though not exploitable on a commercial scale. Here he found pebbles and boulders of titaniferous magnetite, possibly the products of segregation from a magnetite-rich basaltic magma, on hill slopes and in valleys of small *nalas*.

#### FUTURE

No large deposits of magnetite sand have come to light in Saurashtra so far, but careful search in the coastal areas of the State might lead to associated ilmenite, particularly in view of the recent discovery of extensive deposits of ilmenite in the coastal sands in the Ratnagiri district in Bombay. (5).

#### BIBLIOGRAPHY

- (1) Fedden, F., The Geology of the Kathiawar peninsula in Guzerat, *Mem. Geol. Surv. Ind.*, Vol. XXI, Pt. 2, p. 61, 1884.
- (2) Adye, E. H., Economic geology of Nawanagar State, p. 109, 1914.
- (3) Adye, E. H., Economic geology of the Porbandar State, p. 110, 1917.
- (4) Krishnaswamy, S., Progress Report for 1943-44; (unpublished).
- (5) Roy, B. C., Mineral resources of Bombay, pp. 71-74, 1951.

#### MANGANESE-ORE

The laterites in Saurashtra at times show some quantities of manganese in a sporadic fashion, but nowhere the concentration is sufficient enough to warrant any mining operations.



Recently an unofficial report in the form of a letter, from a gentleman in the U.S.A. to the Hon'ble Prime Minister of India, referred to a very rich deposit of manganese-ore within a foot of the surface in the dry sea bed north of Dhrangadhra. Mr. C. Karunakaran (1) investigated the alleged occurrence by making several traverses. There are nearly 2,000 shallow brine wells in this area which facilitated a detailed examination of the sub-surface strata. No trace of manganese minerals was found. Records of past geological surveys in this area also do not contain any mention of manganese-ore in the Little Rann of Kutch.

#### BIBLIOGRAPHY

- (1) Karunakaran C., Investigation of an alleged occurrence of manganese-ore in the dry sea bed north of Dhrangadhra, November 1952; (unpublished).

#### PYRITE

A sample of a soft powdery material, recovered from certain new wells at Kotada ( $22^{\circ}19' : 71^{\circ}24'$ ) and Nadala ( $22^{\circ}20' : 71^{\circ}28'$ ) in the Sayla taluk, Zalawad district, was recently examined in the Geological Survey laboratory. It was identified as a calcareous clay or marl, containing pyrite (up to 0.1 mm. in size), calcite, chlorite and limonite. The sample on analysis showed total sulphur content as sulphide to be 8.27 per cent. and sulphur as sulphate in traces.

The pyrite bearing samples were analysed at the Directorate of Industries, Government of Saurashtra, with the following results:—

|   | Kotada.<br>Per cent. | Nadala.<br>Per cent. |
|---|----------------------|----------------------|
| Insolubles .. .. .  | 37.90                | 9.35                 |
| Fe <sub>2</sub> O <sub>3</sub> & Al <sub>2</sub> O <sub>3</sub> .. .. . | 17.25                | 39.50                |
| CaO .. .. .   | 20.96                | 24.50                |
| MgO .. .. .   | 2.00                 | 1.70                 |
| SO <sub>3</sub> .. .. .   | 0.50                 | 0.70                 |
| SnO <sub>2</sub> .. .. .  | 0.50                 | 0.50                 |
| Alkalies .. .. .  | n.d.                 | n.d.                 |

The material represents altered trap, judging from the localities and other samples. The associated pyrite has no economic significance. The presence of a minute quantity of  $\text{SnO}_2$ , as recorded in the analysis at the Directorate of Industries, seems doubtful (1).

#### BIBLIOGRAPHY

- (1) Roy, B. C., Investigation of economic minerals and rocks in parts of Saurashtra, May 1953; (unpublished).

#### ROCK CRYSTAL

##### GENERAL

In view of the piezo-electric properties, thin slices of properly oriented rock crystals are employed in telephony and telegraphy, and in radio apparatus, for depth measurements in submarines. According to specifications, the crystals should be at least  $4\frac{1}{2}$  inches long and 2 inches in diameter; only untwinned, perfectly transparent crystals, free from flaws, foreign particles and cracks, are required. The general size of the crystals should be such that roughly one cubic inch of good material is obtainable.

##### FUTURE

No suitable crystals have been recorded within Saurashtra. The Deccan traps sometimes show small rock crystals in geodes, but there is always a chance of finding large crystals showing well developed faces in such traps. Future prospecting may yield a small amount of rock crystals of various sizes and grades, but no mining of a payable nature is visualised.

#### WITHERITE

##### GENERAL

Witherite ( $\text{BaCO}_3$ ) is a white, grey or yellow mineral, with a specific gravity of 4.29 to 4.35. It has a hardness of 3-4 on the Moh's scale of hardness.

It is a commercial ore of barium which is used mostly in preparation of chemicals and in a limited quantity in special alloys.

## DISTRIBUTION

Although reported to occur in traps in Nawanagar State, Dr. H. Crookshank (1) was unable to confirm it during his recent investigation. He states that the reported witherite probably represents a zeolite which is known to contain small amounts of barium. Unless occurring in appreciable amounts it would not have any economic significance.

## BIBLIOGRAPHY

- (1) Crookshank, H., Note on the economic geology of Nawanagar State; (unpublished).

## WOLFRAM

Dr. M. R. Sahni (1) examined an alleged occurrence of wolfram nugget in Mangrol State in 1942, but it turned out to be impure iron-ore, mixed with silica and calcite.

## BIBLIOGRAPHY

- (1) Sahni, M.R., Note on the reported occurrence of wolfram in Mangrol State, 1943; (unpublished).

## ZEOLITES

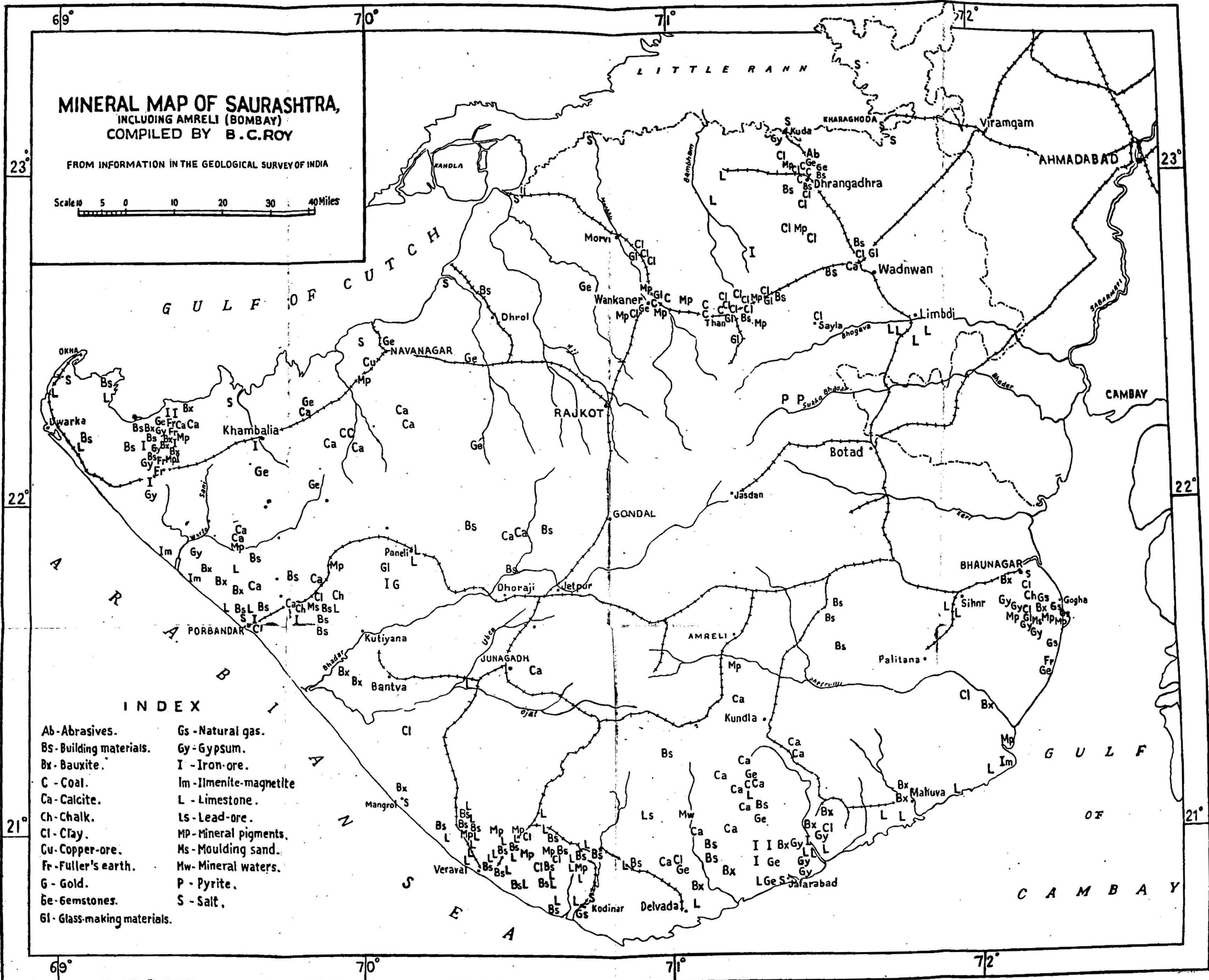
Zeolites are secondary minerals characterised by inferior hardness (3.5 to 5.5 on the Moh's scale), found commonly in veins and cavities in amygdular traps. They are a well defined hydrous silicates of aluminium with sodium, potassium or calcium, rarely containing barium and strontium. Among the varieties so far recognised in Saurashtra are mesolite, stilbite, chabazite, scolecite and natrolite. They do not have any economic importance. They exhibit characteristic phenomena of crystal growth and are thus of interest to the mineralogists as museum specimens. Some are known to have been used as water softener and in Indian medicines.

# MINERAL MAP OF SAURASHTRA, INCLUDING AMRELI (BOMBAY)

COMPILED BY B. C. ROY

FROM INFORMATION IN THE GEOLOGICAL SURVEY OF INDIA

Scale 0 5 10 20 30 40 Miles



## INDEX

- |                              |                         |
|------------------------------|-------------------------|
| Ab - Abrasives.              | Gs - Natural gas.       |
| Bs - Building materials.     | Gy - Gypsum.            |
| Bx - Bauxite.                | I - Iron-ore.           |
| C - Coal.                    | Im - Ilmenite-magnetite |
| Ca - Calcite.                | L - Limestone.          |
| Ch - Chalk.                  | Ls - Lead-ore.          |
| Cl - Clay.                   | Mp - Mineral pigments.  |
| Cu - Copper-ore.             | Ms - Moulding sand.     |
| Fr - Fuller's earth.         | Mw - Mineral waters.    |
| G - Gold.                    | P - Pyrite.             |
| Ge - Gemstones.              | S - Salt.               |
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