

## P R E F A C E.

During the first few years of its tentative existence the Mineral Survey of Kashmir printed none of its reports but was indebted to my old department of the Geological Survey of India for publishing in their *Records* accounts of certain mineral occurrences. Since then five subsequent reports have been printed by order of the Kashmir Government. The present report on the Coalfields of Jammu Province is therefore the sixth of this latter series (see list at end of Preface). Like its predecessors it appears under my name, and the responsibility for its contents and form, and for a great part of the field and other work on which it is based rests with me.

Nevertheless much intrinsic help in map work, pit sinking and drilling, and in determinative (and a certain amount of analytical) work was supplied by my colleagues, Mr. Joti Parshad, B. A., F. G. S., late Senior Assistant Superintendent, and Messrs. Labhu Ram Badyal, M. Sc., and Sohani Ram, B. Sc., Junior Assistant Superintendents. Latterly Mr. L. Zutshi, B. Sc., A. R. S. M., F. G. S., assisted as Mining Engineer in proving the Ber-Goa area. The Industrial Chemist, Srinagar, has contributed nearly all the recent coal analyses, with the exception of a few done by the Geological Survey of India.

The present published account will be followed by others on the metallic and non-metallic minerals, and on the precious and semi-precious gemstones, ornamental stones etc. These, it is hoped, will appear as soon as the material can be put up and passed through the press; so that, before long, the economic minerals of Jammu and Kashmir will be permanently recorded, so far as at present known, for general information.

Subjoined is a list of all the printed reports on Kashmir minerals that have so far appeared since the Mineral Survey started work in 1917 :—

- (1) Note on the Aquamarine mines of Daso on the Braldu R., Shigar Valley, Baltistan, by C. S. Middlemiss and Joti Parshad (published in *Records Geological Survey of India*, Vol. XLIX, pt. 3, 1918 with plates 6 to 10).
- (2) Possible occurrence of Petroleum in Jammu Province :  
Preliminary note on the Nar-Budhan dome of Kotli

tehsil in the Punch Valley, by C. S. Middlemiss  
(published in *Records Geological Survey of India*,  
XLIX, pt. 4, 1919, with plates 13 to 16).

- (3) Lignitic Coalfields in the Karewa formation of the Kashmir Valley, by C. S. Middlemiss (published in *Records Geological Survey of India*, Vol. LV, pt. 3, 1923, with plates 28 to 30).
- (4) Abrasives : Note on the Polishing material of Risin Spur Khunamuh near Srinagar, by C. S. Middlemiss (printed by order of the Kashmir Government, with plates 1 and 2).
- (5) The Graphite deposit of Braripura, Uri tehsil, Kashmir, by C. S. Middlemiss (printed by order of the Kashmir Government, with plates 1 to 5).
- (6) Ochre deposits of Nur Khwah, Rata Sar and Jhuggi in the Jhelum Valley, Uri tehsil, Kashmir, by C. S. Middlemiss (printed by order of the Kashmir Government, with plates 1 to 6).
- (7) The Gypsum deposit of the Lachhipura, Bagna, Islamabad, Limbar and Katha nalas, Uri tehsil, Kashmir, by C. S. Middlemiss (printed by order of the Kashmir Government).
- (8) ~~Bauxite~~ Bauxite deposits of Jammu Province, by C. S. Middlemiss (printed by order of the Kashmir Government, with plates 1 to 17).

C. S. MIDDLEMISS.

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A Resurvey of JAMMU COALFIELDS :  
the KALAKOT, METKA and MAHO-  
GALA fields (with notes on the Chakar,  
Chinkah & the newly discovered Dhansal  
Sawalkot fields) by C. S. MIDDLEMISS,  
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INTRODUCTION.

THE coal of Jammu Province has long been known. Early Investigations : Several geologists and prospectors have examined it from time to time, and its age and position among the other formations are fairly well known. About the year 1900 the attention of the Kashmir Durbar was especially drawn to it, and the outcrops, often hidden by surface material, were opened up at a number of places, preparatory to a conference of geological, mining and engineering specialists which took place in 1903. In 1901 General Raja Sir Amar Singh, K. C. S. I., Commander-in-Chief and Vice-President of the State Council, had taken special interest in this work and he had carried out a tour of inspection of the coalfields and written an enthusiastic diary of it.

Concerning these earlier investigations it is sufficient for present purposes to refer to Mr. R. R. Simpson's published report (*Memoirs, Geological Survey of India, Vol. XXXII, pt. 4, 1904*).

Mr. Simpson was at that time Mining Specialist in the Geological Survey of India; and after enquiries and conferences on the spot with Mr. R. D. Oldham, Superintendent of the Geological Survey, and Mr. E. L. Hope, Manager of the North-Western Railway Company's collieries at Dandot; and after several months spent later in examining the Jammu coalfields, assisted by Messrs.

Mr. R. R. Simpson's  
report, 1904.

Godwin and Stewart (who carried out the prospecting operations), he compiled a full report of his results in the above-mentioned publication. This has remained the standard account of work done on the coalfields up to the recent re-examination by the Mineral Survey.

Unfortunately the volume of the *Memoirs* containing Simpson's account is now out of print. A summary of his conclusions is, therefore, given here, and further details referring to the resurveyed areas will be liberally quoted in subsequent sections of this report.

The coal areas included by R. R. Simpson in his report are practically coincident with those which I have shown on the outline map (See Pl. 7 ) with the exception of the Dhansal-Sawalkot continuation of the Lodhra coalfield, which is a new addition, discovered in 1924 by the Mineral Survey.

Mr. Simpson, for field purposes, worked on the old topographical sheets of the Atlas of India, on a scale of 1 inch to 4 miles, enlarged twice ; and on one small plan of the Jangal Gali workings on a scale of 1 inch to 800 feet, showing the excavations, shafts and drives made by Messrs. Godwin and Stewart.

His most detailed results refer to the Jangal Gali and Anji Valley areas, lying to the east of Riasi, the two being grouped together under the head of the Ladda coalfield. This he concluded to be the most promising locality, because (1) the continuation of the coal underground had been proved to a considerable extent, (2) it was, in its southern part, the nearest coalfield to Jammu, along a line *viâ* Mutal and Tikhri, (3) in its northern part (Anji Valley) it was convenient to Riasi *viâ* the Anji Valley, and (4) chemical analyses and practical trials of the coal on the railway had been made with good results.

The rest of the area of the Jammu coalfields was described more cursorily by Mr. Simpson, the remaining areas.

results quoted in his memoir being partly derived from Mr. T. D. LaTouche's published work in the Chakar and Sangarmarg fields (See *Rec. Geol. Surv. of India*, Vol. XXI, pt. 2, 1888, now out of print) and partly from his (Mr. Simpson's) observations and examination of the pits and shafts made by Godwin and Stewart.

As a whole, this monograph by Simpson showed (what Mr. Simpson's conclusions. was for this part of India) a reasonably good supply of available coal of good quality, but it was not made clear that extracting it for use on the North-Western Railway, or for the projected railway to Kashmir, would be a sound commercial proposition.

After some criticisms in detail and a few experiments with briquetting the coal, made subsequent to the above report, the matter was allowed to drop and no further action was taken by the Durbar. When the reorganised Mineral Survey under my direction began work in 1917, I had to accept this general verdict on the coal of Jammu; and, in any case, I saw that our knowledge in regard to this mineral was fairly complete, compared with that of other minerals demanding early attention, and could not be improved on with advantage at that time.

During recent years, however, discoveries by the Mineral Survey of ores of aluminium, followed (Renewed interest in the coal. very recently by those of copper, zinc and lead (in addition to those of iron already known to some extent), have caused me to regard the coal of Jammu from a new point of view; because, for the development of these ores, coal will naturally be a great asset in the processes of roasting, smelting and reduction, as well as possibly for power at the mines and for transportation purposes. It seemed advisable, therefore, to begin a fresh survey of the coalfields in greater detail than hitherto, so as to know our coal resources better and more quantitatively. Incidentally also it might be found that proposals for working the coal which in 1904 did not recommend themselves to Mr. Simpson as being commercially sound, might, on revision in the light of the above new facts, appear



more promising. This aspect of the question has already been partly discussed by Mr. A. T. Arnall in his Memorandum on the "Jammu Bauxite, Coalfields and Manufacture of Alumina and Aluminium" (August 1923).

Hence a serious beginning was at last made in 1926 of the resurvey of these areas, and it is being continued from time to time by the Mineral Survey as opportunity offers.

This report aims principally at elucidating the less well-known area west of the Chenab River, and especially the three connected coalfields of Kalakot, Metka and Mahogala. Apart from these three latter well-defined areas, much large-scale work yet requires to be done, before the resurvey of the whole of the Jammu coalfields can be regarded as accomplished. The present time however, (when we are engaged in taking stock of our recent mineral discoveries and publishing the results) is propitious for compiling this report, which in the main amounts to a recasting of our views about the potentialities of these western coal areas based primarily on the entirely new large-scale maps that my survey has produced, and on the excavations and drilling that we have done. The Chakar, Chinkah and Dhansal-Sawalkot fields will only be briefly described.

It is hoped that this resurvey will be followed up by detailed and extensive proving of the coal seams by underground work and deep drilling. During the present cold weather of 1926, Mr. L. Zutshi, A. R. S. M., F. G. S., Mining Engineer, has begun the former, and the latter may be undertaken later on should his results justify the outlay and transportation of a heavy steam boring plant, capable of exploring to depths of 1,000 feet and over.

For details concerning the eastern areas, with the exception of the newly discovered Dhansal-Sawalkot field, which will be briefly described in the sequel, we must still rely on the data furnished in Simpson's memoir, until those areas in turn come under detailed re-examination.

Concerning one other isolated field in the extreme west, namely, the Dandli coalfield, we have but little information to go on. The Mineral Survey has not yet begun any coal operations there, and Simpson did not visit it. The little there is known about it will be found in the brief note published by C. M. P. Wright (*Rec. Geol. Surv. of India*, Vol. XXXIV, pt. 1, 1906) and in the just published memoir on the geology of Poonch State by D. N. Wadia (*Mem. Geol. Surv. of India*, Vol. LI, pt. 2, 1928). The northern flanks of part of this possible field lie in Poonch State.

Good coal is always an asset as a basic source of power, especially in a world whose reserves in this line are rapidly dwindling and every day becoming more precious. This large-scale, close delineation of some of our coal resources has, therefore, a value in itself that will not become less but greater with time. The position of these western coalfields (as railway communications at present stand) is not perhaps the most favourable for developing them apart from certain metalliferous ores in the surrounding country, though, relatively to other parts of His Highness' dominions, their position is quite close to the edge of the hills. Whether the intervening ranges and dun-like valleys will be opened up presently by extensions of the present railways and roads, or whether other forms of transport will be initiated in the near future is not yet clear ; but in either case the importance of knowing much more exactly than before about our coal supplies is self-evident.

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## GENERAL GEOLOGY OF THE COAL AREAS.

The Coal Measures of Jammu Province, unlike many others in India and elsewhere, are not as a whole of the nature of gently inclined basins or troughs, dropped down by faulting below the ordinary level of the country ; and with regard to which a given seam has a more or less uniform depth at which it can be

struck and whose area is always limited by the edges of the basin.

On the contrary, the Jammu Coal Measures occur on the north-east and south-west flanks of arches or elongated domes in the geological structure of the country. These elongated dome structures are strung out over a length of country the greater portion of which is shown on the Outline Map (Pl. 7) and they comprise (1) the southern and main group, consisting of the large Riasi dome, with the lower reaches of the Chenab River cutting through it from north to south, and the three smaller domes of Mahogala, Metka and Kalakot; (2) the subsidiary more northern group of the Dhansal-Sawalkot field; (3) the Dandli field, which is an isolated distant representative of (1). This last is not shown on the Outline Map and its value is at least doubtful.

These coal-bearing strata are inclined for the most part at moderate to steep angles outwards from the axis of the domes, and, therefore, the depth at which the several coal seams can be struck increases with the distance from the outcrop. Consequently the outward limit of these coalfields is undefined, or may be stated as that which is necessitated by the corresponding depth at which the working of them would no longer pay.

A remarkable feature of these elliptical domes is that the elevation of them has also brought into view at the surface and centre of most of the dome areas certain formations, stratigraphically of lower horizon than the Coal Measures, which are considered to be much older than Tertiary; and so they present the phenomenon of old (probably very old) massive limestones and other rocks protruding through and among the Sub-Himalayan zone of younger Tertiary rocks (the Murree Series), a phenomenon that is exceptional as far as is known all along the similar zone of Siwalik foothills of the Himalayan ranges.

What the particular cause was, that induced these dome Their upheaval at a geologically late date. uplifts at certain points in the Murree zone of Jammu Province, is not known; but, that it was geologically very late is indicated by the fault at the southern edge of the Riasi dome. This fault appears to have been generated contemporaneously with the uplift, and it is certainly later in age than the formation of the Siwalik rocks which are found immediately to the south in the neighbourhood of Pauni (See Outline Map), for it cuts across their folds and outcropping strata, abruptly truncating them, and in a direction almost at right-angles to their line of strike at that particular spot.

Whatever the inciting cause may have been, we owe to it the elevation and bringing to within easy reach of or at the surface, not only of the seams of coal now under description, but also of the various other useful minerals that are found in the underlying limestone, breccia, etc.

A short statement of the sequence of formations which are Formations associated with the Coal Measures. practically always found in association with the Coal Measures and which are exposed in this chain of dome inliers will now be given, together with a table arranged in natural superpositional order and a few remarks on the individual formations.

The Coal Measures as a whole (that is to say the set of beds The Coal Measures lie intermediately between a known and unknown set of formations. from the lowest to the highest with which coal is intercalated) occur at a horizon or horizons separating an upper set of formations (whose age and position in the geological scale are clear) from a lower less obvious set about which little is known as to their stratigraphical position and affinities. The overlying set, includes the well-known Murree Series and Nummulitic Series of Tertiary age which are everywhere well developed in this and neighbouring regions; the underlying set includes part of the Bauxite Series, the Breccia and the Great Limestone, about which little can be said by way of correlating them with any well-known formations outside Jammu Province, for none as yet have yielded any indisputable

traces of organic life from which their geological age can be defined.

*Table of Formations.*

Formation and age.	Description.	Thickness.
(6) MURREE SERIES (U. Tertiary).	Sandstone and shales of purple and chocolate colours.	Very great thickness but unmeasured. Top not seen.
(5) NUMMULITIC SERIES (Eocene).	Concretionary limestone and shales.	About 400 feet.
(4) UPPER COAL MEASURES (Eocene?)	Carbonaceous shales with coal beds and ironstone bands and lenticles.	About 120 feet.
(3) BAUXITE SERIES (with LOWER COAL MEASURES) (Gault to Eocene).	Bauxite, bauxitic clays and kaolin with local ironstone and coal in thick beds at certain places.	4 to 24 feet and over.
(2) BRECCIA (age unknown).	Chert fragments mainly in calcareous and siliceous cement.	20 to 30 feet.
(1) GREAT LIMESTONE (age unknown but probably older than Trias).	Massive grey limestone with bands of chert. No organic remains.	Of great but unknown thickness. Base not seen.

The Great Limestone has usually been considered and shown as of Jurassic age (with a query mark added) in the maps and reports of the Geological Survey of India. As, however, this thick formation has proved entirely unfossiliferous, except for a few doubtful markings, after very thorough search through great thicknesses and extent, this suggested age can no

Age of the Great Limestone.

longer be upheld. It is a massive blue-grey limestone with numerous bands of chert. These characteristics, together with its peculiar mode of weathering, lead one to correlate it much more reasonably with the limestone of unknown age coming below the Trias of Hazara.<sup>1</sup> Thus there is no definite evidence for the age of it, except that it is probably older than Trias—and it may be much older.

The Breccia (or Brecciated Quartzitic Grit as it is also designated) is manifestly in the main a residual rock, derived from the exposed surfaces and edges of the Great Limestone, since all stages in the process of disintegration of the chert and limestone layers are found. The cementing material is calcareous and sandy. Although only of small thickness, the breccia constitutes rough country and weathers into great blocks, littering the slopes and river gorges with its debris.

In its upper part this predominantly chert breccia generally passes up into more quartzose rocks and these pass up into beds of comminuted angular chert and clear quartz grains set in a base of greenish iron silicate thereby linking the Breccia with the Bauxite Series. This green silicate, in which the iron is probably in the ferrous condition, constitutes the protore from which, by alteration everywhere actively going on, has been generated probably the limonite and hematite lumps, pockets and veins that are to be found in the Breccia below, wherever that formation has been deeply dissected by denudation. At all such places (especially remarkable near Chakar) this extremely hard breccia has been pierced by innumerable vertical pits, 15 to 30 feet deep, now mostly fallen in and overgrown, which rumour and the evidence of the oldest inhabitants credit to the local iron-workers of a by-gone but still remembered age. This point cannot be further discussed here, except to remark that the ant-like industry of these old workers in riddling the countryside with these vertical chimney-like shafts in such refractory rock is difficult to understand if iron ore were their only aim, since plenty of ore (limonite, earthy hematite and siderite) lies

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1. *Mem. Geol. Surv. of India*, Vol. XXVI, 1896, p. 23.

exposed at the surface close by among the easily excavated Coal Measures formation.

Whatever be the age of the Breccia and its associated finer textured beds, it is at several places found lying across the upturned edges of the Great Limestone (especially well seen near Khar Gala, in the stream-bed west of 3414 hill, where it lies with a dip of  $35^{\circ}$  across the truncated edges of the Great Limestone dipping at  $70^{\circ}$ ); and so, for this reason and others connected with the obvious source of the chert fragments in it, it clearly marks a great stratigraphical break. On this irregularly surfaced layer of breccia the Bauxite Series, repose as a rule.

The Bauxite Series, among which bauxite proper occurs at certain places has been found by my survey to pass laterally into hard coal. In the western areas certainly, and probably also in some of the eastern areas, where the Bauxite Series has not become modified into true bauxite but remains as a kaolin or sandy kaolin, this coal has quite recently been found to be of importance. Being at this geological horizon it must be of earlier age than the friable coal beds usually classified as Eocene in this part of India and which latter directly underlie and pass up into the Nummulitic Series. These newly discovered lower hard coals will be designated here as the Lower Coal Measures. From evidence found in the neighbouring areas of Hazara district<sup>1</sup>, certain thin coal beds and an underlying pisolite (the possible equivalent of the Jammu bauxite) are certainly younger than Cenomanian (or Gault, according to more recent investigations<sup>2</sup>) as shown by good fossil evidence. From this the age of the Bauxite Series might be something between Gault and Eocene, but the argument cannot be considered very strong or very definite.

The Bauxite Series where typically developed is a definite physical unit, having a thickness of from 4 to 24 feet, or even more in rare cases. This relatively thin layer adheres to the underlying breccia like

1. See Middlemiss: *Mem. Geol. Surv. of India*, Vol. XXVI, 1896.

2. See Cotter: *Rec. Geol. Surv. of India*, Vol. LIX, pt. 4, 1926.

a layer of butter or bread, and, when the breccia passes underground, accompanies it, sandwiched as it were between it and the overlying Coal Measures which will now be designated the Upper Coal Measures. But it varies in composition from point to point. Besides bauxite proper, after which the series is named, it comprises kaolin, ferruginous layers and, as stated above, more rarely coal. The uppermost layer, which invariably has a pisolitic structure, is regular and constant, and its junction surface, where it passes below the shales and other members of the Upper Coal Measures, is also regular and sharp. The variations in petrological facies and composition which appear among the rest of the Bauxite Series are partly connected with the uneven and sometimes pot-hole like hollows into which the underlying breccia has been worn—which latter condition also accounts for occasional rapid increase in the thickness of the Bauxite Series. But all these sudden lateral changes cannot be accounted for in this way by the uneven surface on which they were accumulated. There must have been other potent activities at work. Some of these doubtless operated whilst the Bauxite Series was first forming as a mixed colloid. Others, which have chiefly affected the upper exposed layers, have certainly been of the nature of weathering by meteoric agencies which has been something like, but not identical with, lateritization. In its lower layers the Bauxite Series appears to pass down insensibly into the upper gritty layers of the Breccia.

For further full information regarding the bauxite of this formation the special printed report on the Bauxite deposits of Jammu Province may be consulted.

The Upper Coal Measures follow on in ascending order above the pisolitic uppermost bed of the Bauxite Series. The junction of the two is often vague, but probably indicates overlap, being sharp and decisive. As the Upper Coal Measures form the principle subject of this report, they will be accorded a full treatment in the body of the report, and explanatory remarks on the overlying Nummulitic and Murree Series will also find place there according as they are necessary to complete the account of the coal and its possibilities.



The Lower Coal Measures, consisting of the above referred to newly discovered and generally hidden beds of coal which make a rather perplexing appearance among the Bauxite Series, will also be described as fully as at present known. Although only found locally, they are of importance because of the firm, non-friable nature of the coal, and because of its good to excellent quality and thickness.

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## THE SOUTHERN MAIN GROUP OF COALFIELDS WEST OF THE CHENAB RIVER.

In the descriptions which follow, the order of presentation of the details will be as follows :—

- (1) Position, orographical and other superficial details of the particular field.
- (2) Summary of R. R. Simpson's published account of his examination of it, which is now out of print.
- (3) Additional information furnished by the Mineral Survey.
- (4) Conclusion.

### KALAKOT COALFIELD.

This field is the most westerly of those constituting the southern main group. A reference to the 1 inch to 1 mile Survey of India Sheet, 42 K/8 or the Outline Map (Pl. 7) will show that the position is in lat.  $33^{\circ} 13'$  and long.  $74^{\circ} 25'$  and is some 27 miles away from the plains near Bhimber and some 6 to 8 miles away from the slightly elevated, dun-like country of the Thandapani-Nowshera line where widely spaced waves of the younger Siwalik rocks, in the form of almost continuous ridges, alternate with more open country. The field in fact lies ensconced in the moderately elevated hilly tract characteristic of the Murree

Series, which, though never rising to any great elevation, is much more irregular in the disposition of hill and valley than the Siwalik belt to the south. The average elevation of the coal outcrops is 2,750 feet, the extremes being 2,300 feet in the stream bed S. of Sair and 3,050 feet on the hill-spur S. of Dali.

Structurally the field consists of a twin elliptical dome or hog's-back of the Great Limestone, 5 miles long, surrounded by concentric ellipses of the younger Coal Measures, Nummulitics and Murrees. The Coal Measures and Nummulitics on account of their softer thin-bedded character have generally become the channel for a set of small lateral streams which fall into two larger transverse streams. These latter streams cut their way through the limestone hog's-back making narrow and forbidding, but picturesque gorges with nearly vertical sides. The main stream, passing *viâ* Marot and Sair, drains south and is a perennial source of water. It is noticeable that this stream, flowing transverse to orogenic lines or to the general Himalayan trend (W.N.W.—E. S. E.), plunges straight into the heart of the larger twin Great Limestone ellipse, at a point S. of Marot where the arching anticline in the limestone has been reinforced by a fault. It thus presents the aspect of disappearing into a wall of rock towering up 200 feet above its bed (see Pl. 1). We shall see later on that similar dominant drainage lines intersect all the coalfields of this southern main group especially noteworthy in the case of the Chenab River at Riasi. This clearly shows that the late geological uplift that exposed the older rocks along this chain of inliers was powerless to divert the course of the water into other longitudinal directions parallel with the direction of folding of the strata. Clearly the cutting of the stream bed and the elevation of the Kalakot dome kept pace with each other. Hence the water action had to concentrate on deepening its narrow bed and had no energy left for widening the gorge. The slight bevelling off of the upper edges of the gorge is chiefly due to rain and frost which have operated since the stream sawed its way through making a vertical rift.

The north-western of the twin elliptical domes is marked

by the villages Jigini, Khar Gala, Kura and Marot. It is much narrower than the south-eastern dome, on and about which lie the villages Kalakot, Sair and Ber-Goa. The two twin ellipses coalesce over a third of their respective lengths, the south-eastern part of the one being joined to the north-western part of the other, so that the respective axes of the ellipses are arranged *en echelon*.

In the large-scale plan of the field (see Pl. 8) the Jigini-Khar Gala portion of the north-western ellipse is not shown as it had not been surveyed in detail up to the time of writing.

The numerous scale-sections (See Pl. 11) show that there is a fairly steady dip of the Upper Coal Measures outwards from the larger south-eastern twin dome at angles of about  $18^\circ$  on the south-western side and  $20^\circ$ — $30^\circ$  on the north-eastern side, except along the line of coalescence of the two domes where fold-faulting introduces irregularities. Judging by the overlying formations as seen in the main stream near Marot and Tattapani, this steady dip soon disappears in a north-easterly direction. To the south-west it is maintained for a mile or more below Sair (the upper village of that name on the 1 inch map). But beyond this, between Dhanoa and the lower Sair (not shown on the large-scale plan) occurs another small elliptical dome. This, however, only exposes the Nummulitic Series. It is hoped to drill through this into the underlying Coal Measures during the early part of 1929. The results will be awaited with interest, for they will perhaps throw light on the persistence or otherwise of the coal seams in this direction from their most southerly point of outcrop near Sair.<sup>1</sup>

The Kalakot coalfield is connected with Thandapani *via* Dharmsal, with Rajouri and with the coal-fields of Metka and Mahogala by not very good *bridle-tracks*. A similar track from Dharmsal to Rajouri  
 Communications, etc.

(1) Since the above was set up in type the Upper Coal Measures were entered by the drill at a depth of 194 feet. After much trouble had been experienced by caving, the operations had to be abandoned in June 1929, without being able to prove the thickness of the coal.

passes *viâ* Sial Sui within a mile or two of the Jigini end of the coalfield. Footpaths traverse these hills everywhere connecting village with village. As things stand at present the distance of this field from the nearest rail or motor road is prohibitive against making any use of the coal. But assuming that Riasi or Talwara is connected with Jammu by rail and that secondary lines of transport connect Riasi with Pauni, Thandapani and Dharmsal, the rest of the distance from Dharmsal to the coalfield could be negotiated in some way or other by combinations of tramways or ropeways.

But it remains to be seen whether within the next few years some reliable form of air service will not supersede railways and roads in complex hilly tracts such as these. Kalakot is only 25 miles from Talwara and 43 from Jammu (a fifteen and thirty minutes run by aeroplane or air-ship respectively). The air offers unrestricted routes, and coal by this means could equally well be distributed to any metallurgical centre where it was wanted; and, if it is desirable to sell coal to the North-Western Railway, then Jhelum station is as near to Kalakot as Jammu, whilst Wazirabad is only a few miles further away. The above idea should not be dismissed as fanciful, in view of the rapid strides made by air transport during the last few years.

#### R. R. SIMPSON'S ACCOUNT.

The following notes on this coalfield are taken from Simpson's memoir and reproduced here in some detail because the memoir is completely out of print. Owing to changes in the place-names on the new 1 inch to 1 mile maps, I have added, as far as possible and where necessary, in square brackets a reference to the approximate places on the large-scale plan (Pl. 8):—

“Coal is first seen at Kalakot, where a drive, 7 feet long, exposed 4 feet of coal, dipping North 20°, East, at 53°. Only 50 feet away, however, the seam is reduced to 14 inches. To the north-west, alluvial ground obscures the outcrops, but at Piran [near Marot] half a mile distant, the seam is again seen, 18 inches thick and dipping gently to north-east. About half mile further on a pit on the eastern slope of Jhaltutunia hill [probably between the old and present sulphur springs] was sunk in coal to a depth

of 14 feet. The thickness and dip of the seam were undetermined but the thickness evidently exceeds 8 feet. On the western slope of the hill, a good deal of coal is exposed. Two separate seams can be distinguished. The dip is S.  $10^{\circ}$  E. or towards the limestone, at angles of from  $42^{\circ}$  to  $52^{\circ}$ . Several excavations in the upper seams were made and a representative section of the exposures is :—

Inferior coal.....	1' 0"
Shale.....	from 2" to 1' 0"
Inferior coal.....	1' 0"

"Over a distance of about 250 feet, three excavations in the lower seam, to a depth of from 10 to 14 feet, exposed from 2 feet 7 inches to 4 feet 3 inches of coal. Samples from this locality yielded from 12 to 17 per cent. of ash."

"Between Jhaltutunia and the western end of the inlier a little west of Jigini, a distance of about two miles, four small pits exposed a considerable thickness of coaly shale with thin inconstant bands of shaly coal. At the bend of the outcrops round the narrow ridge of limestone the beds are much disturbed, and the dips contrary. A pit,  $7\frac{1}{2}$  feet deep and 5 feet wide, was sunk, all in coal, without finding the floor of the seam. Just below the village of Jigini, a cutting exposed 8 inches of coal, whilst half a mile further south-east only coaly shales are to be seen. At Kargala the measures are much disturbed, and the coal appears to be patchy. A pit, 7 feet deep, exposed 10 inches of bright coal; whilst 600 feet further east, 4 feet of coal was measured in a pit 6 feet deep. Between Kargala and Sonjpir, a distance of fully 3 miles, the rocks are well exposed but the shales contain only occasional, thin bands of coal. A little north of Sonjpir, the measures dip south-west at from  $15^{\circ}$  to  $20^{\circ}$ . A cutting proved  $2\frac{1}{2}$  feet of coal overlain by 6 inches of coaly shale; whilst 200 yards to the south-east, two cuttings exposed about a foot of coal overlain by a foot of shaly coal."

"At a point about a quarter of a mile before the stream is crossed near Ser [Sair] the coal seam is 23 inches thick, and dips N.  $70^{\circ}$  W. at  $30^{\circ}$  [should be S. W.]. At the point where the outcrops cross the stream, a little to the north of Ser, three cuttings proved coal, varying from 14 to 22 inches in thickness, and dipping S.  $60^{\circ}$  W. at  $15^{\circ}$ . At a point one-third mile to the east, the beds dip S.  $15^{\circ}$  W. at  $25^{\circ}$ . A cutting exposed lenticular bands of coal and coaly shale. Although the rocks are occasionally well exposed on the eastern side of the inlier, no coal is seen until the outcrops at Kalakot are again reached."

Seven chemical analyses are elsewhere given in Simpson's memoir of Kalakot coals, showing 11—33 per cent. ash. These will be found included in the Tables of Analyses in the present report (see p. 82).

It is evident from the above account, which I have given in full, that Simpson did not spend much time on this field. His remarks later on (p. 63 of his memoir) show what he believed to be good reasons for this. He writes :—

“ Although the quality of the coal in this field is marketable, yet its variability in thickness, the disturbed condition of the rocks, the necessity for deep shafts and pumping, together with the difficulty of access, render it impossible to look upon the exploitation of this field as a commercial venture with any prospect of success.”

It will have been gathered, from remarks already made, that the Mineral Survey has something further to say as regards this area. This additional information, collected during the last few years, follows in the next section.

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## MINERAL SURVEY DISCOVERIES.

### LOWER MEASURES.

What may prove to be a remarkable discovery was made by Assistant Superintendent Sohani Ram in 1927. He found a lower seam or seams, which it has been decided to call the Lower Coal Measures for reasons which will presently appear. One of these seams at pit 17 S.E. of Goa on the large-scale plan is, at that place, 17 feet thick, but entirely hidden from view at the surface by superficial accumulations. The other seam (or a continuation of the former—it is not yet certain which), at pit 16, is just visible for a few yards in the stream bed and is 7 feet thick. Both are hard anthracitic coals of excellent quality and they underlie a cover-rock of massive quartzitic sandstone. The full proximate analyses of these seams will be found in the Tables at pp. 89—91.

The average of foot-by-foot samples taken at pit 17 from the 4th foot downwards gave :—

Moisture .....	4.66
Volatile constituents .....	16.57
Fixed carbon .....	63.61
Ash .....	15.16
	<hr/>
Total.....	100.00

The average of foot-by-foot samples from pit 16 gave :—

Moisture .....	0.53
Volatile constituents .....	13.47
Fixed carbon .....	74.71
Ash .....	11.29
	<hr/>
Total.....	100.00

Such thick beds of uniformly first-class coal that can be dug and handled without breaking up into dust were sufficiently phenomenal to warrant further exploration by excavations and borings with the portable G. O. Calyx drill. This I carried out in 1928 assisted by Assistant Superintendent Labhu Ram, who also discovered another hidden seam of what appears to be the same Lower Measures at pit 12. a. in the main stream east of Sair. This latter also is a hard and good coal and 6 feet thick.

Before considering some peculiar and puzzling features presented by these Lower Measures seams which at present are not solved, I shall now give some details, first regarding the seams exposed in pits 17 and 16. To illustrate them a specially large-scale plan (1 inch to 100 feet) was made in the Ber-Goa neighbourhood (see Pl. 9 and sections Pl. 11).

All the pits referred to above (and in what follows) by numbers and letters, will be found marked on one or other of large-scale plans, which should be referred to to make the descriptions clear.

As will be seen from both the maps, the outcrop area of the Coal Measures widens where this lower-horizon coal occurs—a feature which is as noticeable in the Ber-Goa neighbourhood at pits 17 and 16 as east of Sair at pits

Widening of Lower Measures outcrop: incropping basins.

12 b., c., d. and e., and 10 a. and b. The simple steady strike and dip of the formations is seen to give way to more intricate secondary bendings and undulations. Whilst the outcrops of the Upper Measures and their junction with the Nummulitics follow steadily along (at least as far as the great E.—W. Goa fault), the area of the concealed Lower Measures spreads out and transgresses over the Breccia to some extent, making secondary little basins. It would be easy to imagine that these latter really are portions of larger “incropping” shallow basins of the Lower Measures, peeping out from beneath the unconformably overlying Upper Measures; but at present it would be too much to say that this was proved satisfactorily.

For instance, if we follow the concealed outcrop of the bed at pit 17 as revealed first in pits 17. f., and on through 17. c., 17. a., 17. b., 17. d. and 17. e., next round by bore hole 4 and then back on itself under the alluvium and south to the main stream near pit 16, we shall see what is meant in this connection (see Pl. 9).

A few details must be given here. After the original pit 17 was put down by Sohani Ram, subsequent examination and deep trenching at 17. a. during the next season showed the coal there to underlie 4 or 5 feet of hard quartzitic grit (the so-called “cover-rock”) which forms a dip-slope at the junction of the two side-streams which meet at the site of bore hole 1. The eastern of these showed the cover-rock V-ing down this stream-bed and afterwards following along it northwards in a little cliff as far as bore hole 5, appearing again further north near the house and site of bore hole 4. In the opposite direction from 17. a. the cover-rock makes a small appearance at 17. c., and then disappears until it is last seen in this direction in the western stream-bed at the site of pit 17. f.

Though no coal was so far visible at any of these places except pit 17, the obvious procedure was to dig down under the cover-rock wherever it showed a scarp and see what was hidden there. This was done and coal in all cases was struck. At 17. b.



(about 50 feet distant only from 17. a.) the coal was found to be 13 feet thick and similar in every way to that sampled at 17. a. Additionally we proved the absolute connection of the two by driving a tunnel from one to the other (see Pl. 9). The bottom of this tunnel was on the bed-rock and its height 5 feet and width 4 feet. By giving it an arched roof in the body of the coal, the latter proved quite strong enough to stand without any timbering being necessary. The next pit was sunk down to stream level at 17. d. under 8 feet of cover-rock, almost horizontal, and continued with the drill down to bed-rock. Coal was found there and proved to a thickness of 10 feet. Pit 17. e. was carried a little way down until coal was struck, but the place was inconvenient for drilling, so bore hole 5 was put down near it in the fields, proving 10 feet of coal there. Similarly bore hole 4 revealed 8—9 feet of rather inferior coal.

The position of 17. c. was so close to 17. a. that we merely went down under the cover-rock a few feet until coal was duly struck. At 17. f. a pit was first made at the base of the scarp of cover-rock down to stream level and continued with the drill, proving 13 feet of coal.

These results were very gratifying, because the point to be noticed is that, if it had not been for the original pit 17 and the clue furnished by the massive and easily visible cover-rock, there would have been no particular reason for digging or boring at any of these places, since no sign of coal was seen at the surface where the outcrops should be situated. On the slopes, alluvium and cultivation hid everything and the undercliff in the stream-beds was everywhere blocked by earth and boulders, similarly revealing no traces of coal at all.

Bore holes 1 and 14 also pierced the coal bed proving a little over 17 feet of it in each case.

The above rather detailed description was necessitated to explain the discovery and proving, within certain-limits, of the Lower Measures coal and also to illustrate the way in which a thick bed of coal of uniformly excellent quality can remain

entirely hidden from view at the surface in this sort of country, although, on calculating the quantity now known (solely within the limited area covered by the pits and borings) as shown in the large-scale map (pl. 9), it amounts to 200,000 tons.

The coal surface, as exposed in pits 17. a. and b., shows a somewhat uniform material of rather dull to medium brilliance and with the lamination appearing in fine but distinct and regular layers of varying texture and brilliance which are inclined parallel to the bedding of the cover-rock above. The alternations of dull and bright coal are not as well marked as in the best coal of Jharia and Raniganj coalfields, but they are, perhaps as much so as can be expected in a coal of this anthracitic kind, and sufficiently so to define the stratification. There is a certain amount of slipping visible along joint planes in the coal, but there is no general evidence of crushing and churning up into powder such as is more common in the coal of the Upper Measures. The photograph (Pl. 5) shows the coal face at 17. b. extending to the top of the picture and the opening of the tunnel. The photographs (Pl. 4 and 6) show the trenches 17. a. and b. and the massive cover-rock overlying the coal.

I believe the thickness of about 16 feet seen in these coal faces represents, therefore, an original sediment or precipitate of this thickness—the perfectly distinct and fine lamination seeming to prove this incontestably, in spite of the small puckerings and minute fault-slips.

All the other pits in these measures show similar lamination, more or less distinct, as also do the coal samples obtained therefrom when examined in small pieces in the hand.

The coal at pits 16. a. and b. actually crops out visibly in the stream-bed for a short distance and there are a few disconnected patches of it clinging to the surface of the dip-slope of Breccia immediately to the east. The coal at these pits, which is 6—8 feet thick and dips W. and W.S.W. at 35°. is overlaid by a few feet of hard massive cover-rock, which again can be traced in the stream-bed a

few hundred feet to the north of pit 16 and then more obscurely passing up the hill side, and so under the alluvium in that direction into presumed connection with the cover-rock of pit 17. The fact that this coal immediately overlies the Breccia with bauxitic patches, and the presence of massive slabs of the cover-rock immediately above the coal, certainly predispose one to regard this seam as a continuation of that at pit 17, and as such it is marked tentatively on the map. The main difficulty in the way of accepting this view is the analyses which are considerably dissimilar throughout the whole thickness of the coal at these two places (see p. 89 & 90) the coal at pit 16 being a caking coal and that at pit 17 non-caking. The general look of the coal too is different. That at pit 16 is blacker and of a more metallic brilliance than that at pit 17. Both are distinctly laminated. Pit 16 also shows a somewhat irregular junction of the shales of the Upper Measures. This might be interpreted as an unconformable overlap of them above the cover-rock or it might be only due to a small fault.

In a southerly direction the course of this coal seam of pit 16 is tentatively marked on the map as going under the alluvium down to the stream bed at boring 13, where a trace of it only is to be found. Boring 12, at pit 15 b., recorded only 11 inches of coal at this horizon immediately above the Breccia. Still further south-east towards Chenpur nothing more is seen of this seam; boring 6, through what appears to be a cover-rock similar to that of pits 16 and 17, revealing no coal.

We seem forced to conclude that in this southerly direction the coal seam or seams of the Lower Measures of Ber-Goa have either thinned away almost to nothing, or they have been overlapped by the Upper Measures in this direction. Which of these alternatives is correct can only be settled by deeper borings made further away from the outcrop in the direction of the dip.

A short distance to the north of pit 17 the Lower Measures, if still represented in this direction, have been dropped completely out of sight by the long E.—W. Goa fold-fault. In the little valley to the north.

north, before the next Great Limestone mass makes its appearance, there are a number of well seen fragmentary dip-slopes of the cover-rock inclined S. S. W., at an angle of  $30^{\circ}$  lying directly on the Breccia and with neither the Bauxite Series nor coal preserved between them at the outcrop, except in a mere trace of 2 or 3 inches thickness of the former and a little hematite here and there. Just west of the little pass at Khargala the Breccia slope is covered by a white kaolinic quartzose rock of some thickness dipping down southwards under fields which obscure the section above. It is just possible that this general absence of anything at the outcrop might have been caused by the coal and the kaolinic material having been squeezed out and washed away on exposed dip-slopes of this kind. The somewhat wavy bulged aspect of these slabs of cover-rock in certain places and their fractured edges near the Breccia below suggest that there may be remnants left here and there under the cover-rock ; but the matter has not as yet been put to the test by boring. At all events in this direction there is no certainly known continuation of the Lower Measures that at present can be reckoned on to yield a coal supply.

Failing the above, the Lower Measures of Ber-Goa, as represented by the coal of pits 16 and 17, if they are to continue at all, must do so towards the west and south-west. The field work designed for the present season of 1929 may settle this point, by finding that the thickness of the coal seam or seams keeps constant or increases in this direction.

Since the above account was placed in the printer's hands, I have received some statements and sections of the work done early in 1929 by Mr. Zutshi, the Mining Engineer, showing the behaviour of the Lower Coal Measures of Ber-Goa towards the dip, as found by following along the bed by incline workings.

The table below gives some of the results :—

Starting point.	Direction driven.	Distance driven in feet.	Level reached in feet.	General inclination of working.	Dip at further end.
Pit 17. d.....	East.	150	2,719	$30^{\circ}$ (down)	$39^{\circ}$
Tunnel between 17.a. & 17.b.	N. N. W.	52	2,791	$20^{\circ}$ (up)	...
Do. ....	South.	142½	2,722	$25^{\circ}$ (down)	$25^{\circ}$
Pit 17. c.....	W. S. W.	140	2,721	$35^{\circ}$ "	$43^{\circ}$
Pit 17. f.....	S. S. W.	132½	2,749	$20^{\circ}$ ..	$52^{\circ}$

The thickness of the coal keeps fairly constant, being between 12 and 17 feet and occasionally even being more than the latter. Mr. Zutshi describes its quality, as judged by appearance, as being excellent, and more anthracitic than it appeared at the pits first put down. He would be inclined to think the outlook promising for the continuance of these measures towards the south-west, were it not for the "tricky and variable" nature of the seam.

A noticeable feature, well shown by the Mining Engineer's sections, is the great steepening of the dip in the case of most of the workings at their further end.

For instance, in the first in the list above, the dip of the seam increases from an average of  $30^{\circ}$  to about  $40^{\circ}$ . I have been able to incorporate this in my plate of sections (Pl. 11). It will be seen from that that it remains a puzzle as to what will be found in the space marked "structure here unknown". Does the coal bed bend upwards again sharply to a position overlying the Breccia at the outcrop end under the alluvium, or does it strike the Breccia at an angle and become overlapped by the Upper Measures, or is there a fault dropping the whole sequence into this position? Also will the vacant space, marked as unknown, be found occupied by more Lower Measures coal, or by inclusion there of representatives of the Upper Measures?

The steepening of the dip to about  $40^{\circ}$  is certainly peculiar. Such steep dips are not known at the surface on this side of the Kalakot dome,  $20^{\circ}$  being the normal inclination. Similar steep dips are indicated in the section E. of Sair drawn through 12. a. pit, where there is the same difficulty in determining how the 6 foot bed of coal there shown continues in its course further to the south. For the present this also has been marked as unknown.

Before going on to describe the next definite emergence of these Lower Measures from below the  
 Bed-rock below the coal. Upper Measures as seen near Sair, there are a few points to be noted concerning the varying nature of the bed-rock below the coal in the neighbourhood of pits 16 and

17. At the east end of the tunnel the coal of 17. b. pit lies on Breccia of the usual hard and intractable nature, whereas at the west end of the tunnel at pit 17. a., it lies on a splintery shaly bauxitic clay. The other pits and borings north and south of the above generally yielded a few feet of dark grit or sandy rock overlying the Breccia, but occasionally in association with a thin layer of bauxitic clay. In boring 1, at the junction of the two side-streams and south of pits 17. a. and b., after 17 feet 4 inches of coal had been passed through, a similar dark grit was struck between the coal and breccia. It was 3 or 4 feet thick and interbedded with 3 layers of coal, each a few inches thick. It will be interesting to see if these thin layers of coal expand appreciably or not in a westerly direction.

The bed-rock further west, as revealed in boring 2 at the site of pit 17. f., has been described as a sandy dove-coloured rock, having a thickness of about 10 feet before the breccia was struck. I was elsewhere on tour when this boring was made, but later on I examined the section up the stream-bed to the north-west of this pit and boring. The results are of considerable interest. Everything except the coal is very well exposed, the steep little stream-bed being cut out of the rock and very nearly along the dip. For a distance of 100 yards it cuts through these representatives of the Bauxitic Series before the Breccia is reached. The uppermost bed immediately below the coal is a white to dove-coloured sandy hardened kaolin, the sand grains being dotted about the clay matrix in tiny clear spherical blebs. Further down in the section as revealed by ascending the stream bed, the kaolinic matrix changes to a green silicate of iron (and possibly of alumina), the clear little grains of quartz and a few of chert still remaining. A similar green ferrous silicate has been described in the already issued bauxite report as underlying the bauxite and bauxitic clay of certain areas near Chakar. Further down in the section and close to the Breccia the green rock shows all stages of alteration into a rock consisting of almost white kaolinic patches cut through by limonite veins along the joint and bedding planes. The limonite with occasional films of specular hematite increases downwards towards the Breccia, and in places coalesces into iron ore. The slopes on

Section in bed-rock in stream N. W. of pit 17. f.

each side of the stream are abundantly littered with large and small masses and pieces of these kaolinic and ferruginous rocks with varying proportions of the glassy quartz granules. There are a few beds of ordinary fine sandstone. A dip-slope is always difficult to estimate thickness on, but a rough estimate I made placed it at about 50 feet. As, however, only 10 feet of the "sandy rock" below the coal and between it and the Breccia was said to be met with in boring 2 at pit 17. f., the above estimate may be too much. At all events the bauxitic clay with quartz granules and the green rock are much thicker there than at other places north and south of pit 17. a. and b. What happens to the outcrop of them and of the coal and cover-rock to the west and south-west of pit 17. f., is at present a mystery. The hill-side here is covered with tumbled blocks; but the appearance is as if there were some discordance with the Upper Coal Measures and Nummulitics which sweep round in a regular curve as shown on the large-scale plan of the Ber-Goa area (Pl. 9). This appearance tallies with the other suggestions for unconformity or overlap of the Upper Coal Measures on the lower, and strengthens the view that the "incropping" Lower Measures, with the thick seam of coal as exposed in pits 17. a., b., c., d., e. and f., may continue in a shallow hidden basin to the west and south-west under the overlying slope of Upper Measures and Nummulitics in that direction.

Although nothing but a few traces of this Bauxite Series, consisting of white and grey kaolin and the

Traces of the kaolinic and ferruginous bed-rock elsewhere.

green silicate, are found in the stream bed between pits 17 a., b. and 16 a., b.; yet among these patches adhering to the slope the same varieties, showing the leaching out of the iron from the ferrous silicate and the deposition of it in joints and other planes as limonite and occasionally hematite, are to be found; and in addition also the change over of these varieties into a hard compact and perfectly black rock with a specific gravity of only 2.5, which seems to be a carbonaceous variety of bauxitic clay. At other places, as at pit 12. e. east of Sair, the same black compact variety occurs as a thin band under a massive cover-rock somewhat similar to, but really different from, that at pit 17. a. and b. The black compact rock apparently takes the place of the coal of the Lower

Measures. It contains little patches of purer carbonaceous material which suggest organic material *e. g.* portions of stems and twigs.

Kaolinic rocks of the same type, and with the green silicate changing into limonite with traces of vivianite, also cover part of the dip-slope of Breccia on both sides of the main Great Limestone dome especially near Kalakot village. It has not been found possible to separately indicate these on the large-scale plan of the Kalakot coalfield (Pl. 8). At one place also on that side of the dome near 1927 camp and below pits 1, a compact hard black rock, rather like but more sandy than that mentioned above, and a few inches thick, is the only trace of anything intervening between the Breccia and the Upper Measures. It is possible that this black rock represents an actual passage form between the bauxitic clay and coal and that careful search might yield other links in the chain and prove that the apparent lateral passage of bauxite or bauxitic clay into coal (already noted) has been a real petrological passage between sediments or precipitated gels, according to the view we take of their genesis.<sup>1</sup>

There are one or two other places where this half-way stage between kaolin (or bauxitic kaolin) and coal is found at a similar horizon.

Other occurrences.

Very occasionally, as on the dip-slope of Breccia at boring 13 in the Ber-Goa area, a 5 feet thickness of it is found, underneath a thin layer of breccia and reposing on more breccia. Such an occurrence seems to point to the possibility of the top layer of breccia not being in all cases the bottom of the Coal Measures. With our hand-driven Calyx drill, it is only with great and long continued labour that we can penetrate an inch or two into the breccia, because of its hardness and the escape of the pump water down crevices. We have hitherto assumed that nothing further in the way of coal can be found when once the breccia is

1. See C. S. Fox. Sixteenth Indian Science Congress, Madras 1929, Presidential Address Geology Section, where he advocates the view that "the pervading substance which constitutes most of the material in all the coals examined by him is colloidal matter in a State of strain".



struck. From the evidence of boring 13, however, it seems that the breccia layers need not necessarily be all of one precisely identical age. At some distance away from the present outcrop, in the direction of the dip, therefore, certain layers of it might cover up an underlying coal bed or beds. At the present stage of the enquiry this must not be regarded as more than a suggested working hypothesis such as one is led to in all pioneer work in new country.

So far as at present known, the only other place in this coalfield, where the Lower Measures emerge to any appreciable extent from below the Upper Measures and spread out in hollows and synclinal troughs in the Breccia, is at Sair. The evidence for this is mainly furnished by pits 12. a., b., c., d. and e. and boring 8 all low down in the valley east of Sair (see Pl. 8) and secondarily by pits 10. a. and b. and borings 7 and 10 to the north and north-west of Sair.<sup>1</sup>

At pit 12. a. under the gravel of the stream-bed Assistant Superintendent Labhu Ram first detected a hidden seam of fairly hard coal, 6 feet thick, dipping  $45^{\circ}$  S.S.W. and apparently lying directly on the Breccia. Analyses of foot by foot samples are given at p. 90. Most of these show rather high ash (probably due to surface contamination and crushing). The average large sample of the more solid parts of the bed gave 25 per cent. ash on analysis and this is more likely to be a correct percentage for the bed as a whole. The same bed of the same thickness was pierced by the Calyx drill at boring 8, at a depth of about 35 feet from the surface. This and the rocks exposed at the surface show that the dip of  $45^{\circ}$  at pit 12. a. slackens off to  $20^{\circ}$  or  $15^{\circ}$  as we proceed south

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1. Some apology to the reader seems due on account of the apparently irregular disposition of the pit and borehole numbers on the map which are difficult to follow. This irregularity arose from circumstances of time and necessity, when working in the field; and, having once become current, on our plans, in our field notes and on our labelled specimens and samples it was deemed better to stick to it than to attempt a simplification by renumbering them, which would probably have caused confusion.

(see section Pl. 11). Below the coal in the boring 6 feet or so of bauxitic kaolin and sandy kaolin were met with before the jamming of the tool and stripping of the core-barrel threads compelled us to abandon the hole and the tool without actually reaching the Breccia. The 40 feet or so of overlying dark carbonaceous shales probably all belong to the Lower Measures, and are overlapped outside this little synclinal basin successively by the greenish pseudo-cover-rock found at the site of the boring and by the rest of the shales, etc., above this. Owing to the irregularities of surface soil and boulder gravels, the exact places in the section at which the Upper Measures begin cannot be settled, but the so-called pseudo-cover-rock can be followed and found at many places lying on the breccia or with coal or shales between of much reduced thickness. For the same reason the 2 feet of good hard coal in pit 12. c. which extends nearly horizontally to the south, lying directly on a hummocky mass of breccia in that direction, seems likely to belong to the Upper Measures and not to be a continuation of the 6 ft. bed of coal seen at pit 12. a. and boring 8; and this interpretation of the structure is the one followed in the drawn section.

Pits 12. b., d., and e. further east illustrate the extension of the 6 ft. bed 12. a. in that direction. The thickness of the coal becomes reduced, and eventually, at 12 e., is represented by 2 feet of the compact black passage rock between coal and kaolin (or bauxitic kaolin) already referred to p. 27.

In the other direction pits 10. a. and b. also show from 1 to 2 feet of coal under the pseudo-cover-rock. Borings 7 and 10 near the shrine west of Sair only revealed shales and sandy material down to the Breccia below without any coal at all.

Down-stream from pit 12. c. in the direction of boring 9  
Residuary nature of Lower Seams. there are gentle undulations of the Upper Measures, which here and there are interrupted by bosses, or in some cases faulted masses, of the Breccia. Although we have been unable to mark off on the map by a separate indication the Upper from the Lower Measures, I think it is clear that, below the former, the Lower Measures, (filling

up hollows in the Breccia, or additionally thrown into steeper folds than the Upper Measures) do actually constitute relics of an older set of beds with coal seams, which are generally either overlapped by the younger set or possibly unconformably overlaid by them.

The attempt to feel out another incropping relic of these older seams below the Upper Measures by boring at locality 9 was unsuccessful, well-bedded finely fissile shales continuing down to the Breccia which was struck at a depth of 53 feet below the surface. Shortly before reaching the Breccia there was some grit with white specks followed by 5 to 6 feet of compact black carbonaceous shale, but no coal.

So far as we can see then at present, the small basin of the Lower Measures at Sair has no great extension in any direction that has been tested. It is impossible to say definitely whether this isolation was mainly original and due to the simple filling in of a hollow in the Breccia or whether it arose out of a once widely distributed deposit by flexuring and subsequent partial planing off by denudation prior to the deposition of the Upper Measures. The latter seems, perhaps, the more likely view.

The facts which have been detailed above regarding the peculiarities of position and outcrop of these lower coal seams of Ber-Goa and Sair, at any rate seem to warrant their inclusion in a separate category from the more continuous seams that come next beneath the Nummulitic Series. Hence, for the present at least, it is convenient to class them as Lower Coal Measures, the idea being that their irregularity of position and probable unconformity to the measures above, as well as their genetic connection with the fine kaolinic representatives of the Bauxite Series, show them to be an older formation, with perhaps a time gap between them and what are now spoken of as the Upper Measures.

The question whether, in any of the as yet unexplored parts of the north-western ellipse of the dome area, some further occurrences of the Lower Measures may be present or not is one for the future to

decide ; as also the question as to whether, among the steeply inclined strata immediately north of the Ber-Goa E—W fold-fault there may be portions of them left perhaps at depth. In this connection should be noticed the vertical coal beds just visible against the fault 200 yards W. by S. of pits 2. a. These require more examination ; but they may just as well belong to the Upper as the Lower Measures.

## UPPER MEASURES.

Whilst the details just given about the Lower Measures constitute new material, quite unsuspected by previous workers, the Upper Measures, with their seams exposed to view in places, have not failed to receive a certain amount of attention in the past. The full scheme of them, which argues their practical continuity all round the field, however, had not then been recognised. It contains features of novelty that will be now set forth. The difficulty will be to compress the information that has recently become available into reasonable space. In order to save words, some generalisation will have to be resorted to and reference made as much as possible to the graphical delineation shown on the map and sections and to the table of analyses.

Although continuity and regularity as a whole are a feature of these Upper Measures seams, there are Generally continuous with local gaps. gaps in the outcrops to be found everywhere ; and hence the seams are often shown by broken lines on the plan instead of by continuous lines. The main reason for these gaps is the presence on the slopes of cultivation, soil, alluvium, scree material and fallen debris in large blocks from the overlying cliffs above. To clear all this away and present the outcrops in their naked simplicity would have been manifestly impossible. The most we could do was to probe in here and there in the covered places where the surface accumulations were reasonably thin.

Before proceeding to give details about these coal seams, a few words are necessary to describe the formation as a whole in which they occur. Position, thickness and general features of the Upper Measures. Over the greater part of the coalfield

the Upper Measures have an average thickness of a little over 100 feet, and they form what (disregarding the covered portions) we may infer to be a continuous belt all round the older formations of the elliptical dome areas. With a few exceptions on the north and along the line where the twin domes unite, as well as where the main stream cuts through them, this belt of Coal Measures builds a low, scarped undercliff, or gentle slope, which is, however, relatively inconspicuous in the landscape compared with the much thicker Nummulitic belt of limestones and shales which follow above them. These latter make a second undercliff or steeper scarp, some 400 feet thick, and this again is only of moderate dimensions compared with the final superimposed scarp of the Murree sandstones, whose upward limit is not known. The section ( Pl. 10 ) drawn through the main south-east twin dome will make the above explanation clear.

These Upper Measures, apart from the coal seams, are  
*Lithology.* mostly composed of shales, which towards the middle of the series become splintery and carbonaceous and interbedded with a few sandy and ferruginous layers. The latter, towards the east, develop lithological sequences and bands of clay ironstone and siderite cakes and nodules that serve to link up the individual beds with those of the next coalfield in that direction, namely the Metka (Simpson's Siro Valley) coalfield. In their lower layers these measures become less noticeably carbonaceous and more flaggy and fissile at places where they are superposed on the Breccia, or have come into obscure relationship with the rarely seen outcrops of the Lower Measures. On account of this irregular or vague base to the Upper Measures, it will be convenient to describe them downwards in descending order from the Nummulitic Series above, where a certain regularity does apparently obtain.

A new feature of my survey has been the locating of an  
*New Upper bed.* upper coal bed just along the line of division between the Upper Coal Measures and the Nummulitic Series. Like the coal of the Lower Measures, except for an occasional slight smudge in the soil,

this bed scarcely ever shows up at the surface from underneath its mantle of soil and other slipped and disintegrated material : the soft splintery yellow shales, which form the lower part of the Nummulitics, readily become clay and mud under weathering, and by flowing or working their way down the slope by gravity effectually hide the upper coal seam at the outcrop. Hence this bed does not appear to have received attention from previous observers nor does its existence even seem to have been generally suspected.

The coal of this upper seam is generally black, shiny and flaky or powdery. It is generally also for this reason contaminated and mixed with clay at the outcrops. There is no cover-rock or roof of strong material. The actual seam, when first exposed by digging, frequently appeared to be only a few inches to a foot thick. As we penetrated inwards this rapidly thickened up to an average of 4 feet and a maximum of 5 or 6 feet. The plans and sections and the list of analyses must be consulted for details as to those parts of the outcrop that have been able to be studied. Wherever the bed is not marked on the map it may either be locally absent or it may simply be hidden as described above. It would have been impossible, without trenching and pitting in very great detail indeed, and sometimes fairly deeply into the hill-side, to say which of these causes has everywhere been operative. On the whole I am disposed to believe that continuity, of this seam, is the more normal condition and discontinuity the exceptional one. Owing to what we must believe to have been the crushing, squeezing and stretching of the coal along with the associated clays and shales, in consequence of the tectonic movements that the region has undergone during successive Himalayan upheavals (and of which we have additional evidence in the flaky and powdery condition of the coal), a bed such as this may nevertheless have almost or entirely disappeared in a few places and been proportionately thickened at others. It may also have locally passed into carbonaceous clay owing to original variations in sedimentation. How far such variations have played the chief part in determining the present-day constitution of the seam can only be answered when much more extensive proving of the deposits has been done.

Incidentally it may be remarked that coal of this soft, flaky and powdery character, and that is frequently contaminated with clay, will need briquetting before it can be used as a fuel. In some cases, along with the above operation, washing may be necessary or beneficial. A briquetting plant indeed may be considered as an essential for most of the coals in this and in all the other Jammu coalfields.

From the analyses that have been done on samples from this upper bed of the Upper Measures (see p.91—94) we see that, so far as these outcrop openings are concerned, the coal is of the usual anthracitic kind and the ash percentages as a rule are high, though not always so. Most of the material would rank only as third or fourth class coal by considering the average ash throughout the whole thickness of the seam, though there are exceptions here and there. The material of pit 8. a. in the south-east corner of the field can only be called carbonaceous shale. On the other hand that of pit 10, 400 yards west of Sair, would rank as first class coal. The coal of pit 12 in this upper seam, situated 800 yards east of Sair, with an average of 25 or 26 per cent. ash, though reckoned as third class, is not far below 2nd class. But it is only to be expected that pits at the outcrop in such crushed material would give a higher percentage of ash than properly belongs to the seam at depth. The carbonaceous shale of pit 8. a. consequently may owe its very high ash content to its being an outcrop pit and also, perhaps, chiefly to its being situated in a stream-bed. The coal of pit 8, in the upper seam only 200 yards away, analysed only 6 per cent. ash.

It seems likely nevertheless that surface contamination of this nature need not go very deep, not much deeper perhaps than the depth into the hill that it is necessary to excavate to find out the true thickness of any seam. At pit 12, mentioned in the preceding paragraph, an incline was driven down along the seam to a distance of 17 feet from the original opening, and during this distance the thickness of the seam remained constant at  $5\frac{1}{2}$

feet, and the average ash percentage remained equally constant at about 26. It is true the drive was made very near the top of the hill spur so that the surface was never very far away. Pits 12. g. and 12. h. expose a continuation of this bed. At pit 10 in the upper seam on the other hand, where very good results were obtained on analysis, the hill rises steadily above it and apparently there has been little or no contamination there (where the ash averages only 10 per cent.) through a thickness of nearly 6 feet. Of course, there probably has taken place, far back in time, a deterioration of the upper layers of the seam as a whole by contact with the shales or clays immediately above. In so far as this has been brought about by pressure and earth movements there is no escape from it : the result is the present total quality of the seam. If, however, circulation of ground water has had anything to do with it, the contamination and deterioration may only be local and superficial and will not be found at depth.

Additional remarks on this upper bed are : On the north side of the Kalakot dome area the coal at pit 1, which is about 7 feet thick, has analysed disappointingly ; the lowest ash percentage being 19.20 and the highest 46.80, the average of all the foot-by-foot beds being 36.51—a 3rd or 4th class coal. As elsewhere, the coal is black, but much crushed and powdery and very soft. The position of the pit being unfavourably situated in a small stream-bed, contamination with clay is indicated, in this outcrop pit.

The coal at pit 2. a. (also on the northern side of the dome and on the northern side of the eastern continuation of the E.—W. Ber-Goa fold-fault) is even of poorer quality. The analyses given at p. 92 speak for themselves and need not be summarised here. This coal bed differs from all the others seen in this portion of the field, inasmuch as it occurs as the core of a little anticline in the Upper Measures, lying over recumbently towards the south-south-west. The coal and coaly clay have consequently been doubled in thickness and suffered much crushing and shearing, so that the resulting mixture (at the outcrop at all events) is of very poor quality. It is possible this coal may represent the middle and lower beds, since traces of a still higher coal bed, 30 feet above, are seen.



A few, as yet unmentioned, occurrences of the upper seam on the south-west side of the dome area, namely those of pits 11, 11. a., 13, 14. a., 15, 15. a. and 15. b., show as a rule much crushed and powdered material of variable quality and thickness. These have not been opened up properly yet, nor the coals analysed. They are in line with the upper bed of pit 10, and some of the coal I should expect to be 1st or 2nd class. At pits 15 and 15. b. there are two or three beds rather close together, totalling in the latter case 6 feet 9 inches and dipping at 30° W. S. W., all good-looking coal but powdery. It is, however, possible that the upper and middle or lower beds of the Upper Measures may both be represented here by the intervening shales having become attenuated. More work is required to settle this point. The clear and continuous ascending section of Nummulitic limestone and shales as shown in the stream-bed west of pit 15. b. indicates that there are no higher coal beds in that direction.

The exposures of the upper coal seam as shown in the pits on the north and south of the dome are linked up roughly by outcrops partly excavated at pits 4, 6 and 7 near Dali and pit 18 north of Goa. Of these, systematic sampling and analyses have not yet been done.

On the whole, I should expect a practically continuous 4 foot thickness of coal in this upper bed all round this greater elliptical dome of Kalakot. The quality is not so good, however, as my first impressions in 1928 led me to expect. Occasionally it is very good, even in outcrop sections. More generally it is 2nd or 3rd class. Occasionally it degenerates into carbonaceous shales from contamination with the soft argillaceous roof. When worked to the deep and the whole set of qualities washed, mixed and briquetted, I estimate that a good second class coal fuel will result containing about 20 per cent. ash.

Other seams in this coalfield, coming a short distance below the upper bed, I designate here the middle or middle and lower seams of the Upper Measures. This is on the analogy of the more distinctly seen

sequence of seams in the neighbouring Metka coalfield to the south-east (see p. 44). They are frequently but not everywhere found in place and the coal is often moderately firm and of a more uniformly even and good quality than that of the upper bed though the thickness is less. This coal bed is marked by original lamination being sometimes preserved and comparative absence of crushing.

Several outcrops of these seams are visibly exposed at the surface in natural sections, and these appear to be the ones that have been described by R. R. Simpson, such as those round about Kalakot springs at pits 1 and 3 and those west of Sair at pits 9 and 10.

Other outcrops of these seams, however, have been laid bare by my survey round the south-eastern part of the dome area, which part R. R. Simpson has referred to as showing no coal. The greater and better development of these in this part of the field, as well as the presence of the more continuous upper bed, point to the conclusion that they continue below ground into actual connection with the very similar set of seams and associated beds exposed in the next (Metka) coalfield in this direction.

The following few details may be given :

In the area of pit 1, S. by W. of 3213 feet hill, the total thickness of these Upper Measures is 110 feet and the dip  $25^{\circ}$  N. E. The upper coal bed is followed below, after an interval of 50 feet of shales (with one or two thin concretionary limestone layers and ferruginous concretions in the upper part) by a middle bed of coaly shale 3 feet thick and poor coal 14 inches thick, much sheared into lenticular cakes and having bright black shining surfaces. Below this come 25 feet of more shales, with a few layers of ferruginous concretions and a noticeably harder sandy and ferruginous layer, which tends to split up into loaf-like masses  $2\frac{1}{2}$  feet thick. This "loaf" bed and the ferruginous concretions are also well seen in the stream-bed east of pit 11, and mark a recognisable horizon connecting the south-east part of this field with the Metka coalfield. Next below come 3 or 4 feet of

carbonaceous shale followed by the lower coal seam. Locally this latter is 8 feet thick and is a good but soft anthracitic coal containing 32 per cent. ash. It appears to thin away in 50 yards of outcrop to  $1\frac{1}{2}$  feet only. The remainder of the section consists of more carbonaceous shale followed by pale shales down to the breccia, with the exception of the trace of hard black bauxitic clay found at one place in the stream-bed as mentioned on p. 29.

Pits 2 and 3 show imperfect developments of these coal seams. The hill slope is permeated by springs of water and the coal shows much crushing, contamination with clay and probably some faulting or slipping, whereby the presumably once steep scarp of these measures has been reduced to a gentle slope of about  $20^\circ$ . A peculiar variety of shaly coal makes its appearance here for the first time among these lower seams, but it is better developed elsewhere. It consists of very thin laminae of good, silky, anthracitic coal, interleaved with shaly and sandy material in varying amounts. The result is a hard flaggy bed, splitting up into material that is apt to be rejected at first sight as being worthless for fuel—which, however, is far from being the case. It will be mentioned again later on.

In the south-east corner of the coalfield pits 7 and 8 have exposed what I regard as typical examples of this middle or lower bed (more probably middle). Its thickness is about 2 feet 6 inches, the lower two feet being excellent, rather firm, coal and the upper six inches the peculiar shaly coal referred to in the previous paragraph. The coal of the 2 feet bed has preserved its laminated appearance to a considerable extent, from which fact and from its relative firmness one may presume that the seam has not been so much crushed or disturbed as have most of the Upper Measure seams. This is furthermore borne out by the section exposed in a short drive started a little below the outcrop at pit 8, and which was made to reach the coal dipping  $20^\circ$  S. by W. at about 18 feet horizontally. During the excavation of this no timbering was necessary, except at the entrance, the coal remaining firm and the thickness uniform.

The anthracitic character of the coal, and its excellent quality as shown by the ash percentages being very low, will be gathered from the table of analyses (p. 94 ). The shaly coal above, which is 6 inches thick, appears at first sight as unpromising as that at pit 3. Minutely examined, however, the fine laminae, which are brown or grey on all natural surfaces, are found to be compact and of a dull dark colour and rather silky sheen, when freshly broken across the lamination. Weighed in the hand they appear manifestly light compared with an ordinary shale (the specific gravities actually being about 1.5). An analysis of one sample gave 31 per cent. ash but towards the top of the 6 inch layer the quality deteriorated gradually. Tested in a fire-grate, this at first unprepossessing looking stuff surprised one by its vigorous combustion and the great heat evolved (see p. 104). In the first stages it burns with a continuous crackling noise.

A few traces of these middle or lower seams have been exposed further to the west below pit 12. f. The outcrop shows a few inches of coal in two layers and below it some of the free-burning shaly coal as described in the preceding paragraph.

The next good exposure of a seam at this horizon is furnished by the bare cliff west of Sair at pits 9 and 10. This is one of the localities mentioned by Simpson.

As the section here, combined with partial sections in the river bed between that point and pit 11, forms one of the best natural exposures of the Upper Coal Measures, I append in tabular form a detailed section of it in descending order : —

Yellow nodular limestone—base of Nummulitic Series.

Calcareous concretionary band ..... 2—3 ft.

Carbonaceous shales ..... 10 ft.

COAL (upper seam).....	4 ft. 3 in. to 5 ft. 6 in.
Shales (carbonaceous at the top) .....	15 ft.
Hard shelly bed about .....	1 ft.
Carbonaceous shales .....	10 ft.
COAL (trace? middle bed) .....	2 in.
Carbonaceous shales with one or two bands of siderite nodules near the top .....	10 ft.
COAL (? lower seam) .....	2 ft.
Carbonaceous shales with siderite nodules and pyrites towards the top .....	20 ft.
Grey fissile shales .....	15 ft.
Concretions with cone-in-cone structure .....	1 ft.
Grey fissile shales .....	10 ft.
Hard sandy carbonaceous shales .....	20 ft.
Hard sandy ferruginous bed .....	10 ft.
BRECCIA below.	

The two-foot bed of coal is clearly exposed and had evidently been cut into by Simpson's party in previous years. It is partly visible as a black band rather high up on the face of the cut-away scarp. Where not so visible it is merely hidden by a crust of sandy clay adhering to it, on scraping away which the seam is at once made visible. (I mention this as another

Pits 9 and 10.

example of the many ways in which a coal seam in these hills can become disguised).

A 20 feet horizontal drive was made below the outcrop at pit 9, so as to cut the 2 feet bed, dipping  $18^{\circ}$ — $20^{\circ}$  S. W., at that distance from the outcrop. The coal was found to be fairly uniformly of the bright laminated variety, firm (getting firmer within) and its ash percentage only about 8.

The same bed continues along the exposed scarp to a point below pit 10 where another little excavation was made yielding a similar thickness of firm, bright, laminated coal, not analysed as yet, but which from its appearance I judge to be a first class coal similar to that at pit and drive 9.

From the relatively firm condition and excellent quality of the coal and coaly shales of pits 7, 8, 9 and 10, I believe that this material could be mined with advantage notwithstanding that the thickness is only 2— $2\frac{1}{2}$  feet. Of course, a great deal will depend on the requirements and the purpose for which the coal would be utilized.

Further north-west on towards Chenpur village this coal seam appears to pass into coaly shale and carbonaceous shale, at least so far as outcrop excavations have made manifest. Pit 13. a., cut out of a bare little patch in a stream-bed, shows 4 feet or more of coaly shale, analyses of which are given in the list. One part at least of this outcrop near the middle yielded a general bulk sample having only 28 per cent. ash. This material is hard and platy, breaking up into little slabs of most unprepossessing appearance. But the burning qualities are similar to those of the coaly shale of pits 7 and 8 and cannot be disregarded (see p. 104).

Still further north-west along the Coal Measures outcrop, a few traces may be seen of similar shales and occasional coal beds; but generally speaking the middle or lower beds appear to be not represented, unless pits 15 and 15. b., where the upper bed apparently splits

up into more than one bed, may, on the other hand, be regarded as embracing representatives of them. Still further north-west, in the area of the second and smaller twin ellipse, details have yet to be worked out.

### CONCLUSION.

It is clear that the detailed mapping on a large-scale and exploration by pits, short underground approaches and borings in this Kalakot coalfield, carried out by my survey, have considerably added to the known coal content. The discovery has been made of thick, hard seams of first class coal, (the Lower Measures) lying locally and irregularly in separate small basins beneath the Upper Measures.

#### *New discoveries.*

There has also been discovered a fairly continuous 4 feet bed of the Upper Measures, which is frequently a rich, but sometimes locally contaminated (at the outcrop) coal, very friable and powdery.

The middle, or middle and lower seams, which are the ones previously partly known, have been found to consist of a rather firm coal of first class quality as a rule, but restricted in thickness to 2 or  $2\frac{1}{2}$  feet. Associated with this are some hard coaly shales with a high ash percentage, but having a recognisable fuel value. The outcrops of this seam or seams have not as yet been detected everywhere, sometimes because of covered ground but also, it is believed, by the beds thinning out or passing into carbonaceous shales.

All the coal in these Upper and Lower Measures is anthracitic, coming about midway between a bituminous coal and a pure anthracite. Much of it is a coking coal.

Exploration of parts of this coalfield are still in progress. Endeavours are being made this year (1929) to finish the detailed mapping of the smaller ellipse between Marot and Jigini, to follow the Lower Measures in their extension beneath the Upper

Measures and to drill the detached little anticline in the Numulitics lying between Sair and Dhanoa.<sup>1</sup>

A short estimate may here be attempted of the coal tonnage so far made evident. The area immediately covered by the Lower Measures in the neighbourhood of pits 16 and 17, I estimate to contain 170,000 tons of excellent hard coal. The smaller area near Sair of the same measures I estimate to contain 20,000 tons making 190,000 tons altogether. It is reasonable, however, to suppose that the former area will extend at least for  $\frac{1}{4}$  mile to the dip and so yield altogether about 1,000,000 tons.

Beyond this in the long gaps between the holes that have yielded nothing, it is possible there may yet be found more small basins of these Lower Measures, either directly on or a little off the line of outcrop towards the dip. As these are problematical they are not estimated here.

The Upper bed of the Upper Measures I am reckoning to extend for 5 miles round the larger ellipse with an average thickness of 4 feet. Allowing that this may be workable for half a mile towards the dip and to a depth below the surface of about 1,000 feet. I estimate that it will yield about 6,000,000 tons of a good second class briquetted fuel after deductions have been made for washing and wastage.

For the middle and lower seams, reckoned to the same depth and extension to the dip and reducing the thickness from 2 or  $2\frac{1}{2}$  feet to  $1\frac{1}{2}$  to allow for gaps and thinnings away, we can add another 2,000,000 tons of very good material, much of which (and perhaps all) will require briquetting.

There are still the areas in the north-west ellipse to add, but, as these are not yet surveyed, I prefer to leave them out of the tonnage calculations.

1. Mr. Labhu Ram has since completed the large-scale mapping of the Marot-Jigini area. He has also finished that of the detached anticline between Sair and Dhanoa. Notes on the mining results obtained among the Lower Measures of Ber-Goa will be found at p. 23.



By addition we then have for the  $\frac{2}{3}$  area of the Kalakot coalfield so far examined in detail :—

	Tons.
Lower Measures .....	1,000,000
Upper Measures upper bed .....	6,000,000
Upper Measures middle and lower beds	2,000,000
	9,000,000
Total.....	9,000,000

### METKA COALFIELD.

The Coal Measures of Kalakot, together with the overlying Nummulitic limestone and shales, at their extreme south-eastern edge pass under the ridge of Murree sandstones in that direction which form an almost flat anticline and, after disappearing in this way for a little over a mile, emerge again in a small valley-system draining the neighbourhood of Metka. As the rather large village of that name lies sub-centrally in that small area (see map Pl. 13) I have renamed this coalfield after it, instead of using the name "Siro Valley" given to it by Simpson. The village of Saroh on the new 1 inch maps (which doubtless accounted for the title given to the field by Simpson) lies a mile or more away to the south-west, entirely on the Murree Series, and so is not so appropriate. The only other village name marked on the 1 inch sheets as lying within the coalfield is that of Gabar, half-a-mile north-west of Metka. The village referred to as "Nimbal" by Simpson in his published description I have not been able to identify. Probably it has disappeared or changed its name since the old Atlas of India Sheets (1 inch to 4 miles) were published.

Metka coalfield lies in latitude  $33^{\circ} 12 \frac{1}{2}'$  and longitude  $74^{\circ} 27 \frac{1}{2}'$ . It consists of an inlier of the Upper Coal Measures, surrounded by an irregularly encircling ring of the Nummulitics, and occupying a shallow valley, the whole being in the form of an anticline having dips from  $0^{\circ}$  to  $10^{\circ}$  S. on the south side and steeper dips of  $30^{\circ}$  to  $40^{\circ}$  N. N. E. on the north side of the anticline.

The Upper Coal Measures are the lowest formation that erosion has laid bare along the crest of the anticline; but boring No. 1, has penetrated to the Great Limestone below without detecting the Breccia, Bauxite Series or Lower Coal Measures, unless the 14 feet of carbonaceous grit represents the last of these.

The average altitude of the Coal Measures is 2,700 feet; so that it agrees very closely with the average altitude of the Kalakot Coal Measures, thus emphasising the structural unity of the two areas. If the ridge spur south-east of Dali, where the number 3,951 appears on the 1 inch map, were sliced away horizontally the Metka coalfield would be seen to be merely a south-east prolongation of the Kalakot coalfield.

The horizontal section ( Pl. 14 ) running north and south will sufficiently illustrate the main structural features of the Metka field.

Bridle-roads (much out of repair) cross the intervening ridges both north-west and south-east joining it up with the Kalakot and Mahogala fields respectively. Its natural outlet, however, is down stream south-west towards Dharmsal and Thandapani.

### *R. R. Simpson's Account.*

The following account of this field taken from Simpson's memoir is added here for completeness' sake, though the details cannot now be followed on the new map:—

“ Following the path from Mahogala, coal is first seen at Nimbai, on the left bank of the stream which flows down the eastern side of the valley. In a drive, 80 feet in length, the thickness was 4 feet, whilst in a shaft, 22 feet deep, only a few yards away, the thickness was  $3\frac{1}{2}$  feet, thinning to  $3\frac{1}{4}$  feet at a distance of 5 feet from the pit. In a shaft, sunk in the fields on the western side of the stream, and about 500 feet distant, the seam, at a depth of 16 feet, was 19 inches thick. Five hundred feet further up-stream, a pit,

13 feet deep, exposed a thickness of 4 feet of coal. In the centre of the valley, at a point about 1,000 feet west of the excavation last mentioned, the following section was exposed in a pit, 6 feet deep:—

Coal .....	0' 9"
Shale .....	0' 6"
Coal .....	0' 10"

“On the right bank of the western stream, a good section exposes two seams of coal separated by 20 feet of shales. Short drives exposed 19 inches of coal in the upper seam, and 3½ feet of bright coal overlaid by a foot of dirty coal, in the lower seam. About 100 yards up-stream, a cutting proved that the lower seam thins to 16 inches. In a branch nala, about 100 yards further north, the same seam is only 12 inches thick, but thickens to 2 feet, and further on is again seen with a thickness of 3 feet. About 100 yards down-stream from the point where the two seams are exposed in one section a cutting in the left bank exposed the lower seam, 9 feet thick, but it thins in 10 yards to 1½ feet. On the opposite bank, the seam, with a fairly constant thickness of 22 inches, can be traced for about 150 yards down-stream. On the left bank again, and about 50 yards further down, the thickness is still 22 inches. The section, at this point, exposes the interesting examples of faulting illustrated in Plate XI. About 100 yards down-stream, a tunnel, 13 feet in length in the right bank of the stream, exposed the upper seam with a thickness of 2 feet. Assays of six samples of coal from this neighbourhood yielded ash varying from 18 to 26 per cent, but another sample, from the upper seam, gave as high a percentage as 42.”

“This field is the most promising of those on the west of the Chenab. The quality of the coal appears to be, on the whole, fairly good. Its thickness, as elsewhere, is variable, but may be considered, as a rule, workable, seeing that the low dip of the beds to the south would allow of free drainage. I do not consider that any reliable estimate of the quantity available can be given, but taking the length of the roughly semi-circular outcrop as one mile and presuming that the thickness of the coal averages 2 feet, and that a 70 per cent. extraction might be made, the amount available, within half a mile of the outcrop, would be rather more than three-quarters of a million tons.”

“The distance of the field from the railway terminus at Jammu (40 miles direct, over very difficult country) renders it extremely doubtful whether the profit from the working of the coal would ever repay the capital expended upon the construction of a railway line.”

#### *Mineral Survey Discoveries.*

A feature in which the Metka coalfield is unique is that the coal-bearing strata, which occupy the flat arch of the anticline in the expanded

Natural sections in river  
cliffs.

portion of the valley, have been eroded by the streams into a set of little cliffs. These are frequently clean-cut vertical escarpments, bare of all vegetation, and sometimes as much as 200 yards long and 20 to 30 feet high. They are illustrated in Plate 16 and their positions are marked on the map by the letters A, B, C, D, E. They have exposed to view very perfectly the lower and middle seams of the Upper Measures together with their associated strata.

A full vertical section up through the whole sequence of formations will now be described in ascending order, beginning with that revealed by boring No. 1. The lowest point reached by that boring was 105 feet below the surface, which just there lies at the 2,710 ft. level. After 5 feet of the Great Limestone (lettered p in the Vertical Sections Pl. 15), a hard grey siliceous limestone, there followed upwards about 14 feet of fine-grained slightly carbonaceous grit (marked o in the Sections) speckled with white grains and containing some pyrites. This, which may represent the Lower Measures here, was succeeded by nearly 50 feet of compact, very slabby and fissile grey shales (n) of uniform composition, except that at the top they become carbonaceous and with large spherical concretions of pyrites  $1\frac{1}{2}$  inch in diameter (m). Here we leave the boring and take our evidence from the cliff sections.

The firm slabby shales (n) are particularly well exposed as a flat floor over which the western or main stream flows in the proximity of cliff C.

A little way above these comes the first or lowest bed of coal (l). This is first poorly exposed in the main stream at the most northern point of the outcropping Coal Measures, next at cliff C, and running up the side stream there from the west, also at the base of cliff B and in cliffs D and E. The intermediate places, where the outcrop of this lowest coal seam is inferred to follow, concealed by alluvium and talus, are shown by the lower set of black dots on the map (Pl. 13). At cliff D and a little south of E the seam disappears by dipping at low angles to the south under the

overlying beds. A little north of cliff E it similarly disappears under the higher beds in that direction.

This bed is of considerable richness, having a fixed carbon percentage of between 80 and 83 (see Tables of Analyses p. 96). A rich bed of thickness 2 to 8 or 10 feet. It varies in thickness between 2 feet and 8 or 10 feet. Most of the coal, in the folding of the rocks, has evidently become crushed and kneaded up, or much traversed by bright shear planes, and reconsolidated again by pressure of the superincumbent rocks after the folding movements had ceased. It is soft and easily crumbles again under any hard treatment. Briquetting will be necessary before it can be burnt.

The lowest coal bed is followed upwards in the sequence, as shown in the Vertical Sections and every-where in the cliff exposures, by 5 or 6 feet of carbonaceous shales (j) and with large nodules of siderite and pyrites in layers at the bottom (k) and otherwise distributed at random among them. This is followed above by 3 or 4 feet of a massive sandy and ferruginous bed weathering and splitting into loaf-like masses and with hematite concretions at the base. This is succeeded above by 5 feet of shales (h) to (d), bearing midway two very regular lines of small cake-like flattened concretions of granular siderite (g) and (e). These cakes and nodular lumps of iron ore, which are a little bigger than the fist, form a disseminated but locally rich ore of iron that would probably be extracted with the coal beds and might be useful.

Next comes the middle coal seam (c), shown in all the cliff exposures except E, and indicated on the maps as following round and above the lower coal seam by a black line and a second series of black dots where superficially covered. Like the lower bed, its outcrop, where it disappears under the next beds above, V-s or loops up or down the main stream and side streams. Its horizon is 12 to 15 feet above the lowest coal seam and it varies from just under 2 feet thickness in A and C cliff exposures to 2½ feet in B. It is firmer in character than that of the lowest coal and

so keeps a fairly regular and uniform course and thickness wherever it is well seen as in the main cliff exposures. It is less well seen in the side nalas where its identification was only rendered possible by reference to the characteristic sequence of the beds below and above it: A long trench was opened up (pit 2 on the map) near "camp" and its quality was proved to be good. Its ash percentage is from 10 to 17 and fixed carbon from 60 to 74 (see Tables of Analyses p. 95—96). It is extractable in very firm lumps with some slack and it was burnt in a grate with excellent results and without the necessity of moulding it into briquettes first.

Above the middle seam of coal we find, in cliff exposure A, 11 feet of shales (b) with some nodules of siderite, and then appears a bed of coal which I have called the upper seam (a). It is  $3\frac{1}{2}$  feet thick at the S. E. end of exposure A through a length of 50 feet. But beyond that owing to a covering of surface soil and fallen rock from the Nummulitic scarp above it cannot be recognised.

This coal bed is fairly firm and can be extracted in lumps. Its quality is moderate (see Table of Analyses p. 95—96) containing as it does only 58 per cent. fixed carbon and 28 per cent. ash. Still it makes a useful fuel.

At this stage in the description of the vertical section difficulties arise, inasmuch as we have reached the upward limit of good clear exposures in the cliffs. The hill-sides now slope gently back, and their covering of scree, rain-wash and slipped material only allows a glimpse here and there of the solid rocks underneath. Shales as a whole continue, but it was not very clear when the author was working there in 1926, whether or not there were more than one coal seam represented above the middle seam. It appeared likely that the upper bed or beds were not everywhere continuous, but sporadic by thinning out or by change to carbonaceous shales. Traces of a bed or beds of coal occurring at higher levels than the well-defined middle seam were undoubtedly found at many other places besides cliff A, for

instance at the top of cliff C, in the main stream-bed in the neighbourhood of pit 4, at several places near pits 5, 5 a., 3, 2, 1, and 1. a. that is to say at various places all round the exposures in the main valley; but whenever more than one seam appeared at varying apparent horizons, the difficulty was to say positively whether or not this was due to reduplication by surface slipping and subsidence. Boring No. 2, which started in the well-marked horizon of a yellow massive limestone (generally accepted as the base of the Nummulitic Series), will be seen from the vertical section to record a 2-feet bed of coal (a') as the highest coal bed. There is also a trace of coal 30 feet below this and 12 feet above what has been correlated as the middle seam.

During a short subsequent visit paid by Mr. Labhu Ram to this field in 1928 endeavours were made to get further information regarding this upper bed or beds. He came to the conclusion that there were about 4 coal bands or sets of lenticles coming between the middle seam and the Nummulitics and varying in thickness from 1 foot to 5 feet. Evidence for these was derived from fresh excavations made at the above recorded points. The thickness of these Measures above the middle seam he believed to vary from 60 feet to 25 feet and he thought this might be due to overlap of the Nummulitic Series. It is clear that the difficulties in the way of appreciating the true state of affairs in connection with these uppermost seams can only be settled after more intensive proving to the deep has been carried out.

From the analyses of the few samples of these upper seams given in the Tables (p. 95—96), the coal, here as at Kalakot, appears to be variable and probably contaminated. The average ash percentage works out at 32, so that after washing and briquetting we might be able to reckon on an average of 2 or 3 feet of second class fuel.

### *Conclusion.*

The total results of the examination of this coalfield are of some theoretical and practical interest. Although no Lower Measures have been

Three coal horizons at least in Upper Measures.

demonstrated in the one boring which penetrated down to the Great Limestone, the Upper Measures agree with those in the Kalakot coalfield in showing three separate coal horizons at least, and there may be more. Most of the coal is friable, and will need briquetting, but some of it, especially that of the middle seam is fairly firm.

The anthracitic character of the coal and its quality are on the whole much the same as at Kalakot.

Character and quality of the coal.

The amount of coal available in this field may be spread over a wider area towards the south than at Kalakot, because of the more gentle dip in that direction. We may regard it as equal to one square mile. This, with an average thickness of 5 feet of coal, would promise about 5,000,000 tons. But it should not be overlooked that the area near the crest of this flat anticline might be capable of a much greater extension in directions W. N. W. and E. S. E. that is to say along the strike. It might then be possible to work out the coal in these directions all the way into connection with the neighbouring fields of Kalakot and Mahogala, in which case the amount of coal realised would be very much more than the figure given above of five million tons.

Amount of coal.

There is also always the possibility of striking, at some point or other in the area, fresh incropping basins of the Lower Measures within workable depths. These possibilities are merely mentioned here with all due reserve. They are not included in the calculations for estimating the available tonnage at present.

### MAHOGALA COALFIELD.

This coalfield, as regards position, bears the same sort of relation to the Metka field that the latter does to the Kalakot field. A ridge of the Murree Series occupies the intervening area, and this ridge it is only necessary to imagine as planed away and then the two coalfields would be united into one, just as we found,

Connection with the other coalfields.



would be the case with the Metka and Kalakot fields. As things are at present, however, the surface arrangement of the outcrops of the Coal Measures at Mahogala form a completely closed ellipse with long axis E. by S. and W. by N.

The map (Pl. 17), which is reduced from the original to a scale of 1 inch to 600 feet and with 50 feet contours (that is to say to the same scale as those of both the Metka and Kalakot fields reproduced in this report), shows the details of this coalfield and the relative magnitude they bear to those of the companion fields. The coalfield will be seen to be situated about 1 mile from Metka, its centre being in lat.  $33^{\circ} 12\frac{1}{2}'$  and long.  $74^{\circ} 29'$ . The average height of the coal-bearing strata is much the same as in the neighbouring areas, and the central elliptical dome of Great Limestone is cut through by a nearly vertical gorge (the exact counterpart of the Kalakot gorge) running S. by W. and through which the Nihari Tawi flows. At the southern end of this gorge the main stream is joined by side streams both from west and east, which help to mark out the surface limits of the coalfield and so repeat very faithfully the orography of the south-east Kalakot dome and, in a less degree, that of the Metka field. At this point of junction the level is 2,350 feet, which is somewhat lower than that of its two prototypes.

The village of Mahogala is situated on the western edge of the ellipse, separated by but a short distance from the neighbouring village of Aiji on the bridle-road going to Metka. Other scattered habitations may be seen near Gali Ban on the banks of the main stream and eastwards along the main line of communications towards Amali Gala and Nanura.

The outer boundary of the map depicts the encircling Nummulitic strata, the Murree Series, which in turn surrounds the latter, not being shown for the sake of economy of space. The ellipse of Great Limestone and the overlying Coal Measures show much the same features as at Kalakot, except that there is no fold-fault along the northern edge. They represent the projection at the surface of

an anticline having, in the Coal Measures, dips of  $30^\circ$  and  $35^\circ$  on the south and  $40^\circ$  to  $50^\circ$  on the north. These angles are considerably steeper than those of the Metka and Kalakot fields. To a large extent the dome-like aspect of the central limestone mass, both here and at Kalakot, is due to the encircling more elevated Nummulitics and Murrees which spread away east and west, but the relief contours show that some of this aspect is real—that there is a certain, if small, pitching of the axis of the anticlines at each end of the ellipses of outcrop, sufficient to warrant the term elliptical dome applied to these structures.

In one or two respects the strata overlying the Great Breccia and Bauxite Limestone show differences, especially as compared with Kalakot. It will be noticed that very little of the Breccia makes its appearance, it being confined to a single patch between pits 8 and 7 and a few traces (too small to map) near Mahogala ; whereas the Bauxite Series (excluding any good bauxite) is much more in evidence, enabling it to be shown on the map in an almost complete ring, except where covered by alluvium and other surface accumulations.

#### *R. R. Simpson's account.*

Mr. Simpson's description of this area is somewhat fuller than those I have quoted previously. I again give them verbatim for the sake of completeness, although the difficulty of following his progress by a sort of "dead reckoning" from point to point is manifest here also :—

"Commencing on the north side, for about one-third of a mile to the eastward of the river (2,500 feet), the measures are obscured by cultivated ground, beyond which, in the higher ground, coal is first seen. A cutting, 6 feet deep, exposed the following section :—

Coaly shale and clay .....	3' 0"
Coal .....	8' 0"
Coaly shale.....	1' 0"

The dip is to N, 20° E. at 65°. An assay of the coal from the 8 feet bed yielded 87 per cent. of ash.

At a point about 500 yards to south-east the seam is exposed in the high bank of the Ganoe stream. Two cuttings were made. The west cutting was driven 8 feet in a thick outcrop of soft coal of which the exact thickness and dip were not ascertained. Only 30 yards to the east the seam was found to be only 1½ feet thick and lying almost horizontal. The coal removed from these cuttings, being intermixed with pyrites, took fire spontaneously, and burnt with a choking sulphurous odour.

At a point 350 yards higher up the stream, a pit has been sunk during former explorations. It was commenced in the shales overlying the coal seam, and, judging from the amount of spoil, must have gone to some considerable depth. Local tradition fixes the depth at about 100 feet, and does not record the finding of coal.

Some 500 feet south of the two cuttings last mentioned, the seam was again exposed in a cutting, but the thickness is only 15 inches. One hundred yards to south-west, a drive, 10 feet long, proved coal, 2 feet 10 inches thick, dipping gently to S. 20° E. On continuing this tunnel to a distance of 14 feet, the coal gradually changed into soft shale containing thin threads of coal. One hundred yards to the west the coal seam, as proved in a 10 feet tunnel, is 3 feet thick; whilst about 50 yards still further west, the same thickness was exposed. From this point, the outcrops begin to descend towards the Aneari Taw stream, 350 feet below. About 50 yards from the highest elevation of the outcrop, a tunnel, 18 feet in length, was driven in coal thinning from 3 feet to 1 foot 10 inches, and dipping south at 20°. An assay of a sample from the face of the drive gave only 11 per cent. of ash. In a cutting 8 feet deep, some 400 feet further west, the seam is 2½ feet thick, and dips at 45°. Some 300 feet further on, a drive, 14 feet in length, was made in coal thickening from 2 feet 8 inches to 3 feet. The coal from this drive is hard and of good appearance. On assay it yielded less than 8 per cent. of ash. Thirty yards further on, coal is last seen, and from this point down to the Aneari Taw, about a third of a mile, the ground is covered by talus, whilst in the bed of the stream a considerable thickness of alluvial deposits obscures the outcrops of the Coal Measures."

"Between the stream and the village of Mahowgala—about half a mile—the measures are not well exposed. In two or three places a coal band, 1 foot thick, is seen in the clays underlying the coal horizon. Just below the village, the outcrops attain their highest point west of the stream. Near here, a tunnel was driven on the coal seam to a distance of 13 feet. The seam

dips north at 35°, is 19 inches thick, and assays only 6½ per cent, of ash. One hundred and fifty yards to the east, a cutting, 8 feet in length, exposed coal exceeding 6 feet in thickness and dipping to the north at 20°. An assay of the coal yielded 8 per cent. of ash. From this point down to the Anari Taw, on the east, a distance of about 300 yards, the Coal Measures are well exposed in the cliff, and coal is seen over practically the whole distance. As was occasionally observed in the Sangar Marg field there are two seams, the upper of which varies from 6 to 12 inches in thickness, and lies about 20 feet above the lower or principal seam. The results of excavations in the lower seam over this ground, may be summarized thus :—

Serial No.	Distance driven in feet.	Thickness of coal, in feet.	Dip.	Ash.
I	12	Exceeding 4	—	—
II	21	½ thickening to 3	—	—
III	6	2	35°	—
IV	6	1½	48°	12½%
V	12	5 thinning to 4	20°	—
VI	7	2½	—	13%
VII	7	5½	45°	—

“In this field the quality of the coal is undoubtedly good. The thickness of the seam is, however, extremely variable. The height of the outcrop maintains a fairly general level, and practically no coal is available above free drainage level. In order to work the coal deep shafts and probably heavy pumping would be necessary. Under these circumstances I am distinctly of the opinion that mining on an extensive scale would not be profitable.”

#### *Mineral Survey Discoveries.*

Corresponding to the greater detail given in R. R. Simpson's report, the Mineral Survey have not done as much opening up of this  
 A definite advance.

coalfield as has been done in the previously described areas and no boring at all has yet been carried out. Such work as has been accomplished will now be briefly recorded. It, together with the large-scale map and some sections, nevertheless, mark a definite advance in our exact knowledge of the field.

My own experience of this area is based on two brief visits made in 1919 and 1927. Most of the details of survey work done. field work has been done by my two present assistants. Of this, Mr. Labhu Ram made the first general map on a scale of 4 inches to the mile whilst engaged on the Bauxite Series in 1922, and he subsequently did some pit-sinking and measuring of sections in 1928. Mr. Sohani Ram is responsible for the full detailed mapping, as shown on the large-scale map given with this report, and for most of the description.

Below is given in descending order a generalised tabular statement of the whole series exposed between the base of the Nummulitic Series and the Great Limestone.

		ft. in.		
		Yellow and grey NUMMULITIC LIME- STONE and SHALES.....		
UPPER COAL MEASURES.	(14) Sandy, ferruginous and carbonaceous shales ...	9	6	
	(13) Coaly black shales.....	1	2	
	(12) UPPER COAL BED ...	{ Coal.....	2	2
		{ Clay.....	0	10
		{ Coal.....	3	6
	(11) Sandy carbonaceous and ferruginous shales...	7	10	
	(10) Shelly bed.....	2	0	
	(9) Carbonaceous sandy and ferruginous beds.....	12	0	
	(8) Thin COAL layer .....	0	2	
	(7) Carbonaceous shales with siderite nodules at base.....	11	10	
(6) MIDDLE COAL BED..... 1 ft. 4 in. to	2	4		
(5) Carbonaceous shales with siderite nodules and hard sandy ferruginous bed ('loaf' bed)..	20	0		
(4) LOWER COAL BED .....	? 3 ft. 4 in to	6	0	
(3) Fissile grey shales with 2 ft. cone-in-cone structure.....	40	0		

		ft. in.
LOWER COAL MEASURES.	{	(2) Hard sandy or gritty ferruginous bed and hard dark grey carbonaceous and siliceous shales... 44 0
	{	(1) Hard carbonaceous rock (bauxitic clay) with 2 layers of coal near top ... 1 ft. 6 in. to 3 4
	{	Basement of BAUXITE SERIES or BRECCIA overlying GREAT LIMESTONE.....

It will be seen from the above that the Lower Measures are Lower Measures poorly definitely, though feebly, represented here. A very noticeable instance of this occurs in the form of little patches of hard resistant coal left sticking on the bare dip-slope surface of the Bauxite Series in the stream-bed north of Mahogala village. Its quality is evidently poor owing to admixture with bauxitic clay. The bauxite sheet is bounded on the north by a little cliff where the Coal Measures are continued, the whole dipping here at 25° northwards.

As in other places in the Kalakot field one cannot say just Possibility of thickening where the Lower and Upper Measures to the dip. come into contact at this point; but it might be well, in the future proving of this field, to drill some little way to the north to see if any thickening of the Lower Measure coal takes place to the dip.

At a few other places coal, lying directly above the Other localities for Lower Bauxite Series, indicates the presence, Measure coal: though much modified and reduced in thickness, of the Lower Measure coal. One of these places is south of pit 8 at the north entrance to the east gorge in the Great Limestone. Here, in a well-exposed little cliff, ferruginous bauxite lies on the Great Limestone and is followed by grey compact bauxitic clay, which is again followed by a few feet of poor coal with 39 per cent. ash and some shales, the whole dipping about 55° N. E. Other places where this coal is found in direct succession to the Bauxite Series are south of pit 7 and E. by S. of pit 10. At the latter place the ash percentage yielded on analysis was 46.

In connection with the possibility of exploring these Lower Measures with the drill in a northward direction, it should be mentioned that the rather steep dips in the overlying Nummulitics on this side of the Mahogala ellipse quickly give way, as seen in the river cliffs near Gali Ban, to irregular and repeated folds which expand the outcrop of the Nummulitics just here to a width of a quarter of a mile. Thus the depth at which the Coal Measures, if present, could be explored would not be so great as might be expected from the steep dips near the Great Limestone.

All three seams of the Upper Measures are represented in Mahogala coalfield and are traceable all round the Great Limestone dome, except at a few places where they are concealed under alluvium, cultivation or talus, especially near Gali Ban and at the southern edge of the coalfield.

On the north side of the dome on the high ground east of the Nihari Tawi the upper coal bed has been well explored at two places. At the first of these at pit 3 there is a thickness of 5 ft. 8 in. of good coal with an average ash percentage of 18 in a 6 ft. 6 in. bed with 10 inches of clayey parting below the upper two feet. Similar results were got at pit 6 but the excavation here was hampered by cultivation. Digging was also carried on at a number of other places such as south-west and north of Mahogala, at pit 2, west of pit 3, near pit 8, north-east of pit 9 and at pits 4 and 5, to prove the continuity of this upper seam, but not sufficiently to prove its quality and thickness. The only analysis done is that of pit 5, where the ash percentages of three one-foot samples were 62.58, 57.74 and 4.92 the samples having been taken in above order from the top downwards.

As compared with the upper and lower seams the middle bed is better exposed and over a greater distance. This is partly due to the association of hard beds above and below it. Eastwards of

the Nihari Tawi in the ground referred to in the previous paragraph this middle seam keeps up its thickness of 2 ft. 4 in. all through. On the western side of the Nihari, at a point near where the main road crosses the river, however, this seam was noted to be 1 ft. 4 in. only at the surface outcrop. The ash percentages at pits 7 and 9 were 12.97 and 16.80 respectively.

The lower seam of these Upper Measures was explored by extensive trenching at three points marked on the map as pits 7, 9 and 5, in the rather flat-lying ground at the south-east angle of the coalfield. Pits 7 and 9 yielded 5 ft. 6 in. thickness of coal which appeared quite good all through, and this is borne out by the foot-by-foot analyses, those of pit 7 giving an average of 4.5 per cent. ash, the highest percentage being 8.0 and the lowest 3.02, and those of pit 9 giving the same average, 4.5, the highest being 10.02 and the lowest 1.32. On the western side of the Nihari, near the river crossing, at pit 10, the lower seam increased from 2 ft. at the surface to 3 ft. 4 inches at a distance of 7 ft. within. The three foot-by-foot analyses reckoned from above downwards gave 5.36, 8.47 and 9.24 ash percentages. (See Table of Analyses, p. 97—99).

### *Conclusion.*

Although coal, evidently belonging to the Lower Measures, has been identified in this field as occurring in the form of thin patches and beds in its usual position associated with the Bauxite Series, there is not enough of it actually seen or suspected to warrant our reckoning on any supply of practical value coming from these Lower Measures

The Upper Measures, on the other hand, especially at the northern and north-eastern edges of the field and in the eastern corner along the stream coming from the direction of Nanura, promise a good supply of excellent coal.

The coal is remarkably black and brilliant, but its soft, powdery or flaky condition will necessitate briquetting. The chemical composition

Colour softness and brilliancy.



indicates a coal of the same anthracitic character as generally found in the previously described fields, and the low percentage of ash (especially marked in the lower seam) testifies to its purity.

In the absence of evidence afforded by boring operations in the southern part of the field, and from the somewhat steep and irregular dip, it is a little difficult to calculate the amount of coal that will be available to moderate depths. Reckoning the length of the outcrops on the north, north-east and south-east part of the field, where the three Upper Measure seams are in evidence, to be two miles, and assuming that we can work downwards to the dip to  $\frac{1}{4}$  mile outwards from the outcrop, the total area is about  $\frac{1}{2}$  square mile. Allowing also that the total thickness of coal from these beds to be 12 feet and reducing this to 8 feet to allow for loss owing to its powdery condition we get about 4,000,000 tons reasonably in sight. There may be much more if the present unknown south and south-west edges of the field also be proved by the drill to contain coal, and still much more if it is found feasible (as seems very likely) to work the intervening area between it and the Metka field, where the overlying arch of Nummulitics and Murree lies flatly. Similar remarks apply to the south-east corner of the field in the direction of Nanura, where the sharp V-ing in that direction of the Coal Measures and Nummulitics up a rather shallow valley is the expression of a flattening out of the dip in that direction too.

### CHAKAR COALFIELD.

Between the well-defined Mahogala coalfield and the more wandering outcrops of the Chakar coalfield there lies a stretch of country some 4 or 5 miles long where the Coal Measures do not actually appear at the surface. Their presence, below the surface at a certain known depth is, however, indicated by occasional strips of the Nummulitics, which make their appearance near the village of Galhan and Nara Majra in the valley of the Tanna Tabi. These have the form of crests of extremely compressed anticlines pitching towards the west-north-west and continuing, *via* the Galhan-Teru and Nara Majra—Sojanpur directions, as the axes of folds, into

connection with the two northern of the digitate loops of Nummulitics and Coal Measures as shown on the outline map (Pl. 7) at Chhapparbari and Chakar respectively.

It will eventually be necessary to drill these strips of Nummulitic strata before it can be known for certain that the Coal Measures underlie them and so link up the Mahogala and Chakar areas.

Drilling necessary to prove the measures.

The village of Chakar lies in lat.  $33^{\circ} 11'$  long.  $74^{\circ} 36'$ .

Position and general remarks. In this area we touch the north-western edge of the great Riasi dome. In addition to the two digitate outcrop loops already referred to at Chhapparbari and Chakar, the outline map shows one or two more smaller loops in a southerly direction until all are eventually cut off by the fault at the south-west edge of the Riasi dome, already alluded to (p. 7). In the opposite direction, that is along the northern side of the Riasi dome from Sojanpur and Chhapparbari, the outcrops of the Coal Measures and Nummulitics form a narrow strip which expresses the fact that, on this northern side of the dome, the strata are inclined very steeply. As working the coal along this steeply dipping part is problematical, at least as far as Panhasa or Chinkah, the Chakar field, although structurally a part of the great Riasi ellipse, becomes naturally circumscribed between the Sojanpur loop and the southern boundary fault.

#### *R. R. Simpson's account.*

The following paragraphs, relating to this coalfield are taken from Simpson's memoir :—

“ At Sojanpur the Coal Measures bend sharply round to the east and run towards Chakka. About a quarter Sojanpur synclinal. of a mile from Chakka a coal outcrop 15 inches thick is seen, but cannot be traced far. Near the tank at Chakka the beds bend abruptly round the eastern end of the syncline and run west. At the bend coal is exposed in several places. A cutting, 9 feet in length, in the bank of a stream, at a point 550 feet north of the tank, exposed 18 inches of coal overlaid by 5 inches of coaly shale. This cutting is situated at a point 150 feet to north  $30^{\circ}$  east, from a pit sunk by Mr. La Touche in 1887. This pit had been filled in, but I had the debris removed to a depth of 49 feet without finding the bottom of the shaft. The coal seam is found at a depth of 41 feet

and is only 15 inches thick and overlain by 6 inches of carbonaceous shale. An assay of a sample from the coal in the pit yielded 27 per cent. of ash, or 6 per cent. less than the result yielded by the coal obtained from the cutting in the outcrop. About 1,000 feet west of the tank, a drive, 9 feet in length, proved 2 feet 10 inches of coal which on assay yielded less than 7 per cent. of ash. Five hundred feet further west the seam has thinned to 15 inches, and this thickness obtains for about 1,000 feet further to the west, beyond which point the seam appears to die out. About three-quarters of a mile from Chakka, the measures sweep round southwards over the top of the main anticline. No coal is exposed."

"After passing down from Chakka over the top of the main anticline the Coal Measures again bend round to the east in the direction of Brehal (1 mile W. by S. of Chakar). At the bend, in the bank of a small stream, the coal seam is excellently exposed. It is 20 inches in thickness and dips  $35^{\circ}$  in a direction S.  $20^{\circ}$  W. Two hundred yards to north-west the thickness is only 12 inches, whilst 60 yards down stream an exposure shows 2 feet of coal lying almost directly on Nummulitic limestone, and dipping south-west at  $45^{\circ}$ . This unusual position of the coal is probably only explainable by faulting."

"At a point 150 yards to the east, a drive exposed  $3\frac{1}{2}$  feet of coal dipping south-west at  $43^{\circ}$ . One hundred yards further east the seam is  $4\frac{1}{2}$  feet thick, whilst about 80 yards still further east only a few inches of coal is found in vertical and contorted shales. About 150 yards further on, a cutting exposed a thickness of 7 feet of coal, dipping S.  $10^{\circ}$  W. at  $30^{\circ}$ . A fault of 3 feet throw, which occurs here, probably accounts for this increased thickness, for only a few yards away a pit, 18 feet deep, proved only 11 inches of coal dipping S.  $20^{\circ}$  W. at  $50^{\circ}$ . From Brehal, the outcrops ascend the slope to the north-east for about 350 feet vertically, and from thence descend steeply to the east towards the Tawi stream. At their highest elevation, and at a point where the path from Ransu joins the path from Brehal to Chakka, coal is exposed. A cutting, 6 feet deep, proved  $3\frac{1}{2}$  feet of coal, which on assay yielded only  $4\frac{1}{2}$  per cent. of ash."

"On the steep descent towards the Tawi stream, coaly traces are seen in several places. A large number of cuttings exposed shaly coal varying in thickness from a few inches to 2 feet. Near the Tawi stream, at 2,700 feet, the rocks are obscured by alluvium. Near the village of Ransu, and about one-third of a mile east of the Tawi a pit, 10 feet deep, exposed 4 feet of shaly coal, dipping S.  $25^{\circ}$  E. at  $75^{\circ}$ . About half a mile further east, on the top of the ridge between Ransu and Kori a cutting, 5 feet deep, proved 15 inches of coal in vertical rocks. An assay of the coal yielded 28 per cent. of ash. For fully three-quarters of a mile further east no coal is exposed."

“At Kalamitti, the band of coal-bearing rocks bends sharply round the eastern end of the Bugoola synclinal and runs back westwards. At the bend there is much disturbance of the beds, and coal is extensively exposed. In this neighbourhood, six cuttings and pits exposed coal varying from 2 to 6 feet in thickness. A sample from a cutting showing 2 feet of coal yielded 25 per cent. of ash, whilst 50 per cent. of ash resulted from the assay of a sample from a cutting showing 4 feet of coal.”

“In the steep nala leading westwards from Kalamitti, four cuttings exposed shaly coal from  $1\frac{1}{2}$  to 6 feet thick. Near the village of Kool, the Coal Measure rocks curve round the western end of the old limestone ridge, which here forms so conspicuous an object in the landscape, and run to the east. On the village lands a pit, 17 feet deep, exposed  $4\frac{1}{2}$  feet of coal which on assay yielded 35 per cent. of ash. The dip is vertical. At a point 150 yards further east, cuttings proved from 2 to  $4\frac{1}{2}$  feet of coal. About a mile further on, coal is again seen. It is shaly, and the beds are much disturbed. A little further east the Coal Measures are faulted down and disappear.”

Mr. Simpson summarises his opinion of the Chakar area as follows:—

“The Sojaupur Synclinal—Over this ground the seam, except in one place, is too thin to be workable. The exception occurs at a point near Chakka where the coal is nearly 3 feet thick, and yields only 7 per cent. of ash. On either side, however, the coal thins in a short distance to 15 inches.”

“The Bugoola Synclinal—From Brehal as far as Kalamitti the quality and thickness of the coal is too variable to afford any hope of its being profitably mined. On the southern side of the syncline a considerable thickness of coal is exposed in several places, but it is found that wherever the seam exceeds about 2 feet the quality of the coal is inferior. I have little hope, therefore, that mining in this area would prove to be commercially successful.”

### *Mineral Survey Discoveries.*

The Mineral Survey has not done much exploration in this field, except for incidental observations only made. made during the detailed survey of the bauxite deposits of Chakar. Plate 7 of the published Bauxite Report shows within a limited area some of the coal outcrops as they occur in the vicinity of the bauxite. A few old trenches and one or two new ones were opened up by my survey, but

the greater part of this field still remains to be investigated in detail. Some of the pits show good seams of coal of between two and three feet in thickness.

The crinkled edge of the Coal Measures between Sojanpur

A rather large area of and Krul, which causes the looped outcrops, feasible coal working. has given rise to an alternation of syncline and anticline, three times repeated, which, with moderate to high dips of from 25° to 45° or 50°, should present a rather large area of feasible coal workings. Although sometimes high, these dips are generally less than those found in the Jangal Gali and Ladda areas.

The absence so far of systematic detailed surveying on More than one seam specially prepared large-scale maps has indicated. not, however, prevented the testing by pits and trenches of a few places, such as those shown in the vertical sections (Pl. 19). This has shown that more than one coal seam and sometimes two or three are present in this coalfield, just as at Mahogala, Metka and Kalakot. My predecessors, La Touche and Simpson, apparently never suspected the presence of more than one coal bed throughout the area of this field, as indeed in most of the others tested by them. The fact of the matter is that here, as elsewhere among these formations in a mountainous country, surface agencies of weathering and slipping of talus debris from the concretionary and shaly layers of the Nummulitic Series, besides crumpling and differential movements of the rocks, have obscured the coal outcrops in so many places that it is only after the hill-side has been opened up to some extent that the outcrops and their full individual thicknesses come to light.

All the other coalfields to the west have yielded 2 or 3, and occasionally more, seams in the Upper Much the same arrangement as in the other fields. Measures alone. From the partial success of the pits sunk by the Mineral Survey near Chakar, I should anticipate that detailed large-scale mapping and exploration of the area will eventually show much the same arrangement in this Chakar field also, and so contribute to a better estimate of its coal content than was arrived at by my predecessors.

*Conclusion.*

From the table of chemical analyses, where a few results only are recorded, it is plain that in quality similar to that of other western fields. character and quality the coal from these Upper Measures is similar to all the coals so far described from further west, that is to say, it is anthracitic and of varying purity, the varying quantity of ash recorded being doubtless due in some instances to different degrees of contamination in the surface outcrops.

No Lower Measures coal has been noticed in this field so far.

As regards any estimate of the quantity of coal available here, it is obvious that no attempt at exactness of calculation can be made based on present data. On the other hand it would be absurd to estimate nothing for this field ; just because the evidence is general rather than particular. In the interests of the bauxite and china-clay deposits, which lie side-by-side with the coal and are of great purity and potential value, it is well to make some attempt at an estimate. The two vertical sections (Pl. 19) show respectively a total of 5 ft. 6 in. and 4 ft. 9 in. of coal in beds of workable thickness. These were the only places tested by the Mineral Survey. So far as their evidence goes ; we may perhaps reduce the above to 3 ft. thickness so as to allow for waste and local thinning away. The above, over a area of say 3 square miles between Sojanpur and Krul, should produce about 9,000,000 tons.

### REMAINING COAL AREAS WEST OF THE CHENAB RIVER.

Of the remaining areas connected with the Riasi dome, west of the Chenab River only a few details will be offered here concerning the position at Chinkah (Cherungha of Simpson's map). No systematic work was done in the intervening ground, only casual traverse notes having been taken.

If the outline map ( Pl. 7 ) and the 4-times enlarged Saro-da-bas outlier on Survey of India sheet (Pl. 10 of the al-Sangarmarg hill. ready published bauxite report) be consulted it will be seen that this intervening ground embraces, first, the little outlier near the summit of the Sangarmarg hill at Saro-dabas. This is of very small size, totalling not more than  $\frac{1}{4}$  square mile, and it is sufficient to say of it that I agree with R. R. Simpson in regarding it as negligible. Of some theoretical interest is the presence of carbonaceous layers interbedded with the quartzitic representative of the Breccia, 80 to 100 feet thick, near Malhad on the Sangarmarg hill (briefly referred to p. 44 of the bauxite report). This peculiar occurrence seems as though it might indicate the persistence of coal-forming conditions even a little lower down in the geological scale than the Lower Coal Measures, which are generally associated with the Bauxite Series. No real coal is at present known from this stage, but it is as well to keep the occurrence in mind in case future drilling operations here should detect concealed coal beds further away at this horizon.

The intervening area also embraces the long stretch of more steeply dipping Coal Measures stretching Intervening area between Chakar and Chinkah. from north of Chakar to the Chenab River at Chinkah and forming part of the northern steep limb of the Riasi dome. This has only been cursorily traversed by the Mineral Survey. I quote here in full, therefore, all R. R. Simpson's published notes concerning it :---

" Returning to the main outcrop, after crossing the Ans stream the measures enter the hilly country to the north of the Radd nala. Coal is first seen at Cherungha, where, in the bank of the Radd stream, a cutting 10 feet deep, exposed nearly 9 feet of coal, of which the upper half is of fair quality. This outcrop can be traced for several hundred feet to the east, but westward is obscured by talus. About a mile further west a small cutting exposed about 2 feet of coaly shale, dipping nearly vertically. From this point the measures ascend to Baldanu gully, from whence they descend for 1,000 feet into the Beddi nala, and again rise to Panasar. On Panasar hill, coal outcrops are found in several places. Over a distance of about half a mile, four pits were sunk in the outcrops to depths of from 6 to 10 feet. The average thickness of coal proved was 6 feet, but it is little better than carbonaceous shale. The surface dips are very conflicting, probably due to landslipping."

"In the Chersu nala, about a mile west of Panasar, coal is again seen. A cutting proved the thickness to exceed 4 feet. A similar thickness was exposed in a cutting made at a point about a quarter of a mile to the west. In the Singar nala the coal can be traced for several hundreds of feet. A cutting, 8 feet deep, exposed the coal seam,  $5\frac{1}{2}$  feet thick, dipping N.  $5^{\circ}$  E. at  $60^{\circ}$ . On the western slope of the gully and about a quarter of a mile distant, two cuttings were made. In the first, coal  $8\frac{1}{2}$  feet thick was exposed, whilst in the second the section exposed showed two bands of coal, 12 inches thick, separated by a foot of shale. The dip is steep to the north. From here the measures can be followed through Behota down to the Radd nala. No coal is exposed. For about a mile the stream is followed, beyond which the beds run up the nala to the south of which lies Boni, to Paddar. Near Boni a coal outcrop, 2 feet in thickness, is to be seen in ground which forms part of a landslip. On the way up to Paddar the measures are well shown. The shales, dipping vertically, are frequently contorted and occasionally contain coaly patches."

"A little beyond Paddar the seam is again seen, dipping north at a high angle. A cutting, 10 feet deep, exposed 5 feet of inferior coal. Between Paddar and Gool several cuttings and pits exposed shaly coal from 6 to 12 inches in thickness. In the village of Gool, the seam is not less than 6 feet thick. At 5,000 feet a small cutting again exposed the seam. On the path to Ikni gully, an irregular coal outcrop, 0—2 feet thick, is seen. On Ikni gully, coal is not seen, but about 100 yards to the north-west a thick coal outcrop is to be found. A tunnel was driven from a point below this outcrop, and struck coal at a distance of 108 feet. The seam is  $6\frac{1}{2}$  feet in thickness, and the dip is steep to the north. The quality of the coal is good, an assay yielded only 18 per cent. of ash."

"From Ikni gully the measures slant down the southern slope of the range towards Sojanpur. At a point about a quarter of a mile west of the Ikni tunnel, a thick outcrop of coal is again to be seen. The dip is vertical. A cutting to a depth of 6 feet exposed a width of 18 feet of coal. Assay showed the coal to be of inferior quality. From this point as far as Sojanpur, a distance of about two miles, the measures are only occasionally to be seen, and no coal is exposed."

### *Chinkah Boring.*

Of the two borings put down, only one reached the coal after much difficulty had been experienced owing to the fissured and concretionary nature of the Nummulitic limestone.

Difficult drilling.



The drill passed through 60 feet of Nummulitic limestone and shales and then struck three beds of coal, which were regarded by the officer in charge of the drilling as being 4 feet, 9 feet and 8 feet in thickness, respectively, separated from each other by carbonaceous shales as shown in the section (Pl. 21 ).

The coal was found in the usual crushed and powdery condition and, since no core could be extracted, the above thicknesses must be accepted with some reserve. The material itself was only collected in the calyx, and so was much mixed with sand and mud from the sides of the bore hole. The chemical analyses, which were afterwards done on this mixed material, are, therefore all extremely high in ash and not worth quoting.

This locality, which is situated on the Radd nala, 1 mile S. W. of Chinkah, was originally explored by Godwin and Simpson's work. by Godwin, who drove a tunnel from the outcrop and made a rough burning test of the coal. The place was afterwards seen by Simpson during his tour and briefly commented on as given in the preceding extract from his memoir. The latter gives two analyses of a 5 feet bed and a 3 feet 9 inches bed from this place, which show a coal of average quality with 24 and 34 per cent. ash respectively. In other respects the chemical composition indicates an anthracitic coal, not unlike those of the previously described coalfields. (See Tables of Analyses p. 85).

The cliff section leading down from the borings to the Radd nala shows about 70 feet more shales, before there comes a trace of the Bauxite Series and Breccia, followed by the Great Limestone exposed in a river cliff. The whole set of formations just here is dipping at a low angle of about 3° N. N. E. This low dip, however, can only continue for a short distance to the north before it steepens, because, in a westerly direction towards Bhaladanun, the whole series of formations dips at 50° — 60°, whilst towards the east the long dip-slope of the Salal fort hill is inclined at about 28°.

### Conclusion.

As at Chakar we must make some attempt to estimate Amount of coal in the area. roughly the amount of coal that may be expected to be got down to reasonable depths along the line of country between Chakar and Chinkah. As a whole the dip will be steeper than that found at Kalakot, Metka or Mahogala ; although here and there places, such as the Panhasa and Bhaldanun hill spurs, will be found where, with a rolling dip towards the south, the outliers on these spurs will lie much more gently inclined than elsewhere. With this steeper dip as a whole, the width of the coal bed from the outcrop that may be considered to be within workable depths will require reduction from  $\frac{1}{4}$  mile (the quantity used before in these calculations) to, say,  $\frac{1}{6}$  mile over a total length of 12 miles. Similarly, if we average up the thickness records from the data given by Simpson for this area, we arrive at about 5 feet total thickness for the coal. Reducing this to 3 feet for the same reasons as before, we have (throughout this distance of 12 miles) a workable area of  $12 \times \frac{1}{6}$  or 2 square miles ; and this at 3 feet thickness equals about 6,000,000 tons. As was the case with the Chakar outcrops, the rough estimate given above is based on certain generalizations, and it has not, therefore, the same quality of reliability that the calculations made on detailed survey work can claim for the three fully surveyed coalfields of Kalakot, Metka and Mahogala. In the summary, which is given later of the amount of our coal resources, estimated for the whole of the Jammu coal regions, this point will be further discussed.

### DHANSAL-SAWALKOT COALFIELD.

This coalfield is a new discovery made by the Mineral Survey. Lydekker's old map of this region (*Mem. Geol. Surv. of India*, Vol. XXII, 1883) shows the Subathu Series (which includes the coal and other associated formations) as entirely absent along this line of country : the outcrop of the Murree Series being drawn as impinging directly against the Great Limestone. Lydekker's view evidently was that the Subathu Series was unrepresented or faulted out. So far as known to this department, the area was

A new discovery.

equally unsuspected by Godwin as being coal-bearing and was not visited by him or any other subsequent geological explorer.

The view of the Mineral Survey (based on general structural principles) that the coal formation might well be present, was confirmed by Mr. Sohani Ram, Assistant Superintendent, Mineral Survey, after his deputation there to investigate the problem in 1924. To that officer is due the working out of the details summarised below.

If the outline map (Pl. 7) be consulted, it will be seen that this new coalfield is entirely separate from the southern group of coalfields so far described in this report, the distance between the two varying from 4 to 8 miles. This new field is in fact part of another elliptical inlier of the older rocks among the Murree Series, oriented along an anticlinal axis which is parallel to, but distinct from, the southern group of coalfields.

The village of Dhansal (5,500 feet, lat.  $33^{\circ} 12\frac{1}{2}'$ , long.  $74^{\circ} 56'$ ), where the coal was first struck by Sohani Ram, lies some 17 miles from Riasi and 8 miles north-east of the Kanthan suspension bridge over the Chenab River, with which it is connected by a good mule track. From Dhansal the Coal Measures and associated formations were traced south-east *via* Phar Gala, Barmasta, Khei and Sawalkot, and thence, after crossing the Chenab River into connection with the already known Lodhra coalfield, a total distance of 12 miles. The Lodhra coalfield was briefly described by R. R. Simpson in his memoir, pp. 34—37; but in consequence of the coal from it analysing very poor (the ash percentages varying from 59 to 78 per cent.) the Lodhra coalfield was, therefore, condemned.

A portion of the new Dhansal-Sawalkot coalfield is shown delineated on the geological map given with this report (Pl. 22). It will be seen therefrom that the normal sequence of formations, as found elsewhere in Jammu Province, is fully represented there also, it being a continuous sequence from the Great

Limestone up through the Breccia, Bauxite Series, Coal Measures, Nummulitics and Murrees. At many places, however, one or more members of this sequence are obscured by surface accumulations of debris derived from the Great Limestone ridge which towers above them to the north-east. This illustrates once more the care required in unravelling the geology of this mountainous tract and probably explains the non-detection of the coal by previous explorers.

The sequence of formations as mentioned above forms, undulating dip towards what may be deduced to be, a continuous S. W. belt along the south-western flank of the Great Limestone ridge. Although obscured locally, this set of beds dips as a whole south-west ; but in certain places, such as at Dhansal, the dip is undulating for a width of a quarter of a mile. The sections (Pl. 23) illustrate this peculiarity, which is of importance since it widens the area where coal can be got.

Our Survey has not yet examined the north-east edge of this elliptical inlier, to see whether on that side too the full sequence of formations or nay part of it is represented; but from Simpson's map of the Lodhra end of this coalfield, which shows a faulted junction as far as the Chenab River, one may provisionally accept the fault as continuing at least for some unknown distance along that north-east edge.

In the map of this area (Pl. 22 ) no attempt has been made to delineate the Coal Measures separately from the Nummulitics. This can only be done on large-scale maps. The sections exposed show much the same set of individual strata as found in the southern group of coalfields, except that the lower more shaly portion among which the coal occurs is not so thick and not so sharply differentiated from the Nummulitics above as in those other coalfields. The Nummulitics themselves are also thinner than in the southern coalfields, both they and the coal-bearing shales being not more than 200 feet thick.

The main coal seam lies directly on the bauxite, but it is not certain whether or not it represents the coal of the Lower Measures of Kalakot and

Two coal seams.

Mahogala. Forty feet above this is another thinner bed of coal with intervening carbonaceous shales and some limestone, the latter forming a bed 8 feet thick. This occurrence of limestone at a horizon between the coal seams is peculiar to this locality.

Several pits were opened by Sohani Ram in the more expanded gently sloping Dhansal area. Excavations made. The positions of these are shown on the enlarged map (Pl. 24) here reproduced on a scale of 1 inch to 200 feet. Sohani Ram describes these excavations as follows:—

*Southern Locality Pit No. 1.*—After the pit had proceeded to a depth of 6 ft., it collapsed on account of the great inrush of percolating water. For the top 4 ft., the material was uniformly of bright good character, while lower down it became much argillaceous with here and there pockets of purer stuff.

The top layers of the bed seem to have been denuded away at this exposure.

The material is characterised by the occurrence of numerous iron pyrites nodules in it.

The dip, though not very well seen, appears to be in a south-easterly direction.

*Pit No. 2.*—This excavation sunk to a depth of 10 ft. gave the following section:—

Depth in feet.		
1	.....	Black shining graphitic coal.
2	} .....	Black shining graphitic coal with lenticles of pulverised shale.
3		
4	} .....	Black shining graphitic coal (less so than 1).
5		
6	} .....	Dull black coal.
7		

8 }  
 9 } ..... Pulverised coaly shales.  
 10 }

Numerous rounded fragments of calcareous coaly shales and iron pyrites nodules were found scattered through the above section.

The graphitic coal bed, as seen here, is followed above by pale brownish coloured shales, apparently dipping at an angle of about 40° S. E.

*Excavations Nos. 3 and 4.*—Some 36 feet west of pit No. 2, a trench, 10 ft. long 4 ft. wide and 6 ft. deep, revealed below 1—2 ft. of the surface stuff, bottom 5 ft. of the graphitic coal bed, the top layers having been removed by erosion. The lower 3 ft. only comprised material of good quality while the upper 2 ft. were of a very argillaceous nature.

The dip here is very gentle approaching almost to horizontality.

Fifteen feet north-west of excavation No. 3, a pit (No. 4) proved the existence of the graphitic coal below 6 ft. of scree material.

*Pit No. 5.*—(50 ft. south-west of pit 4) 14 ft. deep, exposed the following section :—

Depth in feet.		
1 } 2 }	.....	Graphitic coal much mixed with surface stuff.
3 } 4 }	.....	Fairly good graphitic coal.
5	.....	Partly shining graphitic coal.
6 } 7 } 8 }	.....	Partly shining graphitic coal (more so than 5).

9	.....	Graphitic coal getting slightly mixed with argillaceous matter.
10	} .....	Pulverised coaly shale.
11		
12		
13	} .....	Graphitic coal fairly good.
14		

(Bauxite Series below).

The dip being very steep, the above does not show the actual thickness of the graphitic coal bed, which may be only 8—10 ft. and the rock directly underlying the graphitic coal bed, as seen in the case of all the above exposures, is bauxite, which is rather of a kaolinic nature here.

*Pits Nos. 6, 7 & 8.*—Fifty feet further south-west a shallow digging (No. 6) displayed another coal band, which being overlaid by a pale brownish coloured clay of the Bauxite Series is lower in sequence than the one already described.

Some 60 feet north of the last point another pit (No. 7) was sunk through 8 feet of talus without there appearing any sign of the coaly matter and it is probable that the outcrop of the graphitic coal bed does not extend to this point.

About 70 yards north of pit 7, a cutting (No. 8) proved 5 ft. of graphitic coal, containing as usual a few streaks and lenticles of shale. The coal bed was succeeded below by a kaolinic material full of quartzite pieces and was overlaid by carbonaceous and pale olive coloured shales.

Besides the above, traces of coal are to be seen at a few more places, but the cuttings (9, 10 and 11) made at these points showed them all to be of a derived nature, the actual outcrop being still further below the superficial overburden.

To sum up :—

The graphitic coal bed under description lies directly over—

the Bauxite Series (kaolin) and is followed above by pale coloured, slightly carbonaceous shales.

From this bed we can safely depend upon at least 4 ft. of good material, which is of an extremely soft nature and flaky structure and has a deep black colour and bright shining lustre.

The outcropping of the bottom members of the Nummulitic (Subathu) series at this locality is consequent upon a minor anticlinal folding, combined with subsequent erosion. The southern limb of the fold has a rather steep dip but the beds, soon after slightly bending over, assume northwards a very low angle of dip.

*Northern outcrop.*—A little less than half a mile N. N. W. of the locality described above, there is to be seen along the outcrops of the main anticline another exposure of the graphitic coal just at the foot of the Great Limestone ridge. Two trenches put down here side by side, exposed 3—4 ft. of coal carrying numerous shale lenticles. Thus the thickness of the actual coaly matter may be about 2 ft. only. Lying as it does over the shale beds, this coal band seems to be different from and higher in sequence than that already described and which here is completely hidden under the huge breccia blocks and other scree material. The dip at the junction with the Great Limestone is very steep, approaching almost to verticality, and even to a slight inversion particularly at the excavations just mentioned. But southward, it soon flattens to a very low angle, thus bringing the bottom members of the measures, as far as the southern locality, to a reasonable distance below the surface (see Section Pl. 23)

Following along the main outcrop in its south-eastern extension, the rocks, with the exception of one or two insignificant exposures some 750 yards beyond, continue to be obscured by talus deposit and the coal is not exposed for fully one and a half miles, until Phar Gala is reached.

Passing down south-east from Phar Gala Mr. Sohani Ram was able to locate four graphitic coal exposures, which occur



along a distance of  $1\frac{1}{4}$  miles and the positions of which are marked in circles on the map (Pl. 22 ).

*Locality No. 1.*—Here the thickness of the seam, as seen exposed on the surface is 1 ft. 6 inches. Its smaller thickness as compared with the Dhansal, southern locality graphitic bed, coupled with the fact that it overlies the olive shales, will show that this seam represents the upper bed. The material in all its characteristics resembles that of Dhansal southern locality. The rocks, having been much crumbled and crushed, the minuter structural details are not quite clear. A little above in the cliff, however, the Murrees are seen dipping S. W. at  $45^{\circ}$ — $50^{\circ}$

*Locality No. 2.*—At this locality the presence of coal was evident from the black nature of the soil. Two open tunnels placed some 30 ft. apart, approximately in the direction of the dip, were made there.

The northern excavation, which was 15 ft. long and 4—5 ft. wide, though carried down to a depth as much as 10 ft. did not show any improvement in the nature of the material and much argillaceous black stuff, with scattered thin layers and strings of purer graphitic coal, continued to prevail all through. This is probably due to contamination from the surface and it is possible the material might improve at greater depths.

Resting as it does directly over the Bauxite Series (kaolin) this carbonaceous matter represents the same horizon as occupied by the lower graphitic coal seam of the formation.

The second excavation revealed 2—3 ft. of graphitic coal occurring in irregular shaped layers within 6—7 ft. of the outcrop. This constitutes the upper seam of the series.

The beds here show a very steep, south-westerly dip, so much so that they are even slightly upturned at their outcropping edges. But southwards they soon flatten to a very low angle for a distance of about 400—500 ft., beyond which point the angle again steepens.

*Locality No. 3.*—About one-quarter mile S. E. of the locality mentioned last the graphitic coal (upper band) is again

seen, exposed along a stream bank, and is traceable for a distance of about one hundred feet. A couple of cuttings made here gave the following section :—

Rock.	Thickness.
Graphitic coal with clay (pulverised shale) lenticles.....	1 ft.
Carbonaceous clay (pulverised shale) . . .	1 ft.
Good graphitic coal.....	1 ft.
Olive shales.....	Unknown.

The material (graphitic coal) is of similar good, soft, bright nature as from Dhansal southern locality. It is, however, further characterised by the occurrence in it of lenticular pieces (2"—3" across) of the same stuff, which are of a comparatively harder and firmer nature and which so far as appearance goes resemble graphite more than any other material hithertofore seen in this area.

The dip here, though not exactly determinable, is rather steep (40°—50° S. S. W.). It seems, however, to slacken considerably northwards. The main outcrop, though concealed under detritus, is 400—500 ft. to the north, where the dip as seen in the bauxite bed is 80° S. S. W.

*Locality No. 4.*—Of all the sections that were come across in this area the section at locality No. 4 is the one where almost the full thickness of the Nummulitic (Subathu) beds is exposed. Here again the graphitic coal occurs at two different horizons, separated by 40—45 ft. of carbonaceous and pale olive coloured shales and one limestone band.

A number of excavations—the largest being 17 ft. long, 5 ft. wide and 10 to 13 ft. deep—made at the outcrop of the lower seam, which overlies the bauxite, exposed some 7 ft. of graphitic coal mixed with shale lenticles and partings. Out of this the purer graphitic coal was hardly 3—4 ft. in total thickness.

The upper seam as seen exposed in the cliff section below varies from 12 inches to as much as 3 ft. in thickness

within a distance of a few feet only. At places it splits up into two, enclosing olive shale lenticles in between.

The material in all its physical characters is similar to that of locality No. 2, upper bed.

The dip of the rocks near the junction with the Old Limestone is about  $75^{\circ}$  S. S. W.

The observations given above may briefly be generalised as follows :—  
Recapitulation.

It will be evident that the Nummulitics of the area under report bear two graphitic coal seams, one lying directly over the Bauxite Series and the other occurring some 40 ft. above it.

These seams, though varying in thickness and quality, are undoubtedly continuous throughout this whole length of 4 miles.

That the upper seam maintains an average thickness of 1 ft. 6 inches in the area between Dhansal and locality No. 4 S. E. of Phar Gala, seems, well nigh proved. But, as regards the lower seam, Mr. Sohani Ram does not think sufficient evidence has yet been obtained to enable an authoritative opinion to be given as to its average thickness, especially in the area, S. E. of Phar Gala. In order to decide this, as well as many other points when found necessary, we must resort to drilling, which, taking into consideration the soft, broken character of the rocks and also their probably water-logged nature at the coal horizons, will be safer, more economical and perhaps (for testing purposes) the only speedy means to accomplish greater depths as compared with excavations by hand.

The Coal Measures at their N. E. edge have always a very high dip and are even inverted, at places, at the junction with the Old Limestone mass. But generally soon southwards they assume a very low angle of dip for distances varying between  $\frac{1}{2}$  to  $\frac{1}{8}$  mile thus affording some space, where the graphitic coal seams may be considered to lie at reasonably workable depths below the surface.

One other remarkable fact noticed is that the exposures that occur furthest away from the limestone ridge show decidedly a great improvement in thickness of the bed as well as quality of the material.

The coal of this Dhansal-Sawalkot field in appearance and composition has some points that should be noted. It is deep black, scaly and of a bright shining lustre resembling in appearance foliated graphite. It easily falls to pieces and soils the fingers much. Its specific gravity ranges between 1.58 and 1.7.

One sample analysed from pit No. 1, Dhansal southern locality gave :—

Moisture at 100° C.....	0.50 per cent.
Volatiles .....	9.50 „
Fixed carbon.....	63.00 „
Ash.....	27.00 „

Besides being anthracitic, as indicated by the above analysis, this coal is also distinctly graphitic, the amount of graphite having been estimated by the Industrial Chemist as 12 per cent.

In view of this coalfield being a newly discovered one, the details as given in Mr. Sohani Ram's account of the excavations made have been fully reproduced here. Much more, however, in the way of analyses and mapping on a large-scale are desirable before we can be said to have fully investigated the possibilities of the field throughout its entire length.

#### *Conclusion.*

From an economic point of view the coal of this coalfield is not likely to have much value as a fuel until the southern set of coalfields which are more accessible have been exhausted. Mr. Sohani Ram has

Amount of coal in the area: particular estimate.

estimated the amount available in the areas exposed by pits as follows :—

Dhansal, southern locality, area $1/16$ square mile and 5 feet thick.....	388,900 tons.
Dhansal, northern outcrop, area $1/16$ square mile and 2 feet thick.....	155,600 ,,
Locality 2 and 3, S. E. of Phar Gala, area $5/16 \times 1/12$ square mile and 2 feet thickness.....	64,800 ,,
Total	... 609,300 tons.

This is a low estimate based only on certain areas that have been pitted. If however we make a more generalised estimate for the whole 12 miles of outcrop with a width of  $\frac{1}{4}$  mile and average thickness of 3 feet, we obtain a total for the whole field as probably amounting to 9,000,000 tons. (See further remarks p. 113).

The above concludes the systematic descriptive part of this report. Nothing will be said here about the Ladda coalfield or other areas on the east, or left bank, of the Chenab River ; because it is felt that, before any useful commentary on Simpson's detailed work in that area can be made, the whole of it should be first geologically resurveyed on large-scale plans such as have been made for the three connected fields of Kalakot, Metka and Mahogala. This work the Survey has not yet had time to undertake.

### CHEMICAL ANALYSES.

The chemical work done on the coals described in this report consists of a large number of proximate analyses. This account of it is arranged in two sets of tables which follow. Of these the first set were done in the Geological Survey of India Laboratory for R. R. Simpson and published in his memoir

Proximate chemical  
analyses by Geological  
Survey of India.

on the Jammu coalfields. These are quoted by me verbatim from that memoir which is now out of print, the additional details therein explaining themselves.

The second set were done in the Industrial Laboratory, Srinagar, for this report. These give Industrial Laboratory, Srinagar. estimations of moisture, volatile constituents, fixed carbon and ash, with occasional estimations of sulphur. Calorimetric tests were unfortunately unable to be carried out owing to the apparatus being out of order<sup>1</sup>. The specific gravity determinations were done by the Mineral Survey, the letters "W. B." indicating that a Walker's Balance was used on lumps and the word "bottle" indicating that the specific gravity bottle was used on the powdered coal—a method often obligatory on account of the friable condition of the coal.

The arrangement of the analytical data in each set is given in the same order as that adopted for Arrangement of analytical data. descriptive purposes in the body of this report for the different coalfields and the different seams there found.

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<sup>1</sup> Some calorific values since received are as follows:—

Kalakot coal, Pit 17, L. Measures,	12,240,	B. T. U's.
" " " 16, " "	13,950	"
" " " " " "	14,760	"

The first two were obtained by the Industrial Chemist, Srinagar. and the last by Messrs. Hughes and Davis of Bombay, the following calorific values have been supplied by the Government Test House, Alipore Calcutta:—

Kalakot coal, Pit 17, c. L. Measures,	12,967,	B. T. U's.
" " near " 17, f. " "	10,248	"
" " " 16 " "	13,565	"
" " " 17, a. b. " "	10,849	"

(Analyses by R. R. Simpson done in Geological Survey of India laboratory).

THE KALAKOT COAL-FIELD.

Locality.	Depth in feet from surface.	Section of coal seam.	Number on map. Plate 1 of R. R. Simpson's Report.	Remarks.	Moisture.	Volatile matter exclusive of moisture and sulphur.	Fixed carbon.	Ash.	Sulphur.	Evaporative factor* by Thomson's calorimeter.	Colour of ash.	Caking properties.
Kalakot ...	7	Coal 4' 0"	84	Thins to 14" in a distance of 50 ft.	0.88	10.00	78.48	10.66	.....	13.51	Grey.	Nil.
Jahlitunia	14	Coal 8' 0"	85	.....	0.96	10.60	71.80	17.14	.....	12.90	Light-brown.	"
Do. ...	10	Coal 2' 7"	86	.....	0.80	6.41	78.00	11.50	3.29	15.16	Grey.	Cakes poorly.
Jigni ...	7½	Coal 6' 0"	87	.....	2.58	7.76	56.74	32.92	.....	12.69	Brownish-red	Nil.
Kargala ...	6	Coal 4' 0"	88	.....	8.98	15.70	52.40	22.92	.....	.....	Red.	"
Sonjpir ...	2½	Coaly shale 0' 6" Coal 2' 6"	89	Sample from the coal band.	0.76	9.64	59.08	30.52	.....	.....	Grey.	"
Ser ...	Outcrop	Coal 1' 8"	90	.....	1.98	11.76	70.56	15.70	.....	13.31	Grey to light-brown.	"

\* Pounds of water evaporated per pound of fuel.

(Analyses by R. R. Simpson done in Geological Survey of India laboratory).

THE SIRO VALLEY (METKA) COAL-FIELD.

Locality.	Depth in feet from surface.	Section of coal seam.	Number on map, Plate 1 of R. R. Simpson's Report.	Remarks.	Moisture.	Volatile matter exclusive of moisture and sulphur.	Fixed carbon.	Ash.	Sulphur.	Evaporative factor* by Thomson's calorimeter.	Colour of ash.	Caking properties.
Nimbal ...	21	Coal 3' 9"	77	Coal thinned to 3' 3" in a distance of 5 feet.	1.30	11.22	69.20	18.28	.....	12.90	Brown.	Cakes poorly.
Do. ...	16	" 1' 7"	78	.....	0.60	11.70	61.92	25.78	.....	.....	"	Nil.
Do. ...	4	Shaly Coal 1' 0" Coal 3' 3"	79	Sample from the lower land.	3.00	9.52	66.12	21.36	.....	12.49	Brownish-red.	"
Do. ...	6	Coal 1' 7"	80	.....	0.74	11.14	63.34	24.78	.....	11.06	Light-brown.	Cakes poorly.
Do. "	8-10	" 2' 0"	81	.....	0.70	8.14	73.04	12.06	6.06	13.72	Brownish-red.	"
Do. ...	0-9	" 4' 0" " 5' 0"	82	Sample from lower band.	0.80	11.84	67.34	20.02	.....	13.10	"	Nil.
Do. ...	13	" 2' 0"	83	.....	0.96	10.52	46.36	42.26	.....	.....	Brown.	"

\*Pounds of water evaporated per pound of fuel.



(Analyses by R. R. Simpson done in Geological Survey of India laboratory)

THE MEHOGALA COAL-FIELD.

Locality.	Depth in feet from surface.	Section of coal seam.	Number on map. Plate 1 of R. R. Simpson's Report.	Remarks.	Moisture.	Volatile matter exclusive of moisture and sulphur.	Fixed carbon.	Ash.	Sulphur.	Evaporative factor* by Thomson's calorimeter.	Colour of ash.	Caking properties.
Gance ...	6	Coaly Shale 3' 0" Coal 8' 0" Coaly shale 1' 0"	70	Sample from the middle band.	1.06	10.56	51.86	36.52	....	....	Brown.	Nil.
Do. ...	18	Coal 1' 10"	71	.....	1.02	12.52	75.20	11.26	.....	13.34	Grey.	Cakes poorly
Do. ...	14	" 3' 0"	72	.....	12.84	26.44	52.23	7.98	0.52	.....	Brownish-red.	Nil.
Mehowgala...	7	" 2' 6"	73	.....	0.78	12.04	74.14	13.04	....	13.31	.....	Cakes poorly.
Do. ...	6	" 1' 9"	74	.....	1.48	11.76	74.20	12.56	.....	13.31	Dark-brown.	Nil.
Do. ...	8	" 6' 0"	75	.....	2.30	11.94	77.50	7.76	.....	13.72	Brownish-red.	"
Do. ...	13	" 1' 7"	76	.....	3.74	13.34	76.35	6.56	....	13.31	Dark-red.	"

\* Pounds of water evaporated per pound of fuel.

(Analyses by R. R. Simpson done in Geological Survey of India laboratory).

THE SANGAR MARG COAL-FIELD.

Locality.	Depth in feet from surface.	Section of coal seam.	Number on map. Plate 1 of R. R. Simpson's Report.	Remarks.	Moisture.	Volatile matter exclusive of moisture and sulphur.	Fixed carbon.	Ash.	Sulphur.	Evaporative factor* by Thomson's calorimeter.	Colour of ash.	Caking properties.
Chimber ...	30	Coal 2' 0"	43	....	1.40	7.74	26.74	64.12	.....	.....	Grey.	Nil.
Kantan ...	5	" 5' 9"	44	Said to have thinned out to two bands 18" and 6" thick.	1.32	3.42	27.46	67.80	.....	.....	"	"
Cherungha (Chinkah)	3-6	" 5' 0"	45	.....	0.74	5.96	69.60	23.80	....	11.87	Light-brown.	"
	6-10	" 3' 9"	46	.....	2.70	8.80	55.40	33.60	.....	.....	Brownish-red.	"
Panasar ...	0-8	" 8' 6"	47	.....	1.12	9.88	3.48	79.52	....	.....	"	"
	3-12	" 8' 6"	48	.....	1.06	8.88	16.26	74.80	.....	.....	Dark-brown.	"
Do. ...	3-9	" 6' 0"	49	.....	1.04	7.88	21.48	69.60	.....	.....	Grey.	"

\* Pounds of water evaporated per pound of fuel.

MIDDLEMISS : Coal deposits of Jammu Province, Kashmir.

(Analyses by R. R. Simpson done in Geological Survey of India laboratory).

THE SANGAR MARB COAL-FIELD—(continued).

Locality.	Depth in feet from surface.	Section of coal seam.	Number on map. Plate 1 of R. R. Simpson's Report.	Remarks.	Moisture.	Volatile matter exclusive of moisture and sulphur.	Fixed carbon.	Ash.	Sulphur.	Evaporative factor* by Thomson's calorimeter.	Colour of ash.	Caking properties.
Pannsar	2-5 5-11	Coal 3' 0"	50	.....	1.12	8.20	25.48	65.20	.....	....	Light-brown.	Nil.
		Shale 3' 0"	...	Samples from coal bands.								
		Coal 2' 6"	51	.....	3.19	7.90	14.18	74.80	.....	.....	Brown.	"
Takhrakot	Outcrop	" 5' 6"	52	.....	1.14	7.46	12.52	78.88	.....	.....	Redish-brown.	"
Paddar ...	9	" 5' 0"	53	.....	1.10	8.02	22.14	68.74	.....	.....	Brown.	"
Sarodabar	Out-crop.	" 3' 6"	54	....	1.56	9.16	46.60	42.68	.....	.....	"	"
		" 3' 6"	55	.....	1.86	9.20	39.14	55.80	.....	.....	"	"
Ikni ...	45	" 6' 6"	56	.....	0.62	10.34	76.00	13.04	....	14.11	Dark-brown.	"

\* Pounds of water evaporated per pound of fuel.

(Analyses by R. R. Simpson done in Geological Survey of India laboratory).

THE SANGAR MARG COAL-FIELD—(continued).

Locality.	Depth in feet from surface.	Section of coal seam.	Number on map, Plate 1 of R. R. Simpson's Report.	Remarks.	Moisture.	Volatile matter exclusive of moisture and sulphur.	Fixed carbon.	Ash.	Sulphur.	Evaporative factor* by Thomson's calorimeter.	Colour of ash.	Caking properties.
Ikni ...	Out-crop.	Coal 6' 6"	57	.....	0.58	8.78	85.60	55.08	.....	.....	Grey.	Nil.
		" 8' 6"	58	.....	0.76	7.70	90.00	61.54	.....	.....	Do.	"
Chakka ...	7	Coaly shale 0' 5" Coal 1' 6"	59	Sample from coal band.	1.02	13.26	52.64	33.08	.....	12.49	Light-brown.	Cakes.
Do. ...	42	Coaly shale 0' 6" Coal 1' 3"	60	"	0.72	13.56	58.76	26.96	.....	12.69	Brown.	"
Do. ...	9	Coal 2' 10"	61	.....	0.60	11.39	77.06	6.66	4.29	15.35	Reddish-brown.	"
Between Chakka and Brehal ...	4	" 8' 6"	62	.....	2.50	13.98	79.06	4.46	.....	14.74	Brick-red.	Nil.
Khari ...	4	" 5' 0"	63	.....	1.72	13.44	57.44	27.40	.....	11.87	"	"

\* Pounds of water evaporated per pound of fuel.

MIDDLEMISS : Coal deposits of Jammu Province, Kashmir.

(Analyses by R. R. Simpson done in Geological Survey of India laboratory).

THE SANGAR MARG COAL-FIELD—(concluded).

Locality.	Depth in feet from surface.	Section of coal seam.	Number on map. Plate 1 of R. R. Simpson's report.	Remarks.	Moisture.	Volatile matter exclusive of moisture and sulphur.	Fixed carbon.	Ash.	Sulphur.	Evaporative factor* by Thomson's calorimeter.	Colour of ash.	Caking properties.
Ponra Camp	3-7	Coal and pyrites 0' 6" Coal 1' 8" Shaly coal 1' 6"	64	Sample from middle bed of section.	0.78	11.08	71.28	16.86	....	13.51	Grey.	Cakes hard.
Ransu ...	10	Coal 4' 0"	65	....	2.68	9.92	11.68	75.72	.....	.....	"	Nil.
Between Ransu and Kori ...	5	" 1' 3"	66	....	17.40	20.14	34.22	28.24	.....	.....	Brown.	"
Kalamitti	6	" 4' 0"	67	....	0.68	8.22	40.50	50.60	.....	.....	Grey.	Cakes.
Do. ...	7	" 1' 11"	68	.....	1.18	13.26	59.84	25.72	.....	12.90	Light-brown.	Cakes poorly.
Krool ...	17	" 4' 6"	69	.....	0.72	13.62	50.60	35.06	.....	.....	Grey.	Nil.

\* Pounds of water evaporated per pound of fuel.

(Analyses done in Industrial Laboratory, Srinagar).

KAILAKOT (LOWER MEASURES).

Localities.	Specific gravity.	Moisture	Volatiles	Fixed carbon	Ash	Sulphur
Pit 17. a. 16 ft. 9 in. seam av. of 6 analyses.		4.77	16.95	62.72	15.55	.....
Pit. 17. a. 16 ft. 9 in. bed 4th and 5th ft.	1.61 W. B.	7.21	18.81	54.12	19.86	.....
Pit 17. a. 16 ft. 9 in. 6th and 7th ft.	1.58 W. B.	3.88	18.72	58.62	18.78	.....
Pit 17. a. 16 ft. 9 in. 8th and 9th ft.	1.57 W. B.	5.82	20.78	55.62	17.78	.....
Pit 17. a. 16 ft. 9 in. bed 10th and 11th ft.	1.53 W. B.	4.62	14.54	69.44	11.40	.....
Pit 17. a. 16 ft. 9 in. bed 12th and 13th ft.	1.52 W. B.	4.02	14.28	68.92	12.78	.....
Pit 17. a. 16 ft. 9 in. bed 14th and 15th ft.	1.52 W. B.	4.14	15.92	68.26	11.68	.....
Pit 17. a. 16 ft. 9 in. bed 16th and 17th ft.	1.48 W. B.	2.95	12.95	70.28	13.82	.....
Pit 17. a. average sample.	1.46 W. B.	4.30	14.65	68.45	12.70	.....
Pit 17. b. average sample.	1.50 W. B.	5.30	16.10	66.70	11.90	.....
Pit 16. 7 ft. seam, av. of 7 ft. by ft. analyses.		0.53	13.47	74.70	11.29	.....
Pit 16. 7 ft. bed 1st foot.	1.42 W. B.	1.15	12.77	72.14	13.49	.....

KALAKOT (LOWER MEASURES).												
Localities.	Pit 16, 7 ft. bed 2nd foot.	Pit 16, 7 ft. bed 3rd foot.	Pit 16, 7 ft. bed 4th foot.	Pit 16, 7 ft. bed 5th foot.	Pit 16, 6th foot.	Pit 16, 7th foot.	Pit 12, a. 6 ft. bed 1st foot.	Pit 12, a. 6 ft. bed 2nd foot.	Pit 12, a. 6 ft. bed 3rd foot.	Pit 12, a. 6 ft. bed 4th foot.	Pit 12, a. 6 ft. bed 4th foot (another estimation).	Pit 12, a. 6 ft. bed 5th foot.
Specific gravity	1.42 W. B.	1.40 W. B.	1.39 W. B.	1.39 W. B.	1.44 W. B.	1.39 W. B.	1.53 Bottle.		1.47 Bottle.			1.73 Bottle.
Moisture	0.63	0.43	0.44	0.43	0.56	0.08	0.60	} 15.68	14.70	} 0.57	} 15.82	} 0.40
Volatiles	14.19	12.45	13.36	13.69	12.72	15.42	14.96		12.97			
Fixed carbon	70.20	78.12	78.68	77.54	70.16	76.10	47.48	69.46	67.00	65.90	64.18	36.70
Ash	14.98	9.00	7.52	8.64	16.56	8.40	36.96	14.86	18.30	20.56	20.00	48.20
Sulphur	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

(Analyses done in Industrial Laboratory, Srinagar).

Localities.	KALAKOT (LOWER MEASURES).		? LOWER MEASURES.		KALAKOT (UPPER MEASURES).							
	Pit 12. s. 6 ft. bed 6th foot.	Pit 12. s. 6 ft. bed (average sample).	Pit 12. s. 1 ft. - 2 ft.	Pit 12. s. (average sample).	Pit 1. U. seam 1st foot.	Pit 1. U. seam 2nd foot.	Pit 1. U. seam 3rd foot.	Pit 1. U. seam 4th foot.	Pit 1. U. seam 5th foot.	Pit 1. U. seam 6th foot.	Pit 1. U. seam 7th foot.	Pit 1. U. seam (general sample).
Specific gravity	1.60	1.58 W. B.	1.48	1.52 W. B.	1.61 Bottle.	1.49 Bottle.	1.60 Bottle.	1.68 Bottle.	1.72 Bottle.	1.66 Bottle.	1.64	
Moisture	15.36	1.10	17.88	1.10	0.85	1.40	1.32	1.38	1.14	1.16	0.80	1.81
Volatiles		13.9		17.7	15.15	12.06	12.18	12.08	11.82	17.01	10.64	13.61
Fixed carbon	29.84	62.0	54.12	57.9	37.20	67.34	52.40	44.58	44.34	45.55	54.00	60.18
Ash	54.60	23.0	28.00	23.3	46.80	19.20	34.10	41.96	42.70	36.78	34.56	24.40
Sulphur	.....	.....	....	.....	.. ...	.....	.....	3.27	.....	.....	3.83	.....

MIDDLEMISS : Coal deposits of Jammu Province, Kashmir.



(Analyses done in Industrial Laboratory, Srinagar).

Localities.	KALAKOT (UPPER MEASURES)— <i>continued</i> .											
	Pit 2, a, U. seam 1st foot.	Pit 2, a, U. seam 2 ft.—7 ft.	Pit 2, a, U. seam 8th foot.	Pit 2, a, U. seam 9 ft.—12 ft.	Pit 2, a, U. seam (average sample).	Pit 8, U. seam (general sample).	Pit 8, a, U. seam 1st foot.	Pit 8, a, U. seam 2nd foot.	Pit 8, a, U. seam 3rd foot.	Pit 8, a, U. seam 4th foot.	Pit 10, U. seam 2nd foot.	Pit 10, U. seam 3rd foot.
Specific gravity	1.40	1.41	1.40	1.40	1.39 W. B.	1.49	2.50 Bottle.				1.43	1.37 Bottle.
Moisture	1.32	0.70	14.26	2.40	1.50	15.24	2.72	2.51	1.76	1.66	8.43	6.44
Volatiles	24.22	11.5		13.30	14.50	27.80	10.48	10.46	18.44	11.72	20.93	26.52
Fixed carbon	40.00	24.90	51.00	20.30	62.70	50.82	7.86	6.24	21.50	41.40	60.16	63.22
Ash	34.46	62.90	34.68	64.00	21.30	6.06	78.94	80.76	68.80	45.22	10.48	3.82
Sulphur	....	.....	.....	.....	.....	.....	....	....	....	.....	.....	.....

(Analyses done in Industrial Laboratory, Srinagar).

KALAKOT (UPPER MEASURES) - continued.

Localities.	Specific gravity	Moisture	Volatiles	Fixed carbon	Ash	Sulphur
Pit 10, U. seam 4th foot.	1.36 Bottle.	8.04	25.00	60.54	6.24	.....
Pit 10, U. seam 5th foot.	1.37 Bottle.	10.01	20.15	64.48	5.36	.....
Pit 10, U. seam 6th foot.	1.51 Bottle.	7.02	18.02	52.32	22.64	.....
Pit 12, U. seam (Outcrop) 1st foot.	1.51 Bottle.	4.90	16.30	60.02	18.78	.....
Pit 12, U. seam (Outcrop) 2nd foot.	1.47 Bottle.	19.60	62.39	18.20	.....	.....
Pit 12, U. seam (Outcrop) 3rd foot.	1.45 Bottle.	19.56	59.96	20.48	.....	.....
Pit 12, U. seam (Outcrop) 4th foot.	1.47 Bottle.	2.70	15.50	53.31	25.49	.....
Pit 12, U. seam (Outcrop) 5th foot.	1.71 Bottle.	3.10	11.50	47.40	38.00	5.78
Pit 12, U. seam (Outcrop) 5½ foot.		3.06	20.48	35.24	41.22	4.44
Pit 12, U. seam (17 ft. inside drive) 1st foot.		2.00	11.81	47.86	38.34	.....
Pit 12, U. seam (17 ft. inside drive) 2nd foot.		1.48	11.96	55.30	31.26	7.28
Pit 12, U. seam (17 ft. inside drive) 3rd foot.		1.36	12.55	57.60	28.49	.....

Localities.	Specific gravity	Moisture	Volatiles	Fixed carbon	Ash	Sulphur	KALAKOT (UPPER MEASURES).	
Pit 12, U. seam (17 ft. inside drive) 4th foot.	1.89	0.82	11.14	73.94	14.80	.....	KALAKOT (UPPER MEASURES).	
Pit 12, U. seam (17 ft. inside drive) 5th foot.		0.82	12.80	68.14	18.44	.....		
Pit 12, U. seam (17 ft. inside drive) 5½ foot.		12.16	62.62	21.22	.....			
Pit 12, c. 1—2 foot.	1.48	17.68		64.12	28.00	.....	UPPER MEASURES.	
Pit 12, c. (average sample).	1.52	1.10	17.70	67.90	23.30	.....		
Pit 1. L. seam (general sample).		2.66	18.02	51.78	32.54	.....	KALAKOT (UPPER MEASURES).	
Pit 7. M. or Lower seam (general sample).	1.86 W. B.	2.64	15.42	79.42	2.52	.....		
Pit 8. M. or L. seam (upper shaly part).	1.74 W. B.	8.30	12.05	63.87	80.78	.....		
Pit 8. M. or L. seam (general sample).	1.34 W. B.	2.70	14.74	79.82	2.74	.....		
Pit 8. M. or L. seam (in drive) 1st foot.	1.31 W. B.	0.74	13.20	73.74	12.32	.....		
Pit 8. M. or L. seam (in drive) 2nd foot.	1.31 W. B.	0.21	13.21	81.42	5.16	.....		
Pit 9. M. or L. seam (in drive). 1st foot.	1.89 W. B.	0.17	13.63	78.12	9.08	.....		

(Analyses done in Industrial Laboratory, Srinagar).

		KALAKOT (UPPER MEASURES).				MERTKA (UPPER MEASURES).						
Localities.												
Specific gravity	Pit 9, L. seam (in drive) 2nd foot.					Upper bed A. Exposure.						
	Pit 13, a. M. or L. seam (shaly coal) 1st foot.	2.08				Pit 2, U. seam (13 ft. inside) 1st foot.	1.81 Bottle.	0.70				
	Pit 13, a. M. or L. seam (shaly coal) 2nd foot.	1.60				Pit 2, U. seam (13 ft. inside) 2nd foot.	1.66 Bottle.	1.50				
	Pit 13, a. M. or L. seam (shaly coal) 3rd foot.	2.08				Pit 2, U. seam (13 ft. inside) 3rd foot.	1.33. Bottle.	2.50				
	Pit 13, a. M. or L. seam (shaly coal) 4th foot.	1.87				Pit 2, U. seam (13 ft. inside) 4th foot.	1.43 Bottle.	1.40				
	Pit 13, a. M. or L. seam (general sample) (shaly coal) 1 ft.—4 ft.	1.56										
	Pit ? stream-bed S. of Ber.											
Moisture	0.27	1.87	14.88	9.92	1.94	2.86	0.60	1.84	0.70	1.50	2.50	1.40
Volatiles	14.29	7.95			11.76	11.64	13.80	11.52	13.50	11.50	15.00	13.80
Fixed carbon	77.60	28.68	40.94	17.28	32.50	57.70	69.86	58.40	47.40	34.50	71.90	52.90
Ash	7.84	62.00	44.18	72.80	64.40	27.90	15.74	28.24	39.40	52.50	10.60	32.40
Sulphur	.....	2.23	.....	.....	.....	1.65	.....	.....	.....	.....	.....	.....

MITKA (UPPER MEASURES).

Localities.	Specific Gravity	Moisture	Volatiles	Fixed carbon.	Ash	Sulphur
Pit 2. U. seam (13 ft. inside) 5th foot.	1.91 Bottle.	1.90	12.40	38.60	47.10	.....
Pit 5. a. U. seam 1st foot.	1.80 Bottle.	1.60	15.10	58.70	24.60	.....
Pit 5. a. U. seam 2nd foot.	1.81 Bottle.	1.10	12.70	64.00	22.20	.....
Middle bed A. Exposure.		1.32	11.43	73.91	13.29	.....
Middle bed C. Exposure (50 ft. below junction of side stream).		1.58	12.04	76.54	9.34	.....
Middle bed C. Exposure (up side stream).		3.98	13.24	65.73	17.05	.....
Middle bed E. Exposure (near Godwin's hole).		9.80	17.60	59.04	13.56	.....
Lower bed B. Exposure.		0.90	10.72	79.42	8.96	.....
Lower bed C. Exposure.	1.29 Bottle.	2.86	12.76	83.46	0.92	.....
Lower bed C. Exposure (up side stream).		4.50	12.72	81.00	1.78	.....
Lower bed E. Exposure.	1.40 Bottle.	3.37	13.15	81.29	2.19	.....
Lower bed E. Exposure (near Godwin's hole).		1.90	11.41	83.32	3.37	.....

(Analyses done in Industrial Laboratory, Srinagar).

MAHOGALA (UPPER MEASTRES).

Specific gravity	Localities.			
	Pit 3. U. seam 1st foot.	2.10	12.80	68.85
	Pit 3. U. seam 2nd foot.	3.14	11.22	65.14
	Pit 3. U. seam 3rd foot.	1.60	13.29	71.20
	Pit 3. U. seam 4th foot.	0.85	14.41	69.60
	Pit 3. U. seam 5th foot.	0.49	15.	73.36
	Pit 3. U. seam 6th foot.	1.11	3.15	68.26
	Pit 5. U. seam (outcrop) 1st foot.	2.24	13.32	21.86
	Pit 5. U. seam (outcrop) 2nd foot.	2.60	12.86	26.80
	Pit 5. U. seam (outcrop) 3rd foot.	1.70	15.44	77.94
	Pit 7. M. seam.	2.34	14.76	69.93
	Pit 9. M. seam.	2.62	18.32	66.76
	Pit 7. L. seam 1st foot.	11.18	10.20	61.62
				21.25
				20.56
				19.91
				15.14
				10.60
				27.48
				62.68
				57.74
				4.92
				12.97
				16.80
				8.00
Moisture		2.10		
Volatiles		3.14		
Fixed carbon		1.60		
Ash		0.85		
Sulphur		0.49		

(Analyses done in Industrial Laboratory, Srinagar).

MAHOGALA (UPPER MEASURES)—continued.

Specific gravity	Localities.	Specific gravity	Localities.
	Pit 7. L. seam 2nd foot.		Pit 7. L. seam 3rd foot.
		1.82 Bottle.	
	Pit 7. L. seam 4th foot.		Pit 7. L. seam 5th foot.
	Pit 9. L. seam 1st foot.		Pit 9. L. seam 2nd foot.
	Pit 9. L. seam 3rd foot.	1.81 Bottle.	Pit 9. L. seam 4th foot.
	Pit 9. L. seam 5th foot (Right bank of Gancoe stream).		Pit 9. L. seam 6th foot.
	Pit 10. L. seam 1st foot.		Pit 10. L. seam 2nd foot.
Moisture	9.00	8.74	8.60
Volatiles	18.82	23.16	20.18
Fixed carbon	68.06	64.68	67.28
Ash	4.12	8.42	4.06
Sulphur	.....	.....	.....

(Analyses done in Industrial Laboratory, Srinagar).

Specific gravity	Localities.		MAHOGALA (UPPER MEASURES).		MAHOGALA (LOWER MEASURES).		CHAKAR.				DHANSAL.	
		Pit 10, L. seam 3rd foot.										
		400 yds. W. by E. of pits 4 and 5.										
		S. of pit 8, Lower Measures.										
		250 ft. E. S. E. of pit 10, Lower Measures.										
		A. area (bottom bed).										
		S. of Camp (bottom bed).										
		S. of Camp (top bed).										
		S. of Camp (top bed).										
		Pit 1. S. locality.										
Moisture	1.82	13.64	2.72	16.52	10.28	4.42	14.47	14.70	0.80			
Volatiles	10.18	26.72			17.32	18.43	22.15	19.40	9.80			
Fixed carbon	79.26	62.50	39.34	37.08	65.74	73.91	63.19	64.36	63.00			
Ash	9.24	8.24	38.94	46.40	6.71	8.24	10.19	11.54	27.00			
Sulphur	.....	.....	.....	.....	.....	.....	.....	.....	.....			



*Remarks on the Analyses.*

The foregoing analyses as a whole, and more especially those done recently for this report, show the class of coal in the area treated of as coming between a typical bituminous coal and an anthracite. It may therefore be called anthracitic or semi-anthracite. That is to say it contains a low percentage of volatile matter and high fixed carbon.

Some of the more obvious conclusions from the analytical results are the following:—The moisture is almost uniformly rather low. Only in two instances does the percentage appear in two figures, it very seldom reaches as much as 5, and very often is below 1 per cent. An average for the 163 analyses, in which the moisture has been estimated apart from the volatiles, works out at 2.75 per cent. This is about double the moisture found in coals of the Barakar stage of the Jharia coalfield somewhat higher than that of the coals of the Raniganj stage of the Jharia coalfield, and very much less than the 6 or 7 per cent. which characterises the higher seams of the Raniganj stage. The average given above of 2.75 is rather higher than the great majority of the analyses would yield if 14 of these in which the percentages are abnormally high (ranging from 8 to 17 per cent.) were thrown out. When this is done the revised average is about 2 per cent.

The volatile matter only exceeds 20 per cent. in about 5 instances, and it only drops below 10 per cent. in 23 instances, the average of the whole 157 analyses being 13.4. Thus the volatiles are not only less than those of any Gondwana coals of Peninsular India, but the variation in quantity that appears in the analyses is confined within small limits. This relative uniformity in the amount of volatiles (excepting in the case of some extremely poor samples that are really carbonaceous shales rather than coals) appears to be but little affected by moderate to fairly great variations in the amount of ash present. Probably this may be interpreted, on the general assumption commonly made, as being due to a steady and fairly uniform loss of volatile matter

due to pressure and heat developed during the time the original coal substance has remained buried at depth and subjected to orogenic forces; that loss thus sustained, remaining almost constant and unaffected by subsequent loss of fixed carbon and by contamination with clay in outcrop exposures or by crushing and mixing at depth.

Along with the low percentage of volatile matter, that of the fixed carbon necessarily runs high among the purer qualities of coal. In 25 analyses, where the ash is generally much below 15 per cent., the fixed carbon is between 70 and 80 per cent. In 10 instances where the ash percentages are only 5 and under, the fixed carbon rises to 80 per cent. and over, the highest reached being in a coal from Mahogala, pit 9, lower seam of Upper Measures, having 83.86 per cent. fixed carbon and 1.32 per cent. ash. The average of 151 analyses gave 63 per cent. fixed carbon.

These very high fixed carbon-volatile ratios, as found in the purer qualities of the Jammu coals, sufficiently bear out the classifying of these coals as anthracitic or semi-anthracite. When the fixed carbon percentage is less than in the above-cited instances, it is due to clayey admixture and hence the high ash percentage. It is never due to any very great increase in the moisture or volatiles present.

Coals of this anthracitic character are not found in the Gondwana fields of Peninsular India, though those of the Barakar stage of the Jharia coalfield come the nearest to them. The latter, however, are considered to be true bituminous coals with an average of 65 per cent. fixed carbon.

The coal of the Darjeeling Himalayas appears to be the only one in India having a somewhat similar anthracitic character, due presumably to the same orogenic causes there as have been assigned to account for that of the Jammu coal.

When once the general composition of the coal is known, the ash percentage determines the quality or grade. This, as already remarked,

Ash.

varies reciprocally with the fixed carbon, and the variation will be seen to be very great. The analyses show that, omitting only some carbonaceous shales with over 50 per cent. ash, we have, out of 151 analyses :—

72	yielding	15 per cent.	or less ash.
22	„	16 to 20 per cent.	ash.
24	„	21 to 30	„ „
18	„	31 to 40	„ „
15	„	41 to 50	„ „

### SPECIFIC GRAVITY.

A number of specific gravities (mostly done by bottle but some with a Walker's balance) were taken of Jammu coals by Assistant Superintendent Labhu Ram. It was hoped to test and perhaps make use of the empirical law connecting the specific gravity and the ash percentage, recently worked out by L. L. Fermor (*Rec. Geol. Surv. of India*. Vol. LX, pt. 4, pp. 313—357). In my bauxite report published lately by this department, a general connection of a similar kind had been noted between the specific gravity and the silica content of the Jammu bauxites and bauxitic kaolins, so long as these were not unfavourably influenced by the presence of iron or titanium in unusual quantities. The use of such a method for rapid prospecting of new coal seams is as obvious (if it can be shown to be reasonably reliable) as the similar method advocated by me for bauxite prospecting.

Fermor's rule is that the ash percentage ( $a$ ) can be shown to be equal to 100 times the difference between the specific gravity of the specimen ( $g$ ) and that of a pure ash-free coal ( $k$ ) of the same kind. Thus:—

$$a = 100 (g - k)$$

The nearest approach to an ash-free sample among our Jammu rocks is the lower bed of C exposure, Metka coalfield with its 0.92 percentage of ash, according to analysis. The

specific gravity of this, determined by bottle, was 1.29; and so we have accepted 1.28 as the standard value for  $k$  in the equation, (which is also the value found by Fermor for his Korea coals).

Thirty-one specimens tested in this way—that is to say by comparing the actual ash percentage as found by analysis with that calculated by the equation—gave a *plus* deviation, and 25 gave a *minus* deviation. The average of 31 *plus* deviations came to 4.4 and that of the 25 *minus* deviations came to 6.5. In both cases there were a smaller number of large deviations, 18 being the largest individual deviation on the *plus* side and 22.8 on the *minus* side. A very large number on the *plus* side were round about 1.

The conclusion is that the method has considerable value in the case of the Jammu coals. It would probably have proved still more valuable and precise for our purposes if we had been able to carry the investigation further and make a set of values for  $k$ , the specific gravity constant, from very careful analyses of selected bright coal, ash-free, pieces, selected from all the different seams and coalfields. This subject merits the attention of future survey parties in these coalfields as a rapid field method for estimating the ash approximately, preparatory to detailed sampling.

### COKING QUALITIES.

A good deal of these Jammu coals cakes more or less strongly. From this and from its general composition one would expect that it would form coke suitable for metallurgical and other purposes. The coal from Kalakot coalfield, pit 16, Ber-Goa area, has been stated to coke strongly by C. S. Fox (Presidential Address, Geology Section, 16th Indian Science Congress Madras 1929 "Geological Aspects of the Formation of Coal" p. 6). R. R. Simpson stated (p. 38 of his memoir) "the coal from the drives on the Ladda slope cokes strongly if subjected to great heat, elsewhere the coal only occasionally exhibits coking qualities". Since Simpson wrote his memoir the whole question of the coking of Indian coals has been studied in detail and many

A complex question: experiments made on Indian coals.

experiments have been made for the production of hard and soft coke for metallurgical purposes and for smokeless household fuel respectively. The hard coke for metallurgical purposes has been found to be largely a matter of finding the right mixtures or blends of different kinds of coal in varying proportion. (See C. S. Fox "Note on Coking Tests on the Gondwana Coals", *Rec. Geol. Surv. of India*, Vol. LXI, pt. 3, 1928, also Balaram Sen on "Coking Coal, its Nature and Synthesis" *Quart. Journ. Geological Mining and Metallurgical Society of India*, Vol. I, March and June 1928).

It is clear from the complexity of the subject as indicated in the publications referred to above, that **Systematic experiments on Jammu coals advocated.** nothing short of extensive experiments carried out of set purpose will be able to show to what extent the Jammu coals can be made to form coke of any particular quality. Some of them we already know do coke strongly of themselves ; but there are probably many more that by judicious selection and blending could be brought to the coke-producing condition. It is work that will have to be undertaken sooner or later in the interests of any metallurgical industries that may be started in the State.

### BURNING TESTS.

Burning tests made on the coal from the coalfields described in this report have not as yet been carried out, except such as could be done roughly in ordinary fire-grates. These latter showed the coal to burn with very little flame for most varieties and the evolution of apparently much heat so long as a proper draught was maintained. The coal showed great lasting qualities, which is what one would expect from coal with such very high carbon content. The great difficulty was preventing the soft varieties from crumbling and dropping through the bars. The hard varieties, such as those from the Lower Measures, Kalakot field, gave no trouble whatever in this respect.

An extraordinary feature was the clear and vigorous hot fire made with hard pieces of the anthracitic shale from pits 7, 8 and

13. a. in spite of its 30 per cent. ash. The reason for this may be connected with the free draught permitted between the hard pieces, which never changed shape throughout the combustion to the very end.

Coal from pit 16, Ber-Goa, Kalakot field, was successfully used in a portable hand-forged smithy work, and was cheerfully accepted by the local blacksmith in camp instead of charcoal for sharpening tools, etc.

Tests on coal from the new drives made this year (1929) in the vicinity of pit 17, Kalakot coalfield. Lower Measures, are being arranged to be carried out on the railway and in the steam-engine of the Jammu Waterworks. Their result will be awaited with much interest, as a further practical trial for the hard coal of the 17 ft. bed at Ber-Goa, in extension of the trials made in 1903 and described by Simpson.

Those 1903 trials were from coal from the eastern areas (Ladda slope, Lain, etc.) and were partly successful, the great difficulty being the crumbling and dropping through the bars of the soft coal and the briquettes as then turned out in this country. The results of these trials are quoted below in tabular form :—

Summary of comparative burning tests at Jammu Waterworks.

Coal from	Variety of fuel.	Spacing of fire-bars.	Maunds burnt per hour.	Stoking details.	Percentage of ash & cinder.	Heat value, Bengal coal being 1.	REMARKS.
Bengal ..	Hard lump ..	.. "	2.43	Thrice during 8 hours.	26½	1	
.....	Selected hard, dry firewood.	7/8"	6.01	..	..	0.40	
E. drive ..	3"—6" lumps ..	7/8"	2.66	Thrice during 8 hours.	23¼	0.91	
Do. ..	3"—2" nuts ..	5/8"	2.66	Do.	36 7/8	0.91	
Do. ..	Briquettes ..	1/8"	3.83	Every hour	39 1/8	0.64	
Lain drive ..	3"—6" lumps, soft	7/8"	4.69	Do.	43 1/2	0.52	
Do. ..	Briquettes ..	5/8"	3.91	Do.	29 1/2	0.62	
Jungle drive ..	Do. ..	7/8"	5.06	Do.	33 3/4	0.48	} Coal dropped through the fire-bars.
Do. ..	Coal dust ..	3/8"	7.20	Thrice every hour.	61	0.34	

Details of locomotive trials with Ladda, Dandot and Bengal coal on the North-Western Railway.

Date.	Runs were between	Miles run.	Average speed in miles per hour.	Average weight of train.	Description of fuel.	Pounds of fuel used per ton-mile.	Pounds of water evaporated per pound of fuel.	REMARKS.
8th to 13th July, 1903.	Lahore and Lala Musa.	493½	22.5	353	Ladda coal 94 per cent. Pitch in briquettes 6 per cent.	0.11	6.53	No clinker.
3rd to 5th and 7th September 1903.	Lala Musa and Kundian.	628	25	259	Do. "	0.15	6.52	
14th to 19th July, 1903.	Lahore and Lala Musa.	493½	21.5	336	Ladda coal 96 per cent. Meal .. 3 " Lime .. 1 " in briquettes.	0.16	5.11	Briquettes extremely fragile. After rain a stack of 10-tons was reduced to pulp. Clinkered slightly.
2nd to 17th July, 1903.	Do. "	493½	23	300	Ladda coal .. 97 per cent. Lime .. 3 per cent. in briquettes.	0.17	5.06	In transit from factory at Haranpur to Lala Musa (51 miles) 25 per cent. of the briquettes crumbled to dust. During trial 10 per cent. of specially-selected briquettes crumbled to pieces. Clinkered badly.



Details of locomotive trials with Ladda, Dandot and Bengal coal on the North-Western Railway.—(continued).

Date.	Runs were between	Miles run.	Average speed in miles per hour.	Average weight of train.	Description of fuel.	Pounds of fuel used per ton-mile.	Pounds of water evaporated per pound of fuel.	REMARKS.
23rd January, 1904	Lala Musa and Makarwal.	45	19	230	Ladda coal .. 92 per cent. Pitch .. 8 per cent. in briquettes.	0·34	3·45	Coal and clinker obstructed fire bars. Average steam pressure only 80 pounds per square inch. Two hours' time were lost on run. Briquettes extremely soft and much worse than those with 6 per cent. only of pitch. 32 per cent. crumbled to dust during transit from factory.
20th to 28th July, 1903.	Lahore and Lala Musa.	493½	21·5	339	Dandot coal.. 92 per cent. Pitch .. 8 per cent. in briquettes.	0·18	4·57	Trials made in wet and windy weather. Clinkered badly.
4th March, 1902 to 27th June 1903.	Lahore, Phillour and Lala Musa.	9,040½	24·4	306	Coal from 15 Bengal collieries.	0·136	6·05	

Mr. Simpson remarks on the locomotive trials :—

“As far as actual fuel consumption is concerned, Ladda coal, except in test No. 5 on 23rd January showed up exceedingly well. In every test, except the one just mentioned, it was superior to Dandot coal, and in one test it was actually considerably superior to Bengal coal. Great trouble was, however, experienced in burning the coal properly owing to the fragility of the briquettes, and this became so accentuated in the final test, when briquettes made with 8 instead of 6 per cent. of pitch were used, that the experiment had to be abandoned before one-third of the contemplated run had been completed.”

There should be no difficulty now-a-days in making briquettes that will stand all the required tests.

### EVAPORATIVE FACTOR.

As already remarked, no tests were able to be carried out in the Industrial Laboratory, Srinagar,<sup>1</sup> with Simpson's results quoted. the bomb calorimeter ; but a number of figures are given in Simpson's analyses (see pp. 82-88) of the evaporative factor (pounds of water evaporated per pound of fuel). Only the better quality coals were so tested, but the figures are sufficiently significant. The average of these, for the 36 samples so tested, is 12.27, which is not far below 12.79 the average evaporative factor for eight of the principal seams of the Jharia coalfield (See "Coalfields of India", *Mem. Geol. Surv. of India*, Vol. XLI, 1913, p. 53). Some particular examples of the Jammu coals given, such as the 5 Mahogala coals, one from each of the places Chakar, Kalakot, Nadla No. 2, Ponra camp and Nimbai, have an evaporative factor of over 13, one each from Chakar and Ikni of over 14, whilst one from Jhaltutunia (Kalakot field) reaches 15.15 and another from Chakar 15.35.

### GRAPHITE.

Graphite, as has already been noted, is present to the extent of about 12 per cent. in the coal of Dhansal. Manufactured graphite : It is highly probable that much of the carbon electrodes. Metka and Kalakot crushed coal is also graphitic. At all events the last two have some graphitic qualities and make up into a

<sup>1</sup> See foot note on page 81.

good black oil-paint and drawing ink (Indian ink). It seems certain that a good deal of the very rich varieties could be readily converted into manufactured graphite; and that, if and when the bauxite deposits of the neighbourhood are used for making aluminium at the Dhian Garh hydro-electric site on the Chenab River these very rich varieties might very well be experimented with in an attempt to manufacture carbon electrodes.

### QUANTITY OF AVAILABLE COAL.

The remarks in the immediately preceding sections of this report have shown the quality of the coal beyond doubt to be high, or in some cases to be above the average for Indian coals, from the point of view of steam-raising and probably for metallurgical and other purposes. We must now consider briefly the subject of the *quantity* available in a way more general and summarised than so far has been attempted in the descriptive sections of this report. In doing so certain comparisons must be made. Comparisons with the coalfields of Bengal and Behar and Orissa are not of course favourable to our Jammu fields. Our two, three, or even in some cases more seams, and the total thickness of the coal measures, reaching 200 feet or so, make a poor showing compared with the 14 or more worked seams in the Raniganj coalfield and the 18 in the Barakar stage of the Jharia coalfield—these numerous seams, and other subsidiary ones, extending through a thickness of many thousands of feet of coal measure strata.

Fortunately, however, for us these latter extensive deposits of coal, as well as others belonging to the Gondwana fields of Peninsular India, yielding their twenty million tons a year, are situated far distant from Jammu, the nearest of them being 700 miles away as the crow flies.

It is more to the purpose to compare our available coal with that of more neighbouring areas, such as the few thin seams of Baluchistan and the Punjab with their outturn of about a hundred thousand tons a year. Of these the most successful in a small way have

been the Khost coalfield where two seams of 26 and 27 inches are known, and the Dandot and the connected fields of the Punjab with their single seam of from 18 to 39 inches.

In marshalling our Jammu resources for this comparison, I must refer back to the descriptions of the separate fields. In the Kalakot area we have a Lower Coal Measure seam or seams which are locally 17 feet and 6 feet thick ; but as to their extension beyond a circumscribed area we have at present but little information. We have a fairly continuous 4 ft. upper bed of the Upper Measures and middle or middle and lower seams, of 2 to 2½ feet. Very recent information received from the field party at work there shows the 17 ft. bed increasing in places to 21 feet and in the Jigini area the upper beds of the Upper Measures similarly increasing locally to 24 feet in thickness. In the Metka coalfield I have estimated that the three coal seams average 5 feet in thickness. In the Mahogala coalfield the three or more seams total 12 feet in thickness. In the Chakar area a preliminary investigation has shown two or three beds totalling about 5 feet, and similar incomplete investigations at Chinkah show still thicker beds at least locally. In the Dhansal-Sawalkot area a 4 ft. bed of graphitic coal has been established over a portion of the field and a 1½ ft. thickness for the upper bed.

#### *Thickness Problems.*

The following points may be noticed with regard to the thickness aspect of our coal resources :—

- (1) The minimum thickness that it will pay to work depends on local circumstances. One foot was the minimum adopted by the Royal Commissioners in their 1905 report on the British coalfields.
- (2) In the South Wales coalfield, the seams are 1 to 12 feet thick, the average being 2½ to 3 feet.
- (3) On account of inexperience in this country and roof difficulties with soft and crushed coals, it will

be safe to take  $2\frac{1}{2}$  feet as the limiting thickness for workability at least for the present. A 4 to 6 ft. seam is a very useful thickness, and regarded as a type of what a really good coal seam should be.

- (4) Whilst a thickness of 2 feet is common in the coal-fields described in this report for the middle or lower bed of the Upper Measures, the coal of which is often fairly firm; the remaining seams of the Upper Measures, containing a frequently rich but soft and crushed coal, have variable thicknesses ranging from 4 feet to 6 or even to 10 or 20 feet locally. The evidence furnished by the long drives made in the Ladda field and described by Simpson, as well as the evidence of seams in the Kalakot and Metka fields show clearly that these soft coal seams, starting perhaps with a thickness of about 4 feet everywhere normally swell out in places to the higher figures given above and thin away to 2 feet or under in other places. This must be regarded as a perfectly natural effect of the severe folding which the rocks have suffered. The soft, rich coal of these seams, once its coherence had given way so that it had become a powder or paste, was obviously in the best condition for being thrown into waves consisting of swelled out portions where the downward pressure was least and thinned out portions where the downward pressure was greatest: the coal in fact became "rucked up" into thickened bulges like a pillow under unequal pressure.

Such rhythmic variations in thickness are not found in areas like those of the Gondwana coals of Peninsular India, where the folds into which the strata are thrown are of a gentler kind. They are not necessarily a disadvantage for working purposes, since the thickening sometimes converts parts of a thin bed into a workable seam.

From all the above comparative remarks we can rest assured

that the coal seams in these Jammu fields that have been the more carefully explored are of average thickness, as a rule well above the limit of workability, and very much better in this respect than the thin seams of Dandot and Khost. Occasionally the thickness is equal to that of such celebrated seams as the Dishargarh seam (18 feet) and the Sanctoria seam (10 feet) of the Raniganj coalfield.

### *Quantity Problems.*

When we come to consider the problems connected with the amount of coal available in these areas, certain difficulties must be explained. In the first place, as already stated in the section dealing with the general geology of the area, the Jammu coalfields are not coal basins except to a limited extent in the case of the Lower Measures. The coal is exposed along the crests of a set of elliptical anticlinal domes, and hence the seams dip continuously away from the outcrops to unknown depths. In the second place we have to make allowance for the thickening and thinning of the seams due to squeezing of the soft crushed coal into local bulges.

Certain minimum totals for each of the fields have already been estimated in the "conclusions" appended to each section of the descriptive part. Those arrived at for the fully surveyed fields are more reliable than those made for the long stretches of outcrop between the Chakar outcrops and the Chenab River. At the same time they are more limited as to area and they do not include those parts that have not yet been finished surveying and those parts which, without the least shadow of doubt, underlie the intervening areas between the coalfields. They are also limited to the narrow width of  $\frac{1}{4}$  mile or less out from the outcrop, such that the depth worked would not exceed 1,000 feet.

Tabulating these here we have :—

	Tons.
Kalakot .....	9,000,000
Metka .....	5,000,000

	Tons.
Mahogala .....	4,000,000
Chakar .....	9,000,000
Other areas W. of the Chenab River ..	6,000,000
Dhansal-Sawalkot .....	9,000,000
Total	... <u>42,000,000</u>

With regard to this estimate it should be remembered that a wide margin of safety has been allowed for loss and thinnings away, and also that the intervening areas between the three surveyed fields and the unfinished parts have not been included in the calculations. But, most of all, the limit of 1,000 feet depth has affected the calculations. This short limiting depth has been adopted because of the difficulties inherent in carrying on deep mining in a country new to the work and which will be for long perhaps without experience and material means for working to great depths.

But depths of 4,000 and 5,000 feet have for long been the recognised limits in England and Europe. Hence it will be seen that if we only double the depth and make it 2,000, we shall still be far from the European limit and the yield would be twice the above or even more, since additional areas proportionately would be included. Thus 100,000,000 tons is not an impossible amount to look forward to when the mines are worked properly by up-to-date methods.

Another consideration that may seriously affect the amount of coal is this: new seams or new and greater thicknesses may be found by further intensive survey and exploration by deep boring. For instance the Lower Measure may be found in other detached basins besides those at Ber-Goa and Sair; whilst over the large areas, outside those which have been already mapped in detail, more seams, at present hidden from view, may well come to light during the further progress of the survey.

At least results of this kind have so far invariably attended the efforts of the Mineral Survey.

### ACCESSIBILITY OF THE COALFIELDS: COMMUNICATION LINES.

At present there are no rail or road communications beyond Jammu in the direction of these coalfields, and only a canal and unmetalled road part of the way as far as Akhnur on the Chenab River. The survey work done on the coalfields so far, and all the proposed work for the future that may be done towards proving the coal, are necessarily based on the assumption that proper communications will be established, something on the lines shown in the outline map (Pl. 7), before any of the coal can be raised at a profit. I have briefly referred to this matter in discussing communications for the Kalakot field, and the same has been tacitly assumed in the bauxite report.

In setting about the work of communications it will be much better to go straight to the heart of things by building a railway to Riasi, than to accept any temporary and cheap palliative, such as a short rail connection from Jangal Gali *via* Tikhri to Jammu Tawi. The latter would mean only a short run, it is true, but at the same time would only open up the southern portion of the Ladda coalfield and nothing more. The intervening ridge of Sukhwal Gali to the north is an absolute barrier to any further extension in that direction. Thus the rest of Simpson's Anji valley portion of the Ladda coalfield would in any case have to find an outlet for its coal through the mountains *via* the narrow gorge of the Anji river, Riasi and the Chenab valley.

Simpson only considered the transport question as affecting the carriage of coal to N. W. Railway. The larger view, that the coal of the Jammu fields will certainly be wanted for the bauxite deposits of Chakar, Sangarmarg, Salal, etc., and probably for other metalliferous minerals such as the hematite of Khandli, the



zincblende of Darabi and the copper ore of Gainta (all of which were unknown in Simpson's day), is an additional argument for making Riasi the great rail centre, from which branch lines or tramways or other secondary means of communication will diverge to the various centres of mineral interest. Riasi, as a railway centre, would also be conveniently situated for the proposed hydro-electric station of Dhian Garh, which is an integral part of the scheme for utilizing the bauxite for making aluminium, as well as probably a paying thing in itself for power generation and transmission.

The opening up of the Chenab valley and also of the beautiful dun-like country west of Riasi in this way may seem a costly undertaking. However, this question of cost is after all a relative one. If we consider the remaining areas of His Highness' dominions, which stretch away through a great complex of mountain systems, we shall be forced to admit that Riasi (as a centre for coal, bauxite, iron, zinc, copper, lead, as well as for the minor minerals like refractory clays, china clays, steatite and barytes) is the best situated of any other mineralized area in Kashmir for communication with the plains of India and the outside world markets. If then the Riasi railway project is too big to finance now, we must *a fortiori* rule out the development of all other less accessible mineral products in the State, with the exception perhaps of those worked for purely local purposes and precious stones and metals, which latter of course are in a class by themselves and may be considered to some extent as independent of graded roads and railways—at least we must rule them out until air transport has definitely superseded hill railways, which it may do some day, since air routes need no 'permanent way' nor expensive (and vulnerable, in time of war) bridges, any more than ocean routes do.

In fairly easy country a 30 or 40 miles of railway connecting Jammu-Tawi with Riasi ought not to discourage the seriously minded industrialist.

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MINERAL SURVEY OF KASHMIR.

*Plate* 1



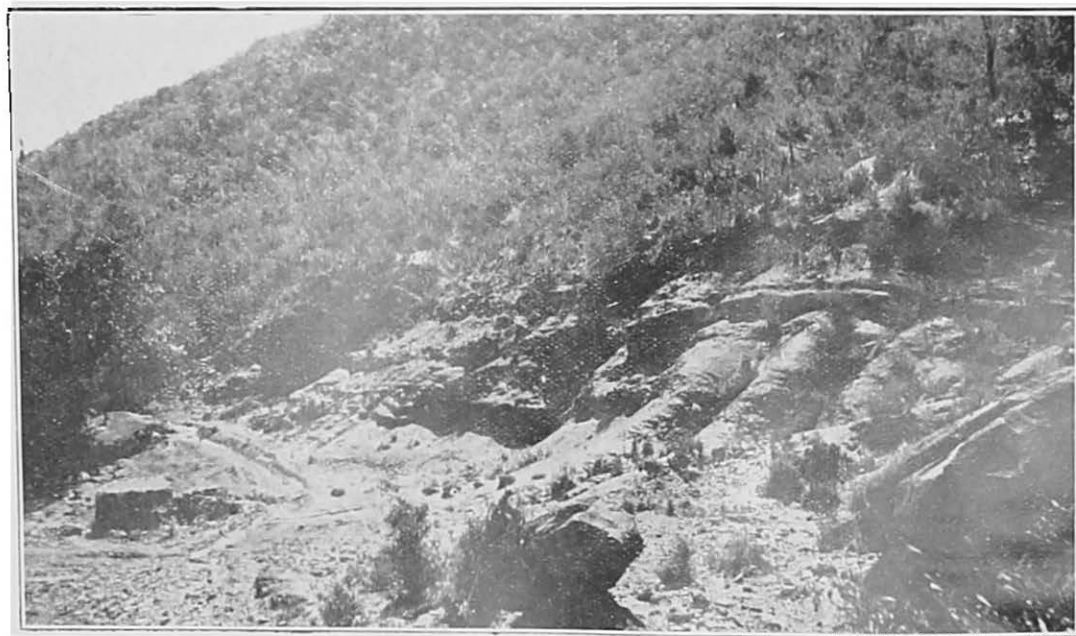
GORGE IN GREAT LIMESTONE, KALAKOT.



UPPER COAL MEASURES OVERLYING BRECCIA, SAIR.

MINERAL SURVEY OF KASHMIR.

Plate 3



UPPER COAL MEASURES, SAIR.



MINERAL SURVEY OF KASHMIR.

Plate 4



PIT 17 a, AND COVER-ROCK, BER-GOA.

MINERAL SURVEY OF KASHMIR.

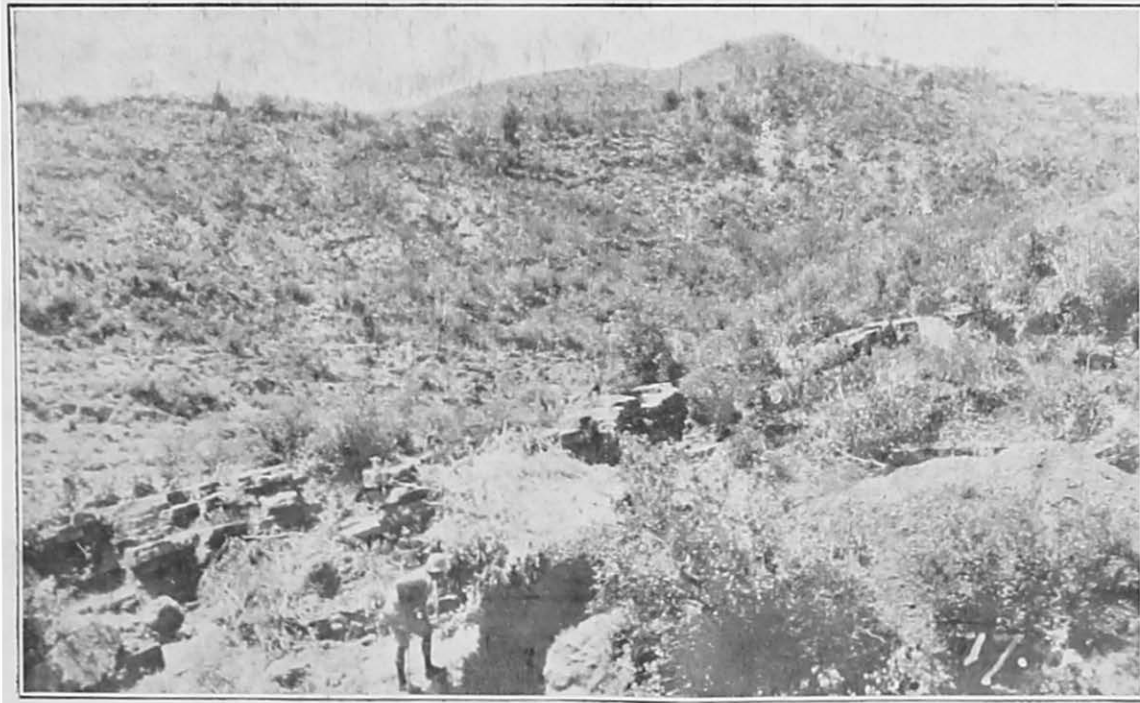
Plate 5



COAL FACE PIT 17 b, BER-GOA.

MINERAL SURVEY OF KASHMIR.

Plate 6



COVER-ROCK AND PIT 17 b, BER-GOA.