MEMOIRS

OF

THE GEOLOGICAL SURVEY OF INDIA.

VOLUME LXIV.



Published by order of the Government of India.

CALCUTTA: SOLD AT THE CENTRAL BOOK DEPÔT, 8, HASTINGS STREET, AND AT THE OFFICE OF THE GEOLOGICAL SURVEY OF INDIA, 27, CHOWRINGHEE ROAD.
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Barytes in the Ceded Districts of the Madras Presidency; with notes on its occurrence in other parts of India. By A. L. Coulson, M.Sc., D.I.C., F.G.S., *Assistant Superintendent, Geological Survey of India.*

PART 2.

Asbestos in the Ceded Districts of Madras Presidency; with notes on its occurrence in other parts of India. By A. L. Coulson, D.Sc., D.I.C., F.G.S., *Assistant Superintendent, Geological Survey of India.*

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VOLUME LXIV, PART 1.

BARYTES IN THE CEDED DISTRICTS OF THE MADRAS PRESIDENCY; WITH NOTES ON ITS OCCURRENCE IN OTHER PARTS OF INDIA. By A. L. COULSON, M.Sc., D.I.C., F.G.S., *Assistant Superintendent, Geological Survey of India* (With Plates 1 to 5).

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1933.

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By A. L. COULSON, M.Sc., D.I.C., F.G.S., *Assistant Superintendent, Geological Survey of India* (With Plates 1 to 5).

CHAPTER I.

INTRODUCTION.

General.

The Ceded or Deccan districts.

Cuddapah, Anantapur and Kurnool districts are three of the four Ceded or Deccan districts[1] which, except for four taluks[2] of Kurnool, were ceded in 1800 to the East India Company by His Exalted Highness the Nizam of Hyderabad. They lie between Hyderabad on the north—the Kistna river and its tributary, the Tungabhadra, forming the boundary—, and Mysore State and the Chittoor district to the south. They also lie between Mysore State and the Bellary district on the west and the Guntur and Nellore districts on the east. Full particulars concerning them will be found by reference to the respective district gazetteers.

[1] Bellary is the fourth district. No barytes is known to occur in it.
[2] Taluk is an administrative subdivision of a district.

and Karnul Formations in the Madras Presidency'.[1] The spelling of the various names is that adopted in the 'Manual of the Geology of India',[2] and in Sir Thomas Holland's memoir on 'Indian Geological Terminology'[3] where this latter differs from the Manual. The modern maps of the Survey of India again have made several alterations in the spelling of the towns, rivers, mountains, villages, etc., from which King named these rocks. Thus the village Goolcheroo (Gulcheru in the table) is now spelt Guvvalacheruvu; and the river Khoond-air (Kundair in the table) is now the Kunderu river. Instances may be multiplied, but to avoid confusion, new spellings have not been introduced.

Vindhyan system (Purana)	Kurnool series	Kundair stage	Nandyal shales
			Koilkuntla limestones
		Panium stage	Pinnacled Quartzites
			Plateau Quartzites
		Jammalamadugu stage	Auk (Owk) shales
			Narji limestones
		Banganapalli stage	Sandstones and grits
	LARGE UNCONFORMITY		
Cuddapah system (Purana)	Kistna series		Srisailam quartzites
			Kolamnala slates
			Irlakonda quartzites
	UNCONFORMITY		
	Nallamalai series		Cumbum slates
			Bairenkonda quartzites
	UNCONFORMITY		
	Cheyair series		Pullampet slates=Tadpatri shales
			Nagari quartzites=Pulivendla quartzites
	UNCONFORMITY [4]		
	Papaghni series		Vaimpalli slates
			Gulcheru quartzites
	GREAT UNCONFORMITY		
(Archæan)	Crystalline rocks		

[1] *Mem. Geol. Surv. Ind.*, VIII, Pt. 1, (1872).
[2] R. D. Oldham, 2nd edn., pp. 78-82, 84-87, (Calcutta, 1893).
[3] *Mem. Geol. Surv. Ind.*, LI, Pt. 1, (1926).
[4] As will be seen, the present author does not believe in the existence of this unconformity.

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Intrusive sills of basic igneous rocks are associated with the Vaimpalli slates and limestones of the Papaghnis and with both stages of the Cheyairs. The exact age of these igneous rocks is a problem which has a very distinct bearing on the barytes deposits, as has been shown later. In this connection, one may be permitted to quote Dr. C. S. Fox's conclusions with regard to the barytes deposits :—

Intrusive sills.

'There is a curious association of barytes deposits with the outcrop of the Vaimpalli shales and limestones and the intercalated basaltic intrusions in these beds. This generalisation appears to be true of the outcrop of the Vaimpalli stage strata throughout their strike from south of Cuddapah near Ganganapalle ; through the Pulivendla taluk, *i.e.*, near Kottapalle ; to Nerijamupalle in the Anantapur district and on to the Kurnool areas around Malkapuram and Betamcherla. A total distance of nearly 100 miles of outcrop of Vaimpalli shales and limestones thus exists from Kurnool town to the tract south of Cuddapah railway station. In some cases, as south of Cuddapah and near Betamcherla, the barytes occurs as nodules in clay. In other cases, as in the hills south of Kottapalle (78° 21′ 30″ : 14° 22′), the barytes deposit is entirely in fault fissures in decomposed basalt. And in the Nerijamupalle deposits of Anantapur, the veins of barytes occur in siliceous limestone. It would seem that the barytes is somehow related to the igneous rocks and has possibly been derived from, and deposited in veins and fissures which developed after the intrusions had occurred and the strata were uplifted, bent and faulted. Prospecting of a kind has already been carried out by private enterprise, but I venture to think that this search was conducted without an appreciation of the relationships to which attention has been directed in this note. It is, therefore, possible that a systematic search along the outcrop of the Vaimpalli limestones and dolerites may lead to the discovery of other deposits of barytes, or prove finally that the field is not as important as might be expected from the chain of association.'

Stratigraphical Notes.

Throughout the description of the barytes deposits, very frequent reference has been made of the Papaghni and Cheyair series of the Cuddapah system and of their constituent stages. It is accordingly advisable that the following brief description of these rocks should be studied.

The Papaghnis are the basal series of the Cuddapah system. The lowest members constitute the Gulcheru stage, which consists of conglomerates, sandstones and quartzites, grits and a few intercalated sandy flags and shales. They rest unconformably upon the Crystallines which form

Papaghni series.

the ancient plain to the west of the Cuddapah basin,[1] extending from Guvvalacheruvu (57 J/15 ; 14° 17′ 30″ : 78° 45′), which is some 11½ miles S. by W. of Cuddapah town, to Joharapuram (57 I/1 ; 15° 49′ : 78° 4′), just east of Kurnool town on the Tungabhadra river. Further to the south-east of Guvvalacheruvu, they are cut out by faulting and the Nagari quartzites, the basal members of the Cheyair stage, abut against the Crystallines.

The Vaimpalli slates and limestones rest conformably upon the Gulcherus. They have great importance economically (in these rocks and their associated traps occurred every single occurrence of asbestos and barytes that was examined by the author).[2] Their longitudinal extent is more or less that of the Gulcherus ; but on account of their greater thickness, which in places is over 3,000 feet, as compared with 900 feet of the Gulcherus, they crop out over a very much larger area. Characteristically they consist of shales, frequently very ferruginous, flaggy, siliceous, dolomitic, magnesian and normal limestones, and beds of a distinctly arenaceous facies. The limestones contain bands of chalcedony which is of various colours and is present in varying amounts.

Intruded generally into the upper members of the Vaimpallis, and conforming to a remarkable degree with the strike and dip of these rocks, are basaltic and doleritic sills. It is at the contacts of these sills with certain siliceous, magnesian and dolomitic limestones that veins of asbestos are found.[3]

The next higher series, the Cheyair, likewise consists of arenaceous rocks at its base, the Nagari or Pulivendla quartzites, and a higher stage of shales with thin limestones the Pullampet slates or Tadpatri shales. King has adopted the names Nagari and Pullampet for his general subdivisions of the Cheyairs, preferring them to the names Pulivendla and Tadpatri ; but the author has not followed him in this procedure for the following reasons. In the first place, there is still some doubt as to the exact age of the Nagari quartzites and their overlying Pullampet slates,[4] though King states as a footnote that he thinks

Cheyair series.

[1] The most concise account of the physiography of the Cuddapah, Anantapur and Kurnool districts will be found in W. King's memoir (*op. cit.*, pp. 14-36).

[2] Barytes does occur in other rocks in the area, but these occurrences were not visited by the author. They will be referred to in due course.

[3] The asbestos occurrences in the Vaimpallis have been described in a separate report, which will be published as Part 2 of this memoir.

[4] W. King, *op. cit.*, pp. 175-181, 203-212.

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'it is almost quite clear that the Poolavaindla quartzites and the Naggerys are the same'.

The outcrops with which the present memoir is concerned are the type areas for the Pulivendla quartzites and the Tadpatri shales. There thus seems to be little point in using the names Nagari and Pullampet.

King insists upon an unconformity between the uppermost Vaimpallis and the basal Cheyairs, *i.e.*, the Pulivendla quartzites, and considers this unconformity to be large in certain parts. He notes that[1]

'a peculiar feature of the superposition of these quartzites upon the subjacent strata is that, for miles and miles of their outcrop, they are apparently quite conformable, when quite suddenly at certain points they are found to be lying on the acutely bevelled edges of the lower beds and to be full of pebbles and fragments of these'.

However, conclusive proof will be given of the erroneous nature of the latter part of these views. The beds which King has taken for Pulivendlas are really Banganapallis, the basal members of the very much younger Kurnool series. The present author considers that the unconformity between the Pulivendlas and the Vaimpallis, if it exists at all, is so small as to be negligible.

Certain of the conglomerates of the Pulivendlas are very reminiscent of the Gulcheru rocks. Characteristically the Pulivendlas consist of conglomerates, pebbly beds, grits, quartzites, flags and sandstones, the pebbles being derived chiefly from the ancient rocks to the west which were the source of the similar pebbles in the Gulcherus. Like the Vaimpalli shales and limestones, the Pulivendlas show contact metamorphic phenomena when they are seen adjacent to intrusive sills of basic igneous rocks.

Rocks of the Tadpatri stage overlie the Pulivendlas perfectly conformably. They consist in general of shales, with thin beds of siliceous limestones, which are very prone to show structures somewhat organic in appearance. The shales, also, show certain discoidal markings suggestive of fossil remains. But neither in these rocks, nor in other members of the various series of the Cuddapah system, nor in the rocks of the Kurnool series, have definite organic remains been found.[2]

[1] *Op. cit.*, p. 169.

[2] The Cuddapahs are certainly pre-Cambrian (Purana) in age, while the Kurnool series is considered to be analogous to rocks of the Vindhyan system in Northern India.

King notes the presence of intrusive sills of basic igneous rocks in the Tadpatris and, also, certain chert-like rocks he thought to be possibly volcanic in origin. This is rather important because if King's views be correct, then part at least of the igneous activity responsible for the presence of the basalts and dolerites must have occurred in the Tadpatri age. This point has been dealt with later.

The author did not have an opportunity of studying rocks of the Nallamalai or Kistna series ; but in the northern part of his area,

Banganapalli beds.

particularly in the Kurnool district, rocks belonging to all four stages of the Kurnool series crop out over a large area, largely masking the outcrops of the older Cuddapah rocks. The diamondiferous Banganapalli beds, forming the basal stage of this series, show certain resemblances to the other arenaceous facies already mentioned, *viz.*, the Gulcherus and the Pulivendlas. Generally, however, the unconformity with which these Banganapalli beds overlie the rocks beneath them is sufficiently large to be unmistakeable.

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CHAPTER II.

BARYTES IN THE CUDDAPAH DISTRICT.

Introduction.

As long ago as 1910, Shaik Meera Sahib held two prospecting licenses for barytes in the Cuddapah district.[1] Mr. A. Ghose and M. R. Ry. B. Chinnamalla Reddi Guru held prospecting licenses for this mineral in 1923 ;[2] and in 1929, Mr. T. H. B. Tiffin, of Messrs. Tiffin and Co., 4, Church Lane, Calcutta, held a prospecting license for barytes.[3] The author is indebted to Mr. Tiffin for information concerning the existence of the greater number of the deposits of barytes in the Cuddapah district hereinafter described.[4] Mr. A. Kristnappa, of Cuddapah, also conducted prospecting operations for barytes and due mention has been made of his activities. Notwithstanding the above, it must be clearly understood here that unless otherwise stated, the descriptive notes given are the results of the author's personal visits to the deposits, and he alone is responsible for their general accuracy.

Previous prospectors.

There is but one published reference to barytes in the Cuddapah district, that being the brief mention of Dr. Fox's visit to the Kottapalle occurrences[5] in the General Report of the Director of the Geological Survey of India for 1930. It is rather amazing that King, Foote and Oldham should have failed to note the occurrence of barytes because certain veins are several feet in thickness and must have formed rather conspicuous outcrops when first brought to the attention of the present-day prospectors.

Dr. C. S. Fox.

Taluks in which barytes occurs.

Barytes occurs in the following taluks of the Cuddapah district[6]:—

A. Cuddapah taluk.

[1] *Rec. Geol. Surv. Ind.*, XLI, p. 200, (1912).
[2] *Op. cit.*, LVI, p. 169, (1926).
[3] *Op. cit.*, LXIII, p. 347, (1930).
[4] Mr. Tiffin has carried out extensive prospecting for barytes not only in the Cuddapah district but also in the Kurnool district. He has now confined his activities to the Cuddapah district.
[5] *Rec. Geol. Surv. Ind.*, LXV, p. 34, (1932).
[6] *See* Plate 3.

B. Kamalapuram taluk.
C. Pulivendla taluk.
D. Razampeta taluk.

Among the deposits of barytes in the Cuddapah district is probably the largest occurrence in Madras, if not in India (No. 14, p. 19). All the deposits, however, suffer the disadvantage of being at a considerable distance from railway stations, and from the lack of first-class roads connecting them with the stations and over which modern conveyances can be used uninterruptedly. They are served by the railway stations of Cuddapah and Muddanuru at miles 162 and 196 from Madras on the broad-gauge line from Madras to Bombay. However, provided adequate assistance to its development is given by the local authorities, the future of the barytes industry in this district is on a safe foundation. Messrs. Tiffin and Co. are to be congratulated on their action in establishing a grinding plant for barytes at Cuddapah station and deserve every encouragement. It is, indeed, unfortunate that the culverts in the roads connecting the chief deposits of this enterprising company with Cuddapah station are in such a deplorable condition that instead of using heavy motor transport, recourse has had once more to be made to primitive bullock carts. These carry a maximum load of about half a ton as compared with the several tons of a motor lorry.

Railway and road communications.

A.—Cuddapah Taluk.

Deposits of barytes in the Cuddapah taluk of the Cuddapah district may be grouped in three areas or zones :—

1. Mittamidapalle (57 J/11 ; 14° 25′ 30″ : 78° 44′).
2. Chimalapenta (57 J/11 ; 14° 26′ : 78° 35′ 30″).
3. Uppalapalle (57 J/11 ; 14° 26′ : 78° 31′ 30″).

All of them lie on sheet 57 J/11 and none of them has been tested thoroughly.

1. *Mittamidapalle (57 J/11 ; 14° 25′ 30″ : 78° 44′).*

Mittamidapalle itself lies some seven miles south-west of Cuddapah town, the nearest railway station, with which it is connected by a third-class road ; it is near the eastern edge of one-inch sheet 57 J/11.

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King's field maps show the country to the south and south-west of Mittamidapalle as being composed of Vaimpalli shales and limestones, overlain by Pulivendla quartzites ; but in his memoir, he states that[1] :—

' the oddly picturesque masses of quartzite strata capping the plateau hills beyond (south of) Cummawarpully (=Kammavaripalle, a quarter of a mile north of Mittamidapalle) are, I think, of the newer Karnuls'.

It is also the author's opinion that the quartzites and sandstones (which in places are very ferruginous), capping unconformably the Vaimpalli shales and limestones, are the Banganapalli beds of the Kurnool series.

All the occurrences of barytes in this Mittamidapalle area are in the Ganganapalle extension reserved forest. No basaltic igneous rocks were noted in their immediate neighbourhood, though such might easily escape observation by being intruded into Vaimpallis hidden under a covering of Banganapallis.

No. 1.—Barytes occurs two miles S. 40° W. of Mittamidapalle as a vein, 2½ feet thick, in Vaimpalli shales and limestones (N 501, 21,749 ; N 502),[2] which dip N. 65° E. at 20°-30°. The vein is exposed in a pit dug by Mr. Tiffin to the north of the third-class cart road leading to Polatala rest house, near the 5 miles 6 furlongs post on the western side of a small *nala*. It cuts across the bedding of the shales and limestones, striking N. 15° E. It is impossible to give the dip of the vein. Judging by the numerous included fragments of country rock, it is possible that it has been deposited in a line of crushing.

It is not thought that the available quantity of barytes is great, though what is present is of good quality.

No. 2.—A number of pits have been dug by Mr. Tiffin in the side of a hill, 1¼ miles S. 70° E. of Pandula Bodu Hill, 1,274 feet. The barytes occurs in Vaimpalli shales, but the pits are not sufficiently wide or deep to enable one to obtain a reliable idea of the quantity of mineral present. The amount of surface debris is large, but there is little doubt that the barytes occurs as a vein, and not as nodules in surface clay. Crystals of barytes (N 504) were chipped off from crystals of quartz (N 503) associated with them. Such association is uncommon. The perfectly formed quartz crystals indicate the presence of vugs.

No. 3.—Other pits have been dug by Mr. Tiffin a short distance to the south-east of the last occurrence, *i.e.*, a quarter of a mile N. 38° E. of hill station, 1,348 feet. As in the previous case, the barytes is of fairly good quality and a certain amount of it has been carted to the village of Kammavaripalle, and from thence to Cuddapah. But as the pits are mere scratchings, it is impossible to form any idea of the quantities available.

[1] *Op. cit.*, p. 175 (parenthesis by the author).

[2] Numbers such as N 501 refer to the registered number of the specimen in the mineral collections of the Geological Survey of India. Numbers such as 21749 refer to the registered number of the thin section in the collections of the same department.

Nos. 2 and 3 lie approximately 3¼ miles S. S. W. of Mittamidapalle.

No. 4.—About seven furlongs east of the last occurrence, barytes (N 507) occurs with quartz in an ochreous and calcareous material. This occurrence is one mile W. S. W. of Gangu Bhavi[1] and 3⅜ miles S. by W. of Mittamidapalle, the nearest village. Several pits have been dug by Mr. Tiffin, but the largest of these alone shows the true nature of the deposit. It occurs in Vaimpalli limestones and shales, not far from the Banaganpalli sandstones which cap the hills to the north. The vein is at least two to three feet wide ; its dip is uncertain. The strike does not differ largely from the E.-W. strike of the Vaimpallis in this area.

It seems probable that the occurrence is connected in origin with Nos. 2 and 3. There are, however, no outcrops of barytes between Nos. 3 and 4, though such may have been missed on account of the high grass present at the time of the author's inspection.

2. *Chimalapenta (57 J/11 ; 14° 26′ : 78° 35′ 30″).*

The several occurrences of barytes that have been classed in the Chimalapenta area are fairly widely separated, and there is no evidence to show that they are interrelated. Moreover, one occurrence (No. 6) is in basalt, whilst the others are in Vaimpalli shales and limestones. All the deposits lie within the Tummaluru and extensions reserved forest. Their nearest railway station is Kamalapuram (57 J/10 ; 14° 36′ : 78° 40′), which is at the confluence of the Penner and Papaghni rivers. The roads to this station, however, are not good, being merely bullock-cart tracks. Such barytes as would be marketed from this area would naturally be taken along the second-class Pulivendla-Cuddapah road, Chimalapenta being some 16½ miles from Cuddapah, which would be the railway station employed. None of the deposits in the Chimalapenta area has been extensively tested. The geology of the area

Geology of the area.

is somewhat akin to that of the Mittamidapalle area, but in the former there are several trap sills intruded between the Vaimpalli shales and limestones. King's field maps and the sections in his memoir show Pulivendla quartzites capping Vaimpallis unconformably. He states that[2]—

' the unconformity of the (Pulivendla) quartzites on the series of limestones beneath them is perhaps most clearly shown in the sharp twist around from the long north-east scarp on the left bank of the Paupugnee (Papaghni), across the river southwards into the country of the right bank. The dip of both series of rocks, for instance, in the low hills south of Boodyapully (now called Chabali ; 57 J/11 ; 14° 30′ :

[1] *Bhavi*=well.

[2] *Op. cit.*, p. 172.

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78° 36′), is so low and varies so little that the unconformity is not seen except in long sections, as for instance along the southern face of the east and west spur of hills between Pugdallpully (Pagadalapalle) and Chinunulpenta (Chimalapenta). This low range is capped by breccias and pebble beds of quartzites, which are on the north side overlying beds of the limestone series different from those which they overlie on the south side of the ridge. Here the bottom breccia beds are very ferruginous and full of fragments of oolitoid chert. At the Paupugnee side of the hills the limestone outcrops are covered by grey brownish and reddish grits in thick beds, which strike into the river and appear on the other side as the beds which eventually turn round and form the scarped Annamall (Animala ; 57 J/11; 14° 28′ : 78° 30′ 30″) ridge.'

The author does not agree with King's views. The Pulivendla quartzites overlie the Vaimpallis perfectly conformably on the western side of the Papaghni river. It seems very improbable that within the space of a mile or two, these same Pulivendla quartzites will lie unconformably on the eroded Vaimpallis. It is far more reasonable to consider that these quartzites and sandstones in the Tummaluru reserved forest are basal members of the Kurnool series, *i.e.*, Banganapalli beds. The author did not have an opportunity of studying the relationships of these beds with the Narji limestones of the Kurnool series (Jammalamadugu stage), under which they dip ; but the conditions resemble those in the Kurnool district so strongly that the author has little hesitation in affirming that these beds should be classed as Banganapallis.

There seems to be little doubt that barytes veins occur in the Vaimpallis hidden by the Banganapallis, because such deposits as were examined lie near the Banganapallis and must have been covered previously by them unconformably.

No. 5.—Barytes (N 509) was noted in a few shallow pits dug by Mr. Tiffin two miles north-east of Chimalapenta. The pits lie within the Tummaluru and Extensions reserved forest, but the eastern boundary of that forest is not as plotted on the latest one-inch sheet (season 1922-23). The rocks in which the barytes occurs are very cherty Vaimpalli limestones (43·913, 21251).[1] It is not thought that the quantity of barytes available is large.

No. 6.—One of the most interesting occurrences of barytes examined was that just under 1½ miles north of Chimalapenta. A very good section is exposed in the stream course of the small southerly-flowing tributary of the stream which flows westwards to Nagayapalle and thence N. N. E. to join the Papaghni river. The stream is, of course, dry except during the monsoon, when a small waterfall occurs over the epidiorite sill in which the barytes occurs. The hillside forms a dip scarp, Banganapalli sandstones capping the hill to the north. These

[1]Numbers such as 43·913 refer to registered specimens in the rock collections of the Geological Survey of India.

rest unconformably upon Vaimpalli shales and limestones into which is intruded an epidiorite sill (21752 ; 43·866, 21753), which dips northwards into the hillside.[1] The sill is about 25 feet thick at the waterfall.

The barytes occurs as a vein in the epidiorite, generally about ten feet from its upper surface ; but it does not always keep to the same horizon in the trap. Thus on the eastern side of the waterfall, the vein bifurcates, and then joins up again. Pits dug by Mr. Tiffin would appear to indicate that the vein does not continue for any great distance on the eastern side of the waterfall, but that barytes occurs for at least 200 yards on its western side. The author considers, however, that possibly other thin veins come in on this western side. The general thickness of the main vein is less than one foot, but some pits indicate a slightly larger thickness than this.

There is nothing to indicate that the vein follows a fault. The evidence, on the contrary, is in favour of the ore being deposited along joint planes which were probably developed at the time of cooling of the magmatic material forming the sill.

The barytes (N 510) varies in colour and quality ; some specimens show a definitely greenish tint. Further trial pits would have to be dug to test the possibilities of the occurrence, but the author does not think that sufficient thickness will be found to warrant the deposit becoming important economically.

No. 7.—A few shallow pits have been dug by persons unknown to the author in Vaimpalli shales and limestones in the valley, just below the Banganapalli sandstones forming hill station 964 feet, one mile west of Chimalapenta. The Vaimpallis dip north into the hill at a very shallow angle, slightly more, however, than the dip of the Banganapallis, which is in the same direction. Barytes (N 518) occurs in a vein of indefinite thickness, which strikes down the hill at right angles to the strike of the limestones. The occurrence does not look promising.

No. 8.—There are several veins of barytes in the Vaimpalli shales and limestones in the western part of the Tummaluru and extensions reserved forest, east of Tummaluru village. A vein of fair size (N 512) occurs one mile E. S. E. of the village, running more or less E.-W. near the top of the valley running in the same direction. Apparently a prospecting license has been taken out for this vein, but the few shallow pits dug can give but small indication of the possibilities of the deposit. Another, but smaller, occurrence of barytes is on the path from the village to the last deposit, being about three-quarters of a mile E. by S. of Tummaluru.

Impure barytes, associated with a cherty rock, originally a limestone (N 513, N 514, 21754) occurs just over a mile E. by N. of the village. This barytes appears to be along a line of brecciation striking W. N. W.-E. S. E. for about half a mile, and is probably related to another occurrence of this mineral (N 515), associated with abundant ferruginous material, three-quarters of a mile E. N. E. of Tummaluru. The shallow pits dug in both cases are not very informative, but it is thought that the economic possibilities of these occurrences are not large. A small basic sill is intruded into the Vaimpallis between the two occurrences.

[1] Reference has been made to this sill in the author's asbestos report.

3. *Uppalapalle* (*57 J/11 ; 14° 26′ : 78° 31′ 30″*).

The barytes occurrences grouped in the Uppalapalle area lie in the hills north-east of the large village of Nandimandalam, which is just over 21 miles from Cuddapah along the road to Pulivendla. Any barytes exported would have to be carted along bullock-cart tracks to this second-class road and thence to Cuddapah railway station.

Geology of the area.

The Vaimpalli limestones in this region have rolling dips, generally of small magnitude, to the north. They were probably previously covered by Banganapalli beds, most of which have since been eroded away. There are no intrusive traps in the immediate neighbourhood of the Uppalapalle occurrences.

No. 9.—Small veins of impure barytes (N 528, 21,767) crop out on the cart road from Uppalapalle to Nandimandalam, seven furlongs south of the former village. They occur in crushed Vaimpalli limestones, which locally are very brecciated. A few hundred yards E. S. E. of this locality, *i.e.*, about one mile S. S. E. of Uppalapalle, another unproved occurrence of barytes was seen. Neither of these deposits has economic possibilities.

No. 10.—A more important vein of barytes (N 529) occurs 1¼ miles E. by N. of Uppalapalle, on the saddle between hill station 1,152 feet and the hill to its S. S. E. The vein, which in places is two feet wide, but which contains many included fragments of cherty rock, runs at a slight angle with the strike of the Vaimpalli limestones, which here dip north under Banganapalli quartzites capping the hill station referred to. The vein is discontinuous on the surface, but can be traced at intervals for some 30 to 40 yards. It has slight economic possibilities, but the amount of included chalcedonised wall-rock would detract considerably from its value. Some prospector has collected specimens from the vein.

Another small occurrence of barytes was noted a quarter of a mile S. S. W. of hill station 1,152 feet, *i.e.*, 1⅛ miles east of Uppalapalle. Possibly both occurrences are connected with the same fault.

The author was informed of the occurrence of barytes near Kotturu (57 J/7 ; 14° 24′ : 78° 30′), but he was unable to trace any deposit in the neighbourhood of this village.

B.—Kamalapuram Taluk.

There is but one deposit of barytes known to, and visited by, the author in the Kamalapuram taluk of the Cuddapah district during the course of his investigations :—

4. *Rajupalem* (*57 J/11 ; 14° 26′ : 78° 31′*).

The occurrence is near the western margin of one-inch sheet 57 J/11. Such barytes as would be marketed from Rajupalem would probably be carted two or three miles along bullock-cart tracks to the second-class road from Pulivendla to Cuddapah, joining that road near mile 23 from Cuddapah, by the village of Kotturu (57 J/7).

No. 11.—The barytes (N 521,21763 ; N 522) is mostly of the granular type as distinct from the crystalline (ordinary) barytes noted in all the previously described occurrences. It occurs associated with calcite in Vaimpalli limestones half a mile W. N. W. of the village of Rajupalem which lies in the south-eastern corner of the Kamalapuram taluk on the left bank of the Papaghni river, which separates the Cuddapah and Kamalapuram taluks. The vein has been traced for about 100 yards by pits dug by Sheikh Suleimann Sett, who, it is understood holds a prospecting licence for the plot (survey No. 501 of Rajupalem) in which it occurs. Its width might be anything up to three feet in places, but the number of included fragments of country rock is such that its value is considerably depreciated. It is thought, also, that the barytes contains a considerable percentage of lime.

The fact that the vein strikes S. 65° W. towards the valley between hill stations 1,711 and 964 feet, together with the abundant presence of fragments of wall-rock, suggests that it lies along a fault line.

There are numerous basic sills in the near neighbourhood, at the contact of which and the Vaimpalli limestones, asbestos has been formed (see the author's asbestos report).

C.—Pulivendla Taluk.

The most important deposits of barytes in the Cuddapah district, if not in the Madras Presidency, occur in the Pulivendla taluk.

Means of communication.

They lie on one-inch map sheets 57 J/2, 57 J/3 and 57 J/7. They have the disadvantage of occurring far removed from the railway line ; their easiest method of tapping this line is by means of Muddanuru and Cuddapah stations. Pulivendla is joined to Cuddapah by a second-class road, some 45 miles in length, and to Muddanuru by a similar road, 23 miles long. A third-class road which runs for some 20 miles from Pulivendla, by way of Velidandla (57 J/2 ; 14° 34′ : 78° 3′) to Parnapalle (57 F/14 ; 14° 34′ : 77° 58′), is really the continuation of the Cuddapah-Pulivendla road. Any barytes exported from the taluk would naturally use one or other of these roads.

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Occurrences of barytes in the Pulivendla taluk of the Cuddapah district may conveniently be subdivided for descriptive purposes into the following areas [1]:—

Classification of barytes deposits.

5. Nandipalle (57 J/7 ; 14° 22′ 30″ : 78° 24′ 30″).
6. Kottapalle (57 J/7 ; 14° 22′ : 78° 21′ 30″).
7. Bakkannagaripalle (57 J/7 ; 14° 20′ : 78° 22′).
8. Midipenta (57 J/7 ; 14° 20′ : 78° 19′).
9. Rachegaripalle (57 J/7 ; 14° 21′ : 78° 19′).
10. Elamvaripalle (57 J/3 ; 14° 23′ 30″ : 78° 14′).
11. Ippatla (57 J/3 ; 14° 25′ 30″ : 78° 11′).
12. Karnapapayapalle (57 J/2 ; 14° 32′ : 78° 4′ 30″).

In practically all the above areas, the barytes is intimately connected with faults, and there is also an apparent relationship between it and basic igneous rocks.

Geology of the area.

The strike of the rocks of the Papaghni and Cheyair series of the Cuddapah system bends round in the form of a bow as it is traced from Vempalle village to Pulivendla (57 J/3 ; 14° 25′ 30″ : 78° 14′), being first S. W.–N. E., then E.–W., and finally N. W.–S. E.

From the base of the Cuddapah system, in ascending order, one meets first the Gulcheru quartzites, which form the Palakonda hills constituting the Gorivikinama reserved forest between the Pulivendla taluk of the Cuddapah district and the Kadiri taluk of Anantapur district and the Rayachoti taluk of the Cuddapah district. Then follow the Vaimpalli shales and limestones, into the upper members of which are intruded large sills of basic igneous rocks which form striking ridges. Pulivendla quartzites conformably overlie the Vaimpallis and are, in turn, overlain conformably by the Tadpatri shales. Basic sills have metamorphosed the Pulivendlas and have been intruded into the Tadpatris.

The accompanying sketch map (Pl. 4, fig. 1) shows the geology in the vicinity of the village of Kottapalle. The structure of the country is most easily understood by tracing the outcrop of the Pulivendla quartzites, which form an easily recognizable datum. In many cases, however, the outcrops of these rocks and of the Vaimpallis and their associated basic sills are masked by cultivation

[1] Mr. T. H. D. Pilla informed the author that barytes occurred in the cultivated land's west (? south) of the main road from Vempalle (57 J/7 ; 14° 22′ : 78° 27′ 30″) to Pulivendla, near Vempalle village; but the author was unsuccessful in finding barytes in this neighbourhood, though possibly it occurs.

Also there has been faulting on a very large scale. The evidence regarding the age of this faulting is not conclusive, but it suggests that it was more or less contemporaneous with the cooling period, if not at the actual time of intrusion of the traps. This would place it late or post-Cheyair, but the point will be elaborated later (*see* pp. 106–108).

There is an important fault, the Vempalle fault, recognized by King and indicated by him on his field maps, striking N. W.-S. E. to the west of Vempalle. This is probably connected with the E.-W. fault running from north of Idupulapaya (57 J/7 ; 14° 20′ 30″: 78° 30′) along the Kondaraju *vanka* (57 J/11). The author knows of no barytes associated with this Vempalle fault though the possible occurrences of barytes near Vempalle, referred to in the footnote on page 16, may be related to it.

A second important fault, termed the Rachegaripalle fault (*see* p. 19), can easily be recognized in the neighbourhood of that village, where it has displaced the Pulivendla quartzites. There seems but little doubt that the main deposit of barytes in the hills south of Kottapalle lies along a fault, which is intimately connected with this Rachegaripalle fault, being very nearly along its eastward continuation.

It is necessary to postulate the existence of a third important fault, the Pulivendla fault, which commences from about $1\frac{3}{4}$ miles W. S. W. of Peddakudala (57 J/3 ; 14° 26′ : 78° 10′), and runs E. S. E. for some 13 miles to Rachegaripalle. This fault is of small and varying magnitude, but generally the throw is sufficiently large to cut out the Pulivendla quartzites, the uppermost basic sill in the Vaimpallis abutting against the Tadpatri shales.

The Pulivendla quartzites crop out in force in the hills near Lingala (57 J/3 ; 14° 30′ : 78° 7′) and again near Rachegaripalle (57 J/7). Blocks of the Pulivendla quartzites which have been employed as fences at Brahmanapalle (57 J/3 ; 14° 25′ : 78° 12′), midway between Lingala and Rachegaripalle, have undoubtedly been dug from the fields near Brahmanapalle ; pebbles from the Pulivendla conglomerates may be seen near Ippatla, W. N. W. of Brahmanapalle. But in no other places along the line of the supposed Pulivendla fault could indications of the Pulivendla quartzites be seen.

A fourth important fault, the Lingala fault, occurs practically at the junction of one-inch sheets 57 J/3 and J/2, striking W. N. W.–

Classification of barytes deposits.

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11. Ippatla (57 J/3 ; 14° 25′ 30″ : 78° 11′).
12. Karnapapayapalle (57 J/2 ; 14° 32′ : 78° 4′ 30″).

Geology of the area.

In practically all the above areas, the barytes is intimately connected with faults, and there is also an apparent relationship between it and basic igneous rocks.

The strike of the rocks of the Papaghni and Cheyair series of the Cuddapah system bends round in the form of a bow as it is traced from Vempalle village to Pulivendla (57 J/3 ; 14° 25′ 30″ : 78° 14′), being first S. W.–N. E., then E.–W., and finally N. W.–S. E.

From the base of the Cuddapah system, in ascending order, one meets first the Gulcheru quartzites, which form the Palakonda hills constituting the Gorivikinama reserved forest between the Pulivendla taluk of the Cuddapah district and the Kadiri taluk of Anantapur district and the Rayachoti taluk of the Cuddapah district. Then follow the Vaimpalli shales and limestones, into the upper members of which are intruded large sills of basic igneous rocks which form striking ridges. Pulivendla quartzites conformably overlie the Vaimpallis and are, in turn, overlain conformably by the Tadpatri shales. Basic sills have metamorphosed the Pulivendlas and have been intruded into the Tadpatris.

The accompanying sketch map (Pl. 4, fig. 1) shows the geology in the vicinity of the village of Kottapalle. The structure of the country is most easily understood by tracing the outcrop of the Pulivendla quartzites, which form an easily recognizable datum. In many cases, however, the outcrops of these rocks and of the Vaimpallis and their associated basic sills are masked by cultivation

[1] Mr. T. H. B. Tiffin informed the author that barytes occurred in the cultivated lands west (? south) of the main road from Vempalle (57 J/7 ; 14° 22′ : 78° 27′ 30″) to Pulivendla, near Vempalle village ; but the author was unsuccessful in finding barytes in this neighbourhood, though possibly it occurs.

Also there has been faulting on a very large scale. The evidence regarding the age of this faulting is not conclusive, but it suggests that it was more or less contemporaneous with the cooling period, if not at the actual time of intrusion of the traps. This would place it late or post-Cheyair, but the point will be elaborated later (*see* pp. 106–108).

There is an important fault, the Vempalle fault, recognized by King and indicated by him on his field maps, striking N. W.-S. E. to the west of Vempalle. This is probably connected with the E.-W. fault running from north of Idupulapaya (57 J/7 ; 14° 20′ 30″: 78° 30′) along the Kondaraju *vanka* (57 J/11). The author knows of no barytes associated with this Vempalle fault though the possible occurrences of barytes near Vempalle, referred to in the footnote on page 16, may be related to it.

A second important fault, termed the Rachegaripalle fault (*see* p. 19), can easily be recognized in the neighbourhood of that village, where it has displaced the Pulivendla quartzites. There seems but little doubt that the main deposit of barytes in the hills south of Kottapalle lies along a fault, which is intimately connected with this Rachegaripalle fault, being very nearly along its eastward continuation.

It is necessary to postulate the existence of a third important fault, the Pulivendla fault, which commences from about $1\frac{3}{4}$ miles W. S. W. of Peddakudala (57 J/3 ; 14° 26′ : 78° 10′), and runs E. S. E. for some 13 miles to Rachegaripalle. This fault is of small and varying magnitude, but generally the throw is sufficiently large to cut out the Pulivendla quartzites, the uppermost basic sill in the Vaimpallis abutting against the Tadpatri shales.

The Pulivendla quartzites crop out in force in the hills near Lingala (57 J/3 ; 14° 30′ : 78° 7′) and again near Rachegaripalle (57 J/7). Blocks of the Pulivendla quartzites which have been employed as fences at Brahmanapalle (57 J/3 ; 14° 25′ : 78° 12′), midway between Lingala and Rachegaripalle, have undoubtedly been dug from the fields near Brahmanapalle ; pebbles from the Pulivendla conglomerates may be seen near Ippatla, W. N. W. of Brahmanapalle. But in no other places along the line of the supposed Pulivendla fault could indications of the Pulivendla quartzites be seen.

A fourth important fault, the Lingala fault, occurs practically at the junction of one-inch sheets 57 J/3 and J/2, striking W. N. W.–

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E. S. E. between the villages of Lingala and Lopatanutula (57 J/3; 14° 30′ : 78° 6′). This Lingala fault and two others, less important, the Ippatla and Ramanutiapalle faults, have been discussed in the author's asbestos report, where full details will also be found concerning the contact between the igneous rocks and the Vaimpalli limestones, and the asbestos mined from this locality.

5. *Nandipalle* (*57 J/7 ; 14° 22′ 30″ : 78° 24′ 30″*).

Nandipalle village is just over 30 miles from Cuddapah station along the Pulivendla road. There is but one deposit of barytes classed under the Nandipalle area.

No. 12.—About a quarter of a mile south-west of Nandipalle,[1] a large deposit of barytes has been proved for over 200 yards by a series of pits dug, it is understood, by Mr. A. Kristnappa of Cuddapah. The barytes (N 531), which is of good quality, occurs in trap with quartz in a series of veins which join and separate. The largest vein is generally about two feet thick, but varies greatly. The thicknesses of the others are matters of inches. The whole occur in a total width of some six to eight feet. They strike E.–W., more or less parallel to the strike of the Pulivendla quartzites that cap the little hill to the north. The main vein becomes thicker as it is followed towards the west. In a pit near the cultivated field which has precluded the proving of the vein further west, it is at least five to six feet thick, with not very much quartz associated with the barytes. It can be seen in the next field but one to the west, and though so far untested, the amount of surface debris would appear to indicate a fair width.

It is possible that this Nandipalle barytes occurs along a fault line in trap. There is undoubtedly a fault between the Pulivendla quartzites east of Tatimakulapalle and the similar rocks north of Tallapalle, which villages lie one on either side of the 32 milestone on the Cuddapah-Pulivendla road; but this Tatimakulapalle fault appears to strike N. N. W.–S. S. E., as distinct from the E.–W. strike of the barytes veins.

The economic possibilities of the occurrence appear to be good.

6. *Kottapalle* (*57 J/7 ; 14° 22′ : 78° 21′ 30″*).

Kottapalle village is 34 miles from Cuddapah and 11 miles from Pulivendla, the village being built on Tadpatri shales just to the north of the northerly dipping Pulivendla quartzites and conglomerates.

Geology of the area.

The old field maps of the Kottapalle area are not accurate inasmuch as they give the downward succession of Pulivendla quartzites, Vaimpallis, trap, more Vaimpallis, more trap, and finally a big spread of Vaimpallis resting upon Gulcherus. Actually, as was also noted by Dr. Fox, who paid a visit to the two chief deposits of barytes in this area, the Pulivendlas are underlain by, and metamorphosed by, a very large sill of trap below which, on the Midipenta side of the ridge, there is only the big spread of Vaimpallis overlying the Gulcherus. The whole sequence has a general northerly dip, varying largely, but very rarely greater than 20°-30°.

[1] *See* Plate 4, fig. 1.

The deposits classified under the Kottapalle area[1] include those upon which Messrs. Tiffin and Co. are concentrating their energies, and, also, some for which Mr. A. Kristnappa of Cuddapah held a prospecting license at the time of the author's visit.

No. 13.—It is convenient to describe first the deposit of barytes occurring two miles one furlong S. by W. of Gondipalle (57 J/7 ; 14° 22′ 30″ : 78° 20′ 30″), in the lands of which village it lies, and two miles south-west of Kottapalle. This large deposit crops out in the low ground (*see* Pl. 1) 600 yards south of hill station 914 feet. It has been tested by Mr. A. Kristnappa of Cuddapah, who has removed, apparently, a large amount of barytes. In places, the main vein is more than 15 feet thick at the surface; its usual thickness is at least 10 feet. The vein dips south at about 60° and strikes very nearly E.–W. (really 95°–275°) towards the saddle in the hills to the east wherein is found the first trace of the deposit described immediately hereafter (No. 14).

Dr. Fox concluded that 'the vein appears to be along a fault in the trappean rocks which are themselves intrusive in the Vaimpalli stage strata'. He noted the presence of slickensided surfaces on the hanging wall of the vein, but these were not visible at the time of the author's visit. There seems to be little doubt, however, that the deposit lies along a fault, which appears to strike to the south of the faulted Pulivendlas, E. S. E. of Rachegaripalle. It is quite possible that the fault curves more northward and runs into the Rachegaripalle fault mentioned previously (p. 17).

Some silica was noted in the mineralised zone of the trap, which is a few feet in thickness. The barytes (N 540) is generally of good colour; some flakes of chalcopyrite were associated with it.

No. 14.—The most important vein of the Kottapalle area is that, the central part of which is about 1½ miles south of the village. The first trace of it is seen on the western side of the saddle in the hills, half a mile east of the last-described deposit, and from here it can be traced in a general easterly direction for over 1½ miles. Plate 2 shows a photograph taken by Dr. Fox from the top of the saddle, and looking westward toward No. 13, which may be distinguished in the low ground in the photograph.

The extreme western part of this deposit, *i.e.*, that part of it occurring on the western side of the saddle, one mile five furlongs S. S. W. of Kottapalle, has been tested by Mr. A. Kristnappa, who held a prospecting license for this area. The remainder, stretching over 1½ miles, is now held, it is understood, on a mining lease

[1] *See* Plate 4, fig. 1.

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granted to Messrs. Tiffin and Co., who have prospected it thoroughly except as regards depth. Here, as in all other deposits visited, there appears to have been no attempt to prove the depth to which the deposit extends, it apparently being taken for granted that it has unlimited depth.

Mr. Kristnappa has dug a series of pits in the top of the valley on the western side of the saddle referred to previously, and has exposed several anastomosing veins, enclosing masses of trap, the general strike of the veins being 100°-280°. The author considers that they are related to the large vein in deposit No. 13 in the low ground, to the west, towards which they strike. They generally have a high dip to the south and they vary in thickness from two to six feet. There is a large quantity of barytes present in this part of the valley, but it is exceedingly irregular in distribution. A bullock-cart track has been made a considerable distance up the valley towards the saddle, and a considerable amount of barytes removed. It is, however, generally not of quite as good quality (N 538) as that in the eastern continuation of the deposit.

As one descends the eastern side of the saddle, in Messrs. Tiffin and Co.'s property, the veins appear to coalesce to one main vein and the strike changes to 102° then gradually to 85°. Three furlongs north-west of hill station 1,617 feet, the vein is three feet wide and dips S. 25° W. at 80°, having a mineralised margin (N 532, 21769) some nine inches wide on either side. The trap itself here is a fine-grained basalt (21770), which weathers easily. The thickness of the vein is far from constant. Thus a little further, east on the same hill shoulder, a pit dug by Mr. Tiffin shows a thickness of only one foot to one and a half feet, near the surface ; but 16 feet lower down the same pit, the thickness has increased to more than six feet. The mineralised margin here is larger and there appear to be several smaller veins of barytes, a few inches in thickness.

The same variation in thickness was noted on a spur a quarter of a mile north of hill station 1,617 feet, where more pits have been dug under the supervision of Mr. Tiffin. The thickness varies from two to six feet, according to the depth. The dip, also, is not constant, though generally it is to the S. S. W.

The vein bears at 70° from this spur to the spur N. N. E. of the same hill station, but the strike is not constant. The variation of thickness is seen excellently in a pit on the latter spur, where it increases from three to ten feet, and then diminishes again to three feet.

The vein bears at 80° from the spur N. N. E. of hill station 1,617 feet. Its dip here is about 70°-80° S. S. W., but in one place where the vein has thickened, the dip is frequently as low as 60°, and even 45° to the south.

From the shoulder three-quarters of a mile north-east of the same hill station, the vein bears at 82°. Its thickness varies but the dip here is usually 70°-80° to either south, S. S. E. or S. S. W.

The last pits dug by Mr. Tiffin are about 1½ miles S. E. by S. of Kottapalle village.

As a rule, the barytes (N 533) is crystalline and clear. Sometimes it is greyish, at others greenish. There seems to be a total absence of minerals other than barytes in the vein. Curiously enough, though the deposit undoubtedly seems to have been deposited along a fault course, yet there are no signs of brecciation along the walls. There are abundant epidote, quartz and iron-ore (21772 ; 21773 ; N 535, 21774), occurring more or less in the form of a pegmatite in trap, but generally

to the north of, though roughly parallel with, the main vein of barytes. The basalts have a general shallow dip of about 15°-20° to the north. The vein itself generally has a dip of some 70°-80° to the south (hade of 10°-20° to the south) or S. S. W. The general question of the origin of the barytes and of the pegmatite will be discussed later (*see* Chapter VI).

This deposit will no doubt form the chief source of barytes for Messrs. Tiffin and Co.'s crushing plant at Cuddapah. It is unfortunate that its position entails the carting of the barytes for some 35 miles to that town. However, the available quantity of barytes is large. Thus assuming an average thickness of only 1½ feet, a length of deposit of 1½ miles and a total depth of only 20 feet, then on the basis of a specific gravity of 4·5, there are almost 30,000 tons of barytes. The average thickness will probably be much larger than this and it is thought that the barytes will persist in depth to a considerably greater distance than 20 feet. Thus the available quantity will probably be many times this figure of 30,000 tons. These figures may be compared with the consumption figures given on pages 134 to 136 and page 141.

No. *15*.—Two small deposits of barytes occur between the large deposit just described and the occurrences grouped under the Bakkannagaripalle area to the south. The first, occurring in trap five furlongs W. N. W. of hill station 1,617 feet, has been tested by a few shallow pits dug by Mr. A. Kristnappa. It is south-west of the saddle separating his part of deposit No. 14 from that belonging to Messrs. Tiffin and Co. There is, apparently, no large quantity of barytes present.

The second deposit is a small vein with no economic prospects, so far untested by any prospector, half a mile W. N. W. of hill station 1,617 feet.

No. *16*.—Mr. Krishnappa has dug shallow pits exposing for about 30 yards a vein of barytes more than six feet wide, occurring in trap less than 1½ miles south-west of Kottapalle, *i.e.*, to the south-west of deposit No. 13. The vein strikes at 115° and dips S. S. W. at a high angle. The pits do not enable one to judge of the possibilities of the deposit.

No. 17.—An important deposit, held under either a prospecting license or a mining lease by Messrs. Tiffin and Co., occurs to the north of the eastern end of the large deposit No. 14. It is approximately 1½ miles S. S. E. of Kottapalle and can be traced striking at 75° through a very coarse-grained dolerite (43·871, 21771) for about a quarter of a mile. The deposit is extremely variable in thickness (two to ten feet) and in the number of veins of which it is composed, as is well shown in the more eastern of the two trenches dug by Mr. Tiffin. The veins all have a definite dip of about 70°-80° to the S. S. E. and they increase and diminish in size in a remarkable manner, at times coalescing to form quite a considerable thickness. In between the veins are masses of trap. There is no sign of brecciation in the veins themselves.

The barytes (N 534) is generally of good quality, but though usually white, it varies in colour to grey, greenish and, very rarely, faintly pink.

No. 18.—To the north-east of the last deposit, and occurring in trap just under one mile south-east of Kottapalle, there are three deposits of barytes which may provisionally be described together. They all occur in uncultivated lands but near the fields of that village. The first crops out just south of the bend in the path from Kottapalle to Tallapalle Velamvaripalle. It strikes E.-W. for about 40 yards and is of uncertain dip and thickness, being at times, however,

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more than six feet thick. Mr. Tiffin's pits are shallow and of no great extent, though a certain quantity of barytes has apparently been taken to Cuddapah. The colour of the barytes is variable, pink varieties occurring (N 536).

Further towards Tallapalle Velamvaripalle, but on the northern and southern sides of the path, more pits have been dug by Mr. Tiffin, but they are too shallow to give much information. It is possible that the barytes on the northern side of the path is the eastward continuation of the deposit just described. The author is of the opinion that the economic possibilities of these deposits are not great.

No. 19.—Mr. Tiffin has dug two shallow pits one mile three furlongs W. S. W. of Kottapalle in the uncultivated lands just south of the Pulivendla quartzite ridge. The barytes in these pits has the rather unusual strike of 130°, with a dip of some 45° to the south-west. The vein is some two to three feet thick and occurs in trap. The occurrence does not appear promising though it has not been tested thoroughly.

7. *Bakkannagaripalle* (*57 J/7 ; 14° 20′ : 78° 22′*).

The deposits of barytes classed under the Bakkannagaripalle area occur to the south of the range of hills in which the important deposits of the Kottapalle area occur.[1] They appear to be related to a series of E.–W. faults, which have affected the Vaimpalli limestones and thin trap sills that dip under the immense sills in which the Kottapalle barytes is found. They differ from the Kottapalle deposits in that they do not invariably occur in trap. They are even worse situated as regards transport than the Kottapalle deposits, inasmuch as barytes exported from the Bakkannagaripalle area would have to be carted over some four to seven miles of bullock-cart tracks before the second-class Pulivendla-Cuddapah road is reached.

No. 20.—A vein of rather impure barytes (N 537), very irregular in nature, crops out seven furlongs north-east of Bakkannagaripalle. It occurs in irregularly dipping Vaimpalli limestones and also in trap, and its nature suggests it to be more or less along an E.–W. striking fault. Messrs. S. S. Guzdar and Co. of Calcutta, have, it is understood, dug the trial pits which expose the vein and have carted barytes away to Cuddapah. The very irregular nature of the deposit and the smallness of the veins detracts from its possible economic value.

No. 21.—Just over half a mile N. N. W. of Bakkannagaripalle, abutting against cultivated fields, pits dug by Mr. Tiffin have exposed a vein of barytes three to four feet thick, which runs at 78° in Vaimpalli limestones parallel to the strike of these rocks. The dip of the vein appears to be 60° to the S. S. W., the opposite direction to that of the limestones, which dip into the hills to the north. The barytes is not of good quality, being associated with abundant iron oxide and being in appearance very reminiscent of the barytes occurring just over a mile E. by N. of Tummaluru (No. 8).

[1] *See* Plate 4, fig 1.

No. 22.—Messrs. S. S. Guzdar and Co. have had pits dug exposing barytes seven furlongs north-west of Bakkannagaripalle, *i.e.*, a quarter of a mile S. S. E. of hill station 1,617 feet. The vein runs E.–W. along what is apparently a fault course between Vaimpalli limestones to its south and trap to its north. There are slickensides and foliation ; included fragments of the country rock occur in the vein. It varies in thickness up to about six feet ; its dip is usually about 80° to the south. The pits have proved the vein for about 40 to 50 yards and the deposit appears to have distinct possibilities.

No. 23.—Barytes occurs as a vein three to six feet wide, striking E.–W. doubtfully in trap one mile three furlongs W. N. W. of Bakkannagaripalle. The veins appears to be along a fault. It has been tested by Mr. Tiffin and possesses possibilities.

No. 24.—Another vein, occurring in the spur W. S. W. of the last deposit and approximately 1½ miles W. by N. of Bakkannagaripalle, has been tested by Mr. Tiffin. It appears to be along a fault course in northerly dipping Vaimpalli limestones and, like the other deposits in this Bakkannagaripalle area, strikes E.–W. Its dip is vertical and its average thickness about six feet, but the latter varies considerably. The deposit has good possibilities but it must be tested thoroughly. The colour of the barytes is generally white, but there are variations.

8. *Midipenta* (*57 J/7 ; 14° 20′ : 78° 19′*).

Midipenta is situated on the same (southern) side of the range of hills south of the Pulivendla-Cuddapah road as is the Bakkannagaripalle area. There is no good bullock-cart track from the village through the hills to this road, and any barytes exported from the Midipenta area would have to be carted *vid* Tallapalle Velamvaripalle, as for the Bakkannagaripalle barytes. This would necessitate carriage over some 7½ to 10½ miles of bad tracks before the Pulivendla-Cuddapah road is reached.

No. 25.—The single deposit of barytes classed under the Midipenta area occurs one mile E. N. E. of the village.[1] Pits dug by Mr. Tiffin for a distance of some 150 yards show an apparently discontinuous vein, varying from two to four feet in thickness, striking E.–W., and dipping south at about 75° in the opposite direction to the dip of the Vaimpalli limestones in which it occurs. It is possible that the vein extends further eastwards into the hills.

Quartz was noted on the borders of the vein but not inside it. The barytes (N 539) is apparently of good quality, but the discontinuous nature of the deposit is not encouraging.

9. *Rachegaripalle* (*57 J/7 ; 14° 21′ : 78° 19′*).

Rachegaripalle is a small village seven furlongs S. S. W. of Vemula, which latter village is 36½ miles from Cuddapah along the

[1] The author was informed locally of the existence of barytes in the neighbourhood of the village of Velpula (57 J/7 ; 14° 21′ 30″ : 78° 16′), between Rachegaripalle and Elamvaripalle ; but a thorough search led him to disbelieve the truth of this assertion.

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second-class Cuddapah-Pulivendla road (six miles from Pulivendla). The three deposits of barytes in this area occur in the trap hills to the south-west of Rachegaripalle,[1] the nearest village ; they occur, however, in the survey lands of the larger village of Vemula.[2]

No. 26.—Mr. Tiffin has dug a trench some ten yards long at the edge of the cultivation three-quarters of a mile south-west of Rachegaripalle. This has exposed a vein of barytes (N 541) of good quality, some five to six feet thick, striking at 128° through trap and dipping at 60° to the S. S. W. or south-west.

A smaller vein, also in trap, occurs about 50 yards west of the main vein to which it strikes in a parallel direction. The occurrence needs further prospecting.

No. 27.—A furlong or so W. N. W. of the last occurrence, Mr. Tiffin has disclosed a vein of barytes in trap, some two to four feet thick, with the more normal strike of 105° and with a southerly dip of 60°-70°. This vein does not appear to have great possibilities though the author met what is probably the same vein some 300 yards to the west.

No. 28.—Mr. Kristnappa has slightly prospected a vein of barytes of indefinite thickness, striking approximately E.–W. through trap on the high ground 1¼ miles S. W. by W. of Rachegaripalle (2⅛ miles south-west of Vemula). The vein does not appear to have any economic possibilities.

10. *Elamvaripalle (57 J/3 ; 14° 23′ 30″ : 78° 14′).*

Elamvaripalle is a small village 1¾ miles due south of the town of Pulivendla.

No. 29.—A quarter of a mile west of Elamvaripalle (about the same distance E. 40° S. of a *khera* of Venkatapuram) a previous prospector (?Mr. Tiffin) has exposed a few veins of barytes, the strike of which is generally indefinite but the main vein of which trends a little south of east. No big pits have been dug, but, judging from the outcrop, the main vein appears to be of fair size but irregular. It is apparently in trap, but the evidence is not conclusive.

This occurrence is very near the locality of the supposed third major fault mentioned previously (*see* p. 17), but it is more likely to be along the line of some smaller subsidiary, or cross fault.

11. *Ippatla (57 J/3 ; 14° 25′ 30″ : 78° 11′).*

Ippatla is a small village some 3½ miles W. N. W. of the town of Pulivendla. It is not far from the asbestos deposits and the structure of the country in its near vicinity is described in full in the author's other report.

[1] *See* Plate 4, fig. 1.

[2] The author was informed locally of the existence of barytes in the neighbourhood of the village of Velpula (57 J/7 ; 14° 21′ 30″ : 78° 16′), between Rachegaripalle and Elamvaripalle ; but a thorough search led him to disbelieve the truth of this assertion.

No. 30.—The author noted a very interesting occurrence of barytes in Vaimpalli limestones, five furlongs S. S. W. of Ippatla. The vein is of varying width and does not appear to have any economic value. Its strike is more or less N. W.–S. E., the same as that of the dolerite-limestone contact in these parts, which here has suffered dislocation. No pits have been dug.

12. *Karnapapayapalle (57 J/2 ; 14° 32′ : 78° 4′ 30″).*

The Karnapapayapalle occurrences have been listed under this name in preference to that of Lopatanutula, to which village they are nearer, as the latter village is on one-inch sheet 57 J/3, whereas the barytes occurrences are on 57 J/2. The nearest village on that sheet is Karnapapayapalle.

The barytes is not very accessible but, if extracted, it would be taken along bullock-cart tracks for some three miles to Lingala which village is nine miles from Pulivendla along the Pulivendla-Parnapalle third-class road. Pulivendla, it will be remembered, is 23 miles from Muddanuru railway station.

Means of communication.

No. 31.—About two miles south (a little east) of Karnapapayapalle (1¼ miles N. 60° W. of Lopatanutula), there is a vein of barytes in Vaimpalli limestones, striking E.–W. at an angle to them. The limestones themselves strike at 110°. The barytes vein (N 550) varies in size, being usually about one foot to 1½ feet in thickness, and in quality. To the south, another vein occurs in the river bed, a third vein just south of the river, and a fourth, the largest of the lot, on the southern side of the stream. The last vein is about two to 2½ feet thick and contains varying amounts of silica. It ' thins ' and ' thickens ' and twists to such an extent that it would not be easy to work. Its general strike, more or less, is E.–W. Its dip is uncertain. It can be traced for some 200 to 300 yards on the southern side of the valley.[1]

The veins appear to lie along a series of parallel minor faults which cross the main Lingala fault (*see* p. 17) at a gentle angle. The four veins crop out within a N.–S. distance of less than a quarter of a mile.

D.—Razampeta Taluk.[2]

The following information concerning the occurrence of barytes in the Razampeta taluk, the southernmost of the three taluks forming the eastern division of the Cuddapah district, was obtained after the conclusion of the author's field work. It was thus not possible for him to report on the occurrences.

[1] The topographical details of this region on the one-inch map are far from accurate and it is rather difficult to ascertain one's position correctly.

[2] Formerly the Pullampet taluk.

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13. *Razampeta (57 N/4 ; 14° 14′ : 79° 38′ 30″).*

No. 32.—M. R. Ry. B. P. Sesha Reddy Guru, M.L.C., of Betamcherla, was kind enough to inform the author of the occurrence of barytes in a locality near to the town of Razampeta. Details of the occurrence are lacking, but it would appear from King's map that the rocks in this locality belong to the Cheyair series. Thus the occurrence is interesting in that the barytes is associated with rocks of a higher horizon than usual. When freshly fractured, the barytes gives off a fetid smell (*see* p. 118). The mineral (N 615) is rather dark-coloured, but a specimen sent by M. R. Ry. Sesha Reddy was found on analysis in 1921 at the Government Test House, Alipore, to contain 97·3 per cent. of barium sulphate.

Two analyses of a powder prepared from specimen N 615, made in December, 1932, by Mahadeo Ram in the Laboratory of the Geological Survey of India, gave the following results:—

	Per cent.	Per cent.
SiO_2	0·19	0·12
BaO	65·48	65·65
SO_3	34·17	34·27
Fe_2O_3 }	0·26	0·22
Al_2O_3 }		
Bituminous matter[1]	0·12	*not detd.*
H_2S [1]	0·02	0·02
	100·24	100·18
Specific gravity	4·435	4·435

The first analysis gives 99·65 per cent. of $BaSO_4$; the second gives 99·92 per cent.

The author is greatly indebted to Dr. E. Spencer, of Messrs. Bird & Co.'s Research Department, Calcutta, for the following note concerning an examination of N 615 which he very kindly performed:—

'A. A portion of the material was broken up into small lumps and pieces about the size of a pea were selected. A known weight of these lumps was taken and the material was ground up in iodine solution of standard strength. The quantity of iodine consumed was then estimated and calculated to the equivalent of sulphur. The figure obtained was 0·0225 per cent. The white residue left after washing away the iodine was still found to smell fairly strongly of sulphuretted hydrogen.

B. A given weight of lumps was again taken and heated for one hour between 600 and 700°C in a stream of hydrogen. The hydrogen was passed into cadmium chloride and the precipitated cadmium sulphide filtered off and estimated. This gave a sulphur figure of 0·07 per cent.

C. As after this treatment the residue still gave off an odour of sulphuretted hydrogen, the estimation was repeated with a fresh sample at the same temperature for about three-quarters of an hour rising to 1000° for half an hour and 15 minutes at 1200°. The sulphur in this case was found to be 0·12 per cent.

[1] *See* Dr. Spencer's note.

The residue from this treatment was found to smell much more strongly of sulphuretted hydrogen than in the first test. Further, on submitting the residue to the ultra-violet lamp the mineral glowed very strongly indicating that quite an appreciable amount of the barium sulphate had been reduced to the sulphide. Hence it is evident that this method of estimation is of doubtful value owing to the tendency for hydrogen to reduce the sulphate to sulphide.

It was also noted that the mineral had become dark coloured and metallic looking along the cleavage plains owing to the deposition of graphite or carbonaceous material from occluded organic matter.

D. In view of the above results it was decided to carry out an estimation in a stream of oxygen, estimating the sulphur as sulphate by absorbing the SO_2 in bromine solution. This was carried out on lump material as in the previous case. Two determinations were made, one of them giving 0·046 per cent. of sulphur and the other 0·04 per cent. These two latter figures are probably very near the correct figure for the sulphur content (in the form of H_2S) in the mineral. After this treatment the mineral was quite white and absolutely free from smell even when the lumps were powdered.

E. The final test was a determination of carbon in the same manner as for sulphur, first absorbing the SO_2 over granulated zinc. By this means the carbon figure was found to be 0·018 per cent.

If the sulphur figure is desired in the form of sulphuretted hydrogen, the above results should be multiplied by the factor 17/16. The result obtained under A is evidently low on account of the grinding only releasing a part of the sulphur. That this is so is confirmed by the fact that in the first determination done by the oxygen method the barytes was *ground* up first and then only gave a result of 0·021 per cent. The difference between this figure and 0·04 or 0·046 represents the amount lost in grinding and is approximately the same as the determination under iodine. Hence the correct figure should be 0·04 or 0·046 per cent.'

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CHAPTER III.

BARYTES IN THE ANANTAPUR DISTRICT.

Introduction.

The occurrences of barytes in the Anantapur district of Madras have far less importance than those of the Cuddapah and Kurnool district. They form a connecting link between these deposits and mostly lie along the same general line, *i.e.*, along the outcrop of the Vaimpalli limestones (with their associated traps) of the Papaghni series of the Cuddapah system. The occurrences at Nerijamupalle were visited by Mr. A. K. Dey and were described briefly in a miscellaneous note by that officer and the author.[1] The same deposits were visited in October, 1930, by Dr. C. S. Fox, to whose unpublished notes reference has been made in the description hereafter.

Visits of Mr. A. K. Dey and Dr. C. S. Fox.

Taluks in which barytes occurs.

It will be seen that the barytes occurrences of this district are in the following taluks :—

E. Tadpatri taluk.
F. Anantapur taluk.
G. Gooty taluk.
H. Kadiri taluk.

The Collector of Anantapur district provided the author with a list giving the prospecting licenses for barytes in his district that had been registered in his office. Full reference has been made to this list under each taluk. The first prospecting licenses for barytes in the Anantapur district were those granted in 1919 to Messrs. B. P. Sesha Reddy and A. Ghose.[2] The first mining lease for this mineral was granted on the 2nd October, 1922, to Mr. A. Ghose.[3]

List of prospecting licenses.

The chief prospector for barytes in recent years in this district appears to have been Mr. M. Rangappa, of Tadpatri, from many of whose pits much information concerning the deposits was obtained. Messrs. S. S. Guzdar and Co., of 226, Bow Bazar Street, Calcutta, hold a mining lease for

Prospectors.

[1] A. L. Coulson and A. K. Dey, *Rec. Geol. Surv. Ind.*, LX, p. 431, (1928).
[2] *Op. cit.*, LI, p. 214, (1921).
[3] *Op. cit.*, LVI, p. 168, (1926).

survey No. 543-3 of Goddumarri in the Tadpatri taluk.[1] Other gentlemen and firms who have interested themselves in barytes in this district are Khan Sahib K. Abdul Hye of Bellary, Nabi Sahib of Hindupur, M. R. Ry. M. Rajagopala Nayadu of Bangalore, M. R. Ry. K. Venkata Subbiah of Tangatur, M. R. Ry. V. Venkata Subbiah of Vuyyur (Kistna district), Mr. A. Kristnappa of Cuddapah, and Messrs. A. F. Simoes, Sons and Co. of Bangalore.

The Anantapur deposits of barytes are, generally speaking, even more badly off as regards railway communications than those of the Cuddapah district. They occur between the broad-gauge line from Madras to Bombay, with its main stations of Muddanuru, Kondapuram, Tadpatri, Rayalacheruvu, Jakkulacheruvu and Gooty, and the Mysore Frontier Extension metre-gauge railway line running from Guntakal southwards with its stations of Kalluru, Garladinne, Anantapur, Kandukur and Dharmavaram, from which last station the Katpadi branch line (metre-gauge) runs south-eastwards with its stations of Chinnekuntapalli, Muktapuram, Mudigubba, Malaka Vemala, etc. Those deposits nearest the Kurnool district (*i.e.*, most northern) are moderately well situated for railway connections with the stations of Rayalacheruvu and Jakkulacheruvu. Generally, however, the further south the deposit is, the worse it is situated.

Railway communications.

E.—Tadpatri Taluk.

Almost all the deposits of barytes visited by the author are situated in the Tadpatri taluk of the Anantapur district. It is in this taluk that the most important deposits are found.

The Papaghnis and Cheyairs enter the southern part of the taluk in the vicinity of Parnapalle (57 F/14 ; 14° 34′ : 77° 58′) and Nerijamupalle (57 J/2). At first more or less north-east, the dip changes gradually to practically due east as the beds are traced generally northwards along their strike. There are numerous major areas of shattering and faulting, and in some cases these are areas of barytes deposition.

Geology of the area.

The first faulted area lies to the north-east of Nerijamupalle in the hills west of Velidandla (57 J/2 ; 14° 34′ : 78° 3′), through which runs the third-class road from Pulivendla to Parnapalle.

[1] *See Rec. Geol. Surv. Ind.*, LXVI, p. 315, (1933) in which the grant of 131·50 acres under mining lease commencing 1st October, 1931, is given.

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The faulting is well shown by the repetition of the outcrops of Pulivendla quartzites. This area contains barytes.

The second faulted area lies to the west of the first and is in the vicinity of Parnapalle, where the Chitravati river flows from the gneissic plain in a general north-easterly direction, more or less parallel to the dip of the Gulcheru, Vaimpalli, Pulivendla and Tadpatri rocks through which it has cut its channel. Its passage appears to have been assisted greatly by a series of faults. This area does not contain barytes.

Several minor strike and cross-faults can be seen as one proceeds northwards from the Chitravati ; also, in the vicinity of Madugupalle (57 F/14 ; 14° 42′ 30″ : 77° 54′), barytes is met where faulting is not prominent.

Still further north, the third important area of faulting, which is also one of barytes deposition, is met at Mutssukota (57 F/13 ; 14° 51′ : 77° 52′ 30″) on either side of the third-class road which joins Tadpatri town with Anantapur.

Further north, a few major faults can be seen before the fourth area of major faulting is met around Peddapappuru (57 F/13 ; 14° 56′ : 77° 52′). The Penner river here winds its easterly course through the Cuddapahs, undoubtedly being assisted by the shattering and faulting of the rocks. This area, like the somewhat similar one at Parnapalle where the Chitravati flows through the same rocks, is surprisingly free from barytes.

The fifth and last area of major faulting lies south-west of Rayalacheruvu (57 E/16 ; 15° 3′ : 77° 49′) and continues into the contiguous Gooty taluk.

The constituent rocks of the Papaghnis and Cheyairs call for little special mention. The Gulcherus vary in thickness, being much less important near the Penner[1] than at the Chitravati valley.[2]

The general dip of the Vaimpallis and of the overlying Pulivendlas usually varies from 10°-30°, but it is frequently less or more. There

[1] At Reddipalle (57 F/13 ; 14° 55′ 30″ : 77° 47′), the total thickness of the Gulcherus is only 2½ feet of a remarkably uniform, felspathic, ferruginous grit (43·884, 21796) overlying the ancient granite (43·883, 21795).

[2] The Gulcherus here are much thicker and their basal beds are more conglomeratic in nature. They overlie granite of varying texture (43·880, 21786 ; 21787), and further south, in the Kadiri taluk, an ancient 'schistose' series (? Dharwar), which itself is intruded by felspar-porphyry dykes (43·881, 21789 ; 21790 ; 43·882, 21791) and dolerite (21788) of varying ages. The eutectic intergrowth of quartz and felspar in the porphyries is similar to that of the much younger Malani porphyries described elsewhere by the author [*Mem. Geol. Surv. Ind.*, LXIII, Pt. 1, pp. 115–127, (1933)].

is generally more than one ridge capped by Pulivendlas. This is sometimes due to faulting ; at others, it is due to simple denudation, with the formation of outliers of Pulivendlas capping the Vaimpallis. All the evidence collected by the author serves to prove that for all intents and purposes, the two stages (Vaimpallis and Pulivendlas) may be considered as being perfectly conformable.

There is no capping of the younger Kurnool rocks (Banganapallis) as is found in most of the Kurnool district to the north-east, and in part of the Cuddapah district to the south-east.

Barytes areas in the Tadpatri taluk.

For descriptive purposes, the barytes areas in the Tadpatri taluk have been subdivided as under :—

14. Nerijamupalle (57 J/2 ; 14° 32′ 30″ : 78° 1′).
15. Rangarajukunta (57 F/14 ; 14° 42′ 30″ : 77° 56′ 30″).
16. Madugupalle (57 F/14 ; 14° 42′ 30″ : 77° 54′).
17. Dosaledu (57 F/13 ; 14° 46′ 30″ : 77° 54′ 30″).
18. Mutssukota (57 F/13 ; 14° 51′ : 77° 52′ 30″).
19. Tabjula (57 F/13 ; 14° 54′ : 77° 49′ 30″).
20. Chandana (57 E/16 ; 15° 5′ : 77° 49′).
21. Lakshumpalle (57 E/16 ; 15° 7′ : 77° 49′ 30″).

14. *Nerijamupalle (57 J/2 ; 14° 32′ 30″ : 78° 1′).*

Two of the three occurrences of barytes grouped under this head lie in the Nerijamupalle reserved forest, whilst the third is in the Daditota reserved forest. As stated previously, they are the only deposits in the Anantapur district which have been recorded.

Railway and road communications.

These deposits are especially badly situated as regards railway communications. The nearest station is Muktapuram on the Dharmavaram-Katpadi branch line (metre-gauge), which is 11 miles distant as the crow flies ; but there is no road to this station worthy of the name and, also, the intervening hills are such that a long detour makes the minimum distance considerably more than 11 miles. Muddanuru on the main broad-gauge line is 24 miles distant as the crow flies, or 43 miles by third and second-class roads *viâ* Velidandla and Pulivendla. However, it would appear best to export barytes from the Kondapuram station on the main broad-gauge line, which is some 22 miles distant by bullock-cart tracks and the second-class Pulivendla-Kondapuram road, which could be joined from Velidandla at Simhadripuram.

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No. 33.—The two veins of barytes in the Nerijamupalle reserved forest lie respectively about two miles east, and the same distance E. S. E., of the village. The former lies to the E. N. E. and the latter to the E. S. E., of hill station 1,529 feet. They occur in survey No. 543-3 of Goddumarri[1] and are held under mining lease by Messrs. S. S. Guzdar and Co. of Calcutta.

Mr. A. K. Dey noted that ' the outcrop of the largest vein (presumably the former of the two veins mentioned above) is from 3 to 11 feet wide and it has been followed for more than half a mile along its strike, N. 110° E. ; three other veins crop out close to the above vein, two of which strike respectively N. 125° E. and N. 110° E.'.[2]

Dr. C. S. Fox found that the vein E. S. E. of hill station 1,529 feet trended south of it towards the village, and that it could be followed to a point south of the top of the main, or eastern summit of this hill. He added that ' a pit has been sunk in the low ground E. S. E. of the main hill, nearly on the boundary between the districts of Anantapur and Cuddapah. The pit was barely 3 feet deep at the time of my visit and showed less than 2 feet 2 inches of barytes in a vertical vein between walls of siliceous and partly pisolitic limestone (N 381). It was not possible to say definitely the direction of hade as the pit was not deep enough. The strike of the vein may be taken as 280° in a continuous bearing (N 80° W.). The vein is irregular and does not continue sharply and appeared to me less attractive westwards. Small segregations of barytes are to be found by searching in the limestone. I did not consider the occurrence as adequately prospected seeing that I was being conducted by the manager of the holder of the prospecting license who has now applied for a mining lease.'[3]

Dr. Fox noted that the other vein was far better defined. ' It is situated E. N. E. of the main peak of hill station 1,529 feet and a pit has been sunk at about the 1,300 feet contour on the slope. Again the pit was not deep enough for a careful examination. The vein is barely half a mile' from the other vein ' measuring from the pits in each '. It ' trends roughly westward and can be traced fairly easily for 200 yards. In the pit, the barytes in the vein is quite 4 feet 3 inches across between the enclosing walls of siliceous limestone. Again I considered that enough prospecting work had not been done.'

The author visited both veins and has little to add to Dr. Fox's remarks. He does not consider that the first vein extends to the village. Trap occurs very near the eastern end of the second (more northerly) vein, but the author was unable to trace its extension into the trap. As has been noted in his asbestos report, the dolerite-limestone contact near the boundary between the two districts is rather indefinite on account of cultivation. There are numerous faults in the area west of Velidandla (see p. 29) and in the Pulivendlas west of Karnapapayapalle (57 J/2 ; 14° 32′ 30″ : 78° 4′ 30″). Accordingly, it is probable, as Dr. Fox apparently considers likely by his use of the word ' hade ', that these two barytes veins lie along the courses of faults.

Some idea of the quantity of barytes present here may be obtained from the following calculation concerning the second of the two veins. Assuming it continues

[1] Goddumarri (57 J/2 ; 14° 36′ : 78° 1′) is on the left bank of the Chitravati river. Nerijamupalle is a hamlet of this village.

[2] A. L. Coulson and A. K. Dey, *Rec. Geol. Surv. Ind.*, LX, p. 131, (1928).

[3] Unpublished manuscript of Dr. Fox.

for 200 yards, has a proved depth of 20 feet and a thickness of four feet, then there would be some 6,000 tons of barytes. Nothing at all seems to have been done in the way of proving these veins in depth. It seems that a mining lease has been taken out before adequate prospecting has been done as there is no proof at present that even the above 6,000 tons of barytes are present. No estimate of reserves can be made until further evidence is available.

No. 34.—Mr. Dey noted that ' another outcrop occurs in the Daditota reserved forest, 1¼ miles north of the chief Nerijamupalle vein, and this also bears N. 110° E.'.[1] Dr. Fox did not visit this barytes vein but it was visited by the author who wishes to modify and add to the above description. The vein occurs in Goddumarri lands, 2¼ miles S. S. E. of that village, or 1⅝ miles N. N. E. of the hamlet of Nerijamupalle. The few pits that have been dug by (?) Mr. Bokhale show that the vein can be traced in Vaimpalli limestones for about a quarter of a mile along its strike of N. 120° E. The barytes (N 551) is very variable in colour and the deposit does not appear to have great possibilities. It varies in thickness from one to four feet.

The vein is situated along a fault line between two hills capped by Pulivendla quartzites, a few furlongs to the north-west of mile 17 on the Pulivendla-Parnapalle road. As has been noted (p. 29), this is an area of much faulting and shattering. From the north, there is first a hinge-fault, trending down the middle of the arrow-head-shaped outcrop of quartzite, on the north side of the road at the gap. There is another fault between the isolated hill of quartzite 1¼ miles W. S. W. of Velidandla and the police outpost ridge. A third fault to the south-west of this is probably continuous with that along which the barytes occurs. Finally, a fourth fault occurs to the east of the isolated hill of Pulivendla quartzites, two miles W. S. W. Velidandla. All these strike at 120°, the strike of the barytes vein.

Information is not available as to the exact survey number of the plot in which barytes No. 34 occurs ; it is thought, however, that it is probably No. 491-A. 2 of Goddumarri.

15. *Rangarajukunta (57 F/14 ; 14° 42′ 30″ : 77° 56′ 30″).*

Geology of the area.

Rangarajukunta is a small village situated on Cheyairs to the east of the hills of Vaimpalli limestones and Pulivendla quartzites, and connected with Tadpatri railway station by some 15 miles of bullock-cart tracks. There is a barren zone of 12 miles along the strike of the rocks between the last described occurrence and that at Rangarajukunta. The Vaimpalli limestones here are full of bands of chalcedonic silica and quartz of varying colours. They are interbedded with reddish shales and highly silicified rocks which are almost quartzites. Sometimes the limestones are very ferruginous, as, *e.g.*, between Ellutla (57 F/14 ; 14° 40′ ; 77° 54′ 30″) and Nadimipalle (14° 39′ 30″ : 77° 53′ 30″), and give a dark-coloured soil suggestive of that derived

[1] Coulson and Dey, *loc. cit.*, (1928).

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from dolerites ; but the author was unable to trace dolerites in the Vaimpallis of this region, or, in fact, at any place except one (*see* p. 38) between the Chitravati and Penner rivers. There are, of course, abundant dolerites in the Tadpatri shales further to the east, but their absence from the Vaimpallis and Pulivendla quartzites is very conspicuous.

No. 35.—Approximately one mile west (a little south) of Rangarajukunta, in the Mutssukota reserved forest, there is an exposure of barytes in Vaimpalli limestones just below the cap of Pulivendla quartzites. A few shallow pits have been dug by some prospector to a depth of a foot or so. The extent of the occurrence is indefinite, but the debris from the vein was spread over a circle of about 20 yards diameter. The strike and dip of the vein could not be made out. The barytes is accompanied by abundant iron oxide. Its economic possibilities are not promising.

16. *Madugupalle* (*57 F/14 ; 14° 42′ 30″ : 77° 54′*).

The barytes in the vicinity of Madugupalle is rather badly situated as regards transport inasmuch as the tracks through the Vaimpallis and Pulivendlas to the Tadpatri plains are very rough indeed. Even so, barytes from Madugupalle would be more easily exported from Tadpatri station on the broad-gauge line, some 16 miles distant as the crow flies, than from stations on the metre-gauge line through Anantapur.

There are no traps in the vicinity of Madugupalle.

No. 36.—A thin vein of barytes, bearing at about 275°, crops out a quarter of a mile E. N. E. of Madugupalle in red Vaimpalli shales and yellowish limestones. The vein can be traced for about 100 yards. There are no pits except one shallow excavation presumably made by the local villagers. The vein is never more than one foot in thickness and has no economic importance.

No. 37.—About a quarter to half mile N. N. E. of Madugupalle, there is another thin impersistent vein of barytes in a crushed zone in Vaimpalli shales and limestones. It strikes approximately at 280° and can be traced for 50 to 100 yards. There are no pits and the vein has merely mineralogical interest.

No. 38.—Barytes occurs slightly more than 1½ miles north (a little east) of Madugupalle. The long valley running E.–W. to the north of the occurrence is probably a line of faulting as the Vaimpalli limestones and shales in the valley are highly disturbed. The barytes, which occurs to the S. S. E. of hill station 1,395 feet, seems to be small in lateral extent and of the nature of a small replacement deposit. The pit, from which a considerable quantity of barytes had been removed by some prospector, had been refilled prior to the author's visit and it was not possible to note the strike or dip of the deposit. The siliceous Vaimpalli limestones in this neighbourhood dip slightly north of west at about 10°-15°.

17. *Dosaledu* (*57 F/13 ; 14° 46′ 30″ : 77° 54′ 30″*).

Dosaledu is a small village just to the east of the Pulivendla quartzite ridge. It is some ten miles S. S. W. of Tadpatri railway station.

Geology of the area.

The general change in direction of dip of the Vaimpallis and Pulivendlas as one proceeds northwards has already been noted (*see* p. 29). In the Madugupalle area, the dips are generally slightly north of east. Proceeding towards the Dosaledu area, the dips become more easterly and even, in places, E. S. E. to south-east at the junction of one-inch sheets 57 F/13 and F/14. There is probably some dislocation along the Karnapudi-Middepalle valley. West of Dosaledu, the dips are easterly and remain so for some considerable distance northwards.

No. 39.—Barytes occurs in a vein of indefinite width and of no great length about 1¾ miles west (a little south) of Dosaledu in plot No. 1,891 of Putluru[1] for which a prospecting license was granted to Mr. M. Rangappa of Tadpatri in October, 1931. The few shallow pits sunk by Mr. Rangappa are not very informative, but it appears that the barytes is associated with an approximately E.–W. fault in crushed limestone. The region is one of faulting on a minor scale.

The barytes is of fair quality but there is a considerable amount of reddish coloured barytes present.

18. *Mutssukota* (*57 F/13 ; 14° 51′ : 77° 52′ 30″*).

Mutssukota[2] is eight miles from Tadpatri along the third-class road from this town to Anantapur. Barytes excavated in its neighbourhood thus has easy access to the broad-gauge railway.

Geology of the area.

Proceeding from Dosaledu towards the Mutssukota area, there appears to be a possible fault along the valley between Dosaledu and Venkatampalle[3] which trends E. S. E.–W. N. W. The Papaghnis and Cheyairs have a gentle easterly dip and the higher hills along the border between the Anantapur and Tadpatri taluks are capped by Pulivendla quartzites, while the lower hills between this border range and the outside (easterly) ridge of Pulivendlas, are formed of Vaimpallis.

[1] This is a good example of the difficulty of locating barytes areas from the survey numbers of the plots. Putluru (57 F/13 : 14° 48′ 30″ : 77° 58′) is six miles from the barytes occurrence and is not the nearest large village. Kadavakallu is nearer to Dosaledu and larger than Putluru. It was only by a chance meeting with the local revenue officer in Putluru village that the author is able definitely to state that the Dosaledu area and the Putluru plot are one and the same. The post office at Putluru is called Patlur.

[2] Mutssukota possesses a post office, the spelling of which is **Muchukota.**

[3] The Venkatampalle occurrences of barytes are described on pages 40 and 41. They are in the Anantapur taluk.

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Abundant faulting appears to have occurred in the vicinity of Mutssukota, more especially to the north-west of the village. This faulting appears to be intimately connected with the barytes occurrences.

No. 40.—One of the most important deposits of barytes in the district occurs in the hill 1¾ miles W. S. W. of Mutssukota, or just E. S. E. of mile 22 on the Anantapur-Tadpatri road but within the Mutssukota reserved forest. The vein is very wide, sometimes exceeding 30 feet. It appears to have been deposited along a fault channel in siliceous Vaimpalli limestones which dip gently towards the east and E. S. E. The dip of the deposit is uncertain. Evidence of faulting is shown by the presence of Pulivendla quartzites on the S. S. W. side of the hill. As will be seen, also, deposits Nos. 45 and 46 in the Anantapur taluk lie more or less along the same general N.–S. line as this Mutssukota deposit (*see* pp. 40–41).

The deposit has been inadequately tested by a few shallow pits dug by some prospector,[1] and a number of cartloads of barytes taken to Tadpatri. Though generally N.–S. the strike of the vein varies greatly. Most of the central part of the hill, the summit of which is just 1,250 feet above sea-level, appears to be composed of barytes.

Certain patches of the deposit are admittedly good in colour. Their extent has not been proved but they merit further testing. The quality seems to deteriorate towards the south. Generally the barytes contains many pieces of chalcedonised limestone and ferruginous material (N 553) and occasionally small crystals of pyrite (N 552).

It may seem idle to give estimates of quantity until further prospecting is done, but the following calculation shows how the quantity of barytes in a deposit of this nature may easily be very considerable in amount. Thus if the average thickness of the vein is proved to be 20 feet for a distance of 100 yards, and the same persists for a depth of 100 feet, then the quantity of barytes present is just under 75,500 tons.

No. 41.—A small vein of barytes was noted just north of the junction of streams, 1¾ miles S. S. W. of Mutssukota, just outside the cultivated area shown on the map. A few hundred yards to the east, and three-quarters of a mile N. N. W. of hill station 1,154 feet, a large pit, 12 feet wide, has been dug by Mr. Rangappa (so it is understood) exposing a vein of massive and crystalline barytes of fairly good colour (N 555). Without further prospecting, one cannot state how far this vein extends as the surface of the ground is covered by debris from the Pulivendla quartzites which cap the hill to the south-east. The vein may join with the first-mentioned one, in which case it trends roughly E.–W. The author considers, however, that it will more probably be found to trend N. E.–S. W., as there appears to have been faulting in the valley of the Surepalle stream. There is also a fault to the north-east of the deposit, there being an excellent example of a fault breccia,

[1] The author was informed locally that the pits were dug by Mr. M. Rangappa of Tadpatri and that this gentleman held a prospecting license for the area. The list dated December, 1931, given to the author by the Collector, states that a prospecting license was granted in July, 1931, for plot Nos. 141 and 1368 of 'Muchukota' to Khan Sahib K. Abdul Hye of Bellary. No mention is made of other plots of Mutssukota.

striking N. N. E. The Pulivendla quartzites in this neighbourhood have shallow rolling dips, so their outcrop is large, though their thickness is small.

The deposit appears to be worth prospecting thoroughly. It is very reminiscent of that (No. 13) 2½ miles south of Gondipalle in the Pulivendla taluk of the Cuddapah district (*see* p. 19).

19. *Tabjula (57 F/13 ; 14° 54′ : 77° 49′ 30″).*

Tabjula is on the right bank of the Penner river, some 10¾ miles due west of Tadpatri railway station.

There are a few major faults between it and Mutssukota, and with one of these is associated the sole deposit of barytes in the vicinity of the village. There is, however, an area of intense faulting just south of, and along the course of, the Penner river in the vicinity of the villages of Peddapappuru (57 F/13 ; 14° 55′ 30″ : 77° 52′) and Chagallu (14° 55′ 30″ : 77° 50′). The hill south of Peddapappuru is a true dome, the Vaimpallis dipping in all directions.

Geology of the area.

One must assume an E.–W. fault along the Penner from Peddapappuru and another running S. W. by W. from the village towards the hill 1,110 feet, half a mile south-east of Chagallu. A third fault probably runs along the front of the Pulivendla quartzites which dip to the north-west. A cross-fault again runs E. S. E. from hill 1,110 feet to the end of the Pulivendlas. Support to this view is given by the apparent existence of three cross-faults in the capping of the hill station, to the south-west of the summit. There is, unfortunately, a lot of wind-blown sand in this region and this makes the interpretation of the structure difficult in many cases.

No barytes was seen in this region, though a conspicuous vein of calcite (N 558) crosses the path near the dam on the path between Chagallu and Chikkepalle (57 F/13 ; 14° 53′ : 77° 52′), just less than half a mile south-east of the latter village. As will be seen, calcite is associated with the barytes occurrence described hereunder.

No. 42.—Barytes, associated with calcite (N 557), occurs 2¼ miles S. S. E. of Tabjula in crushed Vaimpalli limestones in a large vein, several feet wide, striking approximately W. N. W.–E. S. E. along a fault plane both inside and outside the Mutssukota reserved forest. The occurrence is not far distant from the boundary with Anantapur taluk. No pits have been dug, but it appears that a fair quantity of barytes is available as the vein can be traced for over 100 yards. The intimate association of the barytes with calcite would necessitate careful separation in this case.

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It is interesting to note that what is probably the continuation of the same fault to the W. S. W. may be clearly seen on the western end of the large hill, 2¾ miles south of Tabjula, where an undoubted fracture occurs.[1]

The author was informed of the existence of barytes on the north-western side of the large hill near the edge of the reserved forest, just under some two miles S. S. E. of Tabjula ; but he was unable to find it, though it probably exists. A small plug of trap, the only one noted between the Penner and the Chitravati, occurs just on the forest boundary, 1½ miles S. S. E. of Tabjula. It is just over half a mile due north of the above-described deposit (No. 42).

The author is uncertain of the numbers of the plots in which No. 42 occurs ; but Mr. M. Rangappa was granted a prospecting license for barytes in October, 1931, for plots Nos. 382, 383, 391-394, 224, 418 and 422 of Tabjula.

20. *Chandana (57 E/16 ; 15° 5′ : 77° 49′).*

Chandana is two miles N. by W. of Rayalacheruvu railway station, which is 243 miles from Madras on the broad-gauge line to Bombay.

Geology of the area.

The structure of the Vaimpallis immediately north of the Penner river up to, and in the vicinity of, Vengannapalle (57 F/13 ; 14° 58′ : 77° 48′) has importance from the point of view of the occurrence of asbestos and has been discussed by the author elsewhere. No barytes was found here in the Tadpatri taluk until the railway line was passed, though barytes occurs S. S. W. of Kristipadu (*see* p. 41) in the Anantapur taluk.

The Rayalacheruvu (57 E/16 ; 15° 3′ 30″ : 77° 49′) area of major faulting has already been mentioned briefly (p. 30). Two faults trend W. S. W. just south of the large ' tank ' west of Rayalacheruvu, and run into the Anantapur taluk. There is another fault, trending W. N. W., just south of hill station 1,182 feet. There is considerable duplication here of the Pulivendla quartzites which cap the Vaimpallis. They have a general easterly dip which varies from 5°-20°.

No. 43.—Three-quarters of a mile west of Chandana, there is a series of ramifying pits which presumably followed a vein of barytes of which there are abundant fragments on the surface. The pits were filled in long prior to the author's visit and it is impossible to state whether or not the deposit was worked out. Signs of brecciation were noted in the overlying Pulivendla quartzites on the path up from the village to the hills ; and these quartzites contained reef quartz veins. The barytes veins are in yellowish grey Vaimpalli limestones, the deposit apparently

[1] On its eastern side, the large hill forms almost a ' text-book ' illustration of contouring of the surface by uniformly eastward-dipping beds. Unfortunately it was not possible to photograph the hill.

have been formed by replacement (*see* p. 104). The occurrence is typical of many Kurnool district, more especially exemplified by that at Hussainpuram (No. 55) in the Dhone taluk of that district. This type is spoken of hereafter as the ' replacement type '.

It was impossible to ascertain how long ago the pits were dug. The various people questioned gave estimates of time varying from four to 20 years. The Collector's list records the granting of prospecting licenses to Khan Sahib K. Abdul Hye of Bellary in June, 1924, for survey No. 728, and to M. R. Ry. M. Rajagopala Nayadu of Bangalore in October, 1927, for Nos. 1-(2), 62-B and 728-B of Chandana respectively.

21. *Lakshumpalle (57 E/16 ; 15° 7′ : 77° 49′ 30″).*

Lakshumpalle is a small village some 4½ miles north of Rayalacheruvu railway station, and situated in Tadpatri taluk not far from the trijunction of the taluks of Gooty, Tadpatri and Dhone (Kurnool district).

No. 44.—Three-quarters of a mile north-west of Lakshumpalle (one mile N. by E. of Kesavanayanipeta) and just inside the Yadiki reserved forest, barytes occurs as a replacement deposit in Vaimpalli limestones similarly to the occurrence at Chandana.[1] There seems to be no faulting, and the deposit is probably in the nature of a pocket with no great economic possibilities. The barytes is of good quality and five to six feet thick in places, but is of uncertain dip and varying strike. There is a fair amount of chalcedonic silica in the limestones. There is definite evidence of the nearby presence of doleritic rocks as one occurs (43·887, 21799) a quarter of a mile north-west of Kesavanayanipeta, almost immediately under the Pulivendla quartzites, and fragments of it were seen in the cultivated patch which separates the occurrence of barytes from the Pulivendla quartzites to its east.

A few minor veins of barytes (N 562) were seen in limestone in the neighbourhood of the dolerite but they have no economic importance. Trap was also noted in the hills south-west of Kesavanayanipeta, where it apparently dies out to the south.

F.—Anantapur Taluk.

There are but two deposits of barytes in the Anantapur taluk of the district of the same name which were visited by the author, both being in the neighbourhood of Venkatamapalle.

[1] The Collector's list states that in December, 1930, M. R. Ry. V. Venkata Subbiah of Vuyyur, Kistna district, was granted a prospecting license for barytes for an unnoted plot in ' Kesavaraopeta in Gooty taluk '. Further enquiry indicated that ' Kesavaraopeta ' was Kesavanayanipeta, a hamlet of Chandana in the Tadpatri taluk. The list also states that plot No. 516 A of Yadiki (57 E/16 ; 15° 2′ 30″ : 77° 52′ 50″) was granted in September, 1927, to Khan Sahib K. Abdul Hye of Bellary under a prospecting license for barytes. The exact position of this plot could not be ascertained.

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22. *Venkatamapalle (57 F/13 ; 14° 47′ 30″ : 77° 50′).*

Venkatamapalle is a small village $1\frac{1}{4}$ miles south-east of the old fort of Nayanipalle at mile 18 from Anantapur on the third-class road to Tadpatri station. It is thus some 14 miles south-west of that station.

No. 45.—The N.–S. fault line along which lies deposit No. 40 at Mutssukota (*see* p. 36) continues south from that deposit for some considerable distance into, and parallel with part of the boundary of, the Anantapur taluk. Crushing and twisting of the Vaimpalli limestones are very conspicuous in this area. A thin vein of barytes was noted here some $2\frac{1}{4}$ miles north-east of Venkatamapalle. No pits have been dug, but it is thought that the vein has no economic value. Pulivendla quartzites cap the hills to the east and west of the occurrence. As the quartzites to the east are at a higher elevation than those to the west, and all have a constant easterly dip, it follows that there must necessarily be a fault between them ; and it is along this fault that the barytes occurs.

No. 46.—Further south, still along the same N.–S. line of fault, more barytes is met about two miles N. 60° E. of Venkatamapalle. This occurrence is likewise in the Mutssukota reserved forest. A pit has been dug by some prospector[1] and a certain amount of barytes removed ; but it was filled in prior to the visit of the author. It appears, though, that the deposit is very definitely along a fault channel, having a hade of about 30° to the west. The structure is illustrated in Fig. 1 below.

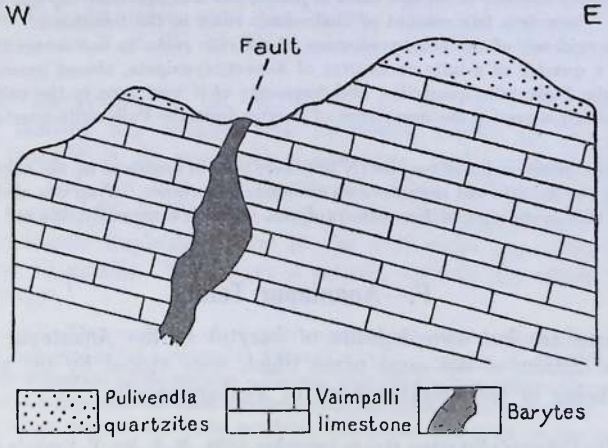


FIG. 1.—Diagrammatic section showing the occurrence of barytes along a fault course near Venkatamapalle, Anantapur taluk, Anantapur district.

[1] The author was informed that Mr. Rangappa had dug the pit. The Collector's list, however, shows that Khan Sahib K. Abdul Hye of Bellary was granted a prospecting license for barytes for plot No. 302 of Venkatamapalle in May, 1931.

Pulivendla quartzites cap the little knoll immediately west of the pit which is on the shoulder between this knoll and the higher main ridge to the east. The Vaimpallis and Pulivendlas are perfectly conformable, and have a low easterly dip of a few degrees.

A curious feature of the deposit is the very large amount of reddish barytes that occurs (N 554). This is so abundant that the deposit can have but little economic value inasmuch as pure white barytes is sought for by the dealers in the mineral.

A feature of the hills in this vicinity and in the hills north-west of Mutssukota is the very large amount of black chalcedony (N 556) occurring in bands in the Vaimpalli limestones, mostly parallel to the bedding (*see* p. 114).

G.—Gooty Taluk.

There is but one deposit of barytes in the Gooty taluk of the Anantapur district which was visited by the author. This is in the neighbourhood of Krishtipadu.

23. *Krishtipadu (57 E/16 ; 15° 4′ : 77° 46′ 30″).*

Krishtipadu is rather an important village with a post office, three miles W. N. W. or Rayalacheruvu railway station, and one mile south-west of mile 62 on the Bellary-Cuddapah road. It is thus well situated for the export of barytes.

No. 47.—A vein of barytes in siliceous Vaimpalli limestones was noted $1\frac{3}{8}$ miles S. S. W. of Krishtipadu and situated in the reserved forest of that name. The width of the vein is indefinite. A few shallow pits had been dug on a fairly steep slope near the top of a hill.[1] The vein strikes approximately N. E.–S. W., but does not persist for any appreciable distance, being traceable only for some 20 to 30 yards. A few cart-loads of barytes (N 561) of fair quality have been carted to Rayalacheruvu station, some five miles distant. It is impossible to judge of the economic possibilities of the occurrence without the assistance of further pits. Its apparent large thickness is in its favour.

An interesting black serpentinous rock (43·918, 21800), with what are apparently phenocrysts of olivine totally altered to serpentine, was noted in the near vicinity of the barytes occurrence. The adjacent rocks have varying dips, though generally easterly at about 20°. Faulting has undoubtedly taken place here.

H.—Kadiri Taluk.

It was not convenient for the author to visit the barytes occurrences in the Kadiri taluk. His knowledge of them is gained from correspondence with the Collector of Anantapur.

[1] The survey number of the plot is apparently 1007-A of Krishtipadu, for which a prospecting license for barytes was granted in September, 1930, to Messrs. A. F. Simoes, Sons and Co. of Bangalore.

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24. *Mudigubba (57 F/15 ; 14° 21′ : 77° 59′).*

Mudigubba is a small village with a railway station on the Katpadi-Dharmavaram metre-gauge line, some 21½ miles from Dharmavaram.

Dorigallu (57 J/3 ; 14° 25′ 30″ : 78° 2′ 30″) is a small village on the Maduleru river, on the plains south-west of the Gulcheru quartzite ridge to the west of Pulivendla. It lies some 6½ miles N. N. E. of Mudigubba railway station.

No. 48.—In September, 1924, the Nabi Sahib of Hindupur was granted a prospecting license for barytes for survey Nos. 1485, 1516, 1540, 1572, 1588 and 1595 of Dorigallu, and also Nos. 473 and 474 of Mudigubba in the Kadiri taluk. The plots of Dorigallu village are from two to 2½ miles east of Mudigubba railway station, and are thus situated on the crystalline gneiss according to King's map. There is, however, a long trap dyke shown by King striking N. E.–S. W. east of Mudigubba, and the country near this village is faulted.

The plots of Mudigubba village are situated two miles W. N. W. of the same railway station. They are also on gneiss, but King shows trap dykes striking W. N. W.–E. S. E. in this area. As will be seen (pp. 106–109), the barytes deposits of the Ceded districts are considered to be related to the trap sills which intrude the Vaimpalli rocks. Accordingly there is no reason why the trap dykes in the neighbourhoods of these villages should not be related to the barytes occurrences. Nor is it at all improbable that these trap dykes are of the same age as those associated with the Vaimpallis.

CHAPTER IV.

BARYTES IN THE KURNOOL DISTRICT.

Introduction.

The occurrences of barytes in the Kurnool district of Madras have great importance and many of them have been known for a very long time. The barytes at the Basavapuram (Buswapoor of King) lead mines was recognized by Newbold[1] in 1844, and confirmed by Wall[2] and King.[3]

Previous literature.

In the 'Manual of the Kurnool District', compiled by N. Gopalakristnamah Chetty,[4] it is stated that *karpurasilayit*–

'sulphate of baryta is found in Jaladurgam and Chandrapalli, Pattikonda Taluk, and in several villages of the Ramallakota Taluk connected with the Erramalas. It is pounded into powder and used by native women in ornamenting the floor. It is also used in medicine.'

The first mention of the large deposits at Balapalapalle was made in the Quinquennial Review for 1909-13[5] on 'information supplied by Mr. A. Ghose'. These have been mentioned since by Dr. J. C. Brown[6] and in the subsequent Quinquennial Reviews[7] for 1914-18, 1919-23 and 1924-28. There is no doubt that the modern development of the barytes industry in the Kurnool district largely resulted from the pioneering work done by Mr. Ghose who is remembered everywhere throughout the district. In later years, M. R. Ry. B. P. Sesha Reddy Guru, M.L.C., of Betamcherla, has done much to develop the industry.

According to a letter from the Collector of Kurnool, there were in operation in December, 1931, five mining leases for the extraction of barytes, all of which were held by M. R. Ry. B. P. Sesha Reddy Guru. These were for survey Nos. 592/1B (3 acres 21 cts.) and 522/1

Collector's list of mining leases and prospecting licenses.

[1] *Madras Journ. Lit. Soc.*, XIII. Pt. 1, pp. 218-219 (1844). See also *Journ. As. Soc. Beng.*, XV, pp. 389-390, (1846).
[2] *Madras Journ. Lit. Soc.*, XX, pp. 279-304, (1859).
[3] *Mem. Geol. Surv. Ind.*, VIII, Pt. 1, pp. 272-273, (1872).
[4] P. 99, (1886). The villages mentioned are now in the Dhone taluk.
[5] *Rec. Geol. Surv. Ind.*, XLVI, p. 237, (1915).
[6] *Bull. Ind. Indus. Lab.*, No. 22, p. 3, (1921).
[7] *Rec. Geol. Surv. Ind.*, LII, p. 261, (1921); *op. cit.*, LVII. p. 369, (1925); *op. cit.*, LXIV, p. 325, (1930).

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(1 acre 55 cts.) of Kommamarri and plots of 86, 16 and ten acres respectively in the Betamcherla reserved forest. On the other hand, there have been some 242 prospecting licenses for barytes held since 1916, though this figure includes several areas held successively by different licensees.[1] There is thus a very disproportionate ratio between the number of mining leases issued and the number of prospecting licenses granted (*see* p. 129).

The development of the barytes industry in the Kurnool district.

Much information may be gathered from a study of the annual reviews of mineral production which are published in the Records of the Geological Survey of India. Where possible, the items of the Collector's list have been checked by reference to these Records, but the details given in these are not extensive. However, in 1909, in the Kurnool district, Abdul Karim Sahib, Mr. Leon Tardival and Messrs. Beardsell and Co. held prospecting licenses for barytes and Mr. A. Ghose and other gentlemen held prospecting licenses for all minerals.[2] In 1911, Mr. A. Ghose held a prospecting license for all minerals for the whole of the Dhone taluk of the Kurnool district.[3] In 1912, Messrs. Beardsell and Co. were granted two prospecting licenses for barytes in the Kurnool district.[4] On the 16th December, 1913, Mr. W. A. Beardsell was granted a mining lease for 30 years for a block of five acres in the Kurnool district.[5] One prospecting license for barytes in the Kurnool district was granted to Mr. Ghose in 1916 (area, 33·05 acres)[6] and four similar licenses were granted to the same gentleman in 1917.[7] Three mining leases were granted to Mr. Ghose in 1921.[8] On the 29th June, 1923, M. R. Ry. B. P. Sesha Reddy Guru was granted a mining lease for a block of 3·21 acres ;[9] and two more mining leases were granted to him on the 2nd February and the 2nd March, 1925; also one to M. R. Ry. V. Venkatasubbayya on the latter date.[10] Another mining lease was granted to M. R. Ry. B. P.

[1] Where possible, the respective numbers of the plots held under prospecting license have been given in the descriptions of the deposits.
[2] *Rec. Geol. Surv. Ind.*, XL, p. 175, (1910).
[3] *Op. cit.*, XLII, p. 194, (1912).
[4] *Op. cit.*, XLIII, pp. 128-129, (1913).
[5] *Op. cit.*, XLV, p. 199, (1916).
[6] *Op. cit.*, XLVIII, p. 90, (1918).
[7] *Op. cit.*, XLIX, p. 107, (1919).
[8] *Op. cit*, LIV, p. 191, (1923).
[9] *Op. cit.*, LVI, p. 169, (1926).
[10] *Op. cit.*, LIX, p. 328, (1927).

Sesha Reddy on the 30th July, 1928 ;[1] one on the 30th June, 1930 ;[2] and finally one on the 8th April, 1931.[3]

Taluks in which barytes occurs.

Barytes has been noted in the following taluks of the Kurnool district :—

I. Dhone taluk.
J. Kurnool taluk.
K. Nandyal taluk.
L. Sirvel taluk.
M. Cumbum taluk.
N. Nandikotkur taluk.

Geology of the area.

The Gulcheru, Vaimpalli and Pulivendla rocks, which so far have been followed along their strike from Cuddapah town, preserve their general characteristics when traced through the Kurnool district; but they appear to have suffered far more severely than their contemporaries in the Anantapur district from faulting and from intrusion of basic sills. Moreover, a very great part of them is covered by the much younger Kurnool rocks which, generally speaking, are absent from the tract of the Anantapur district previously described.

For the first few miles in the Dhone taluk of the Kurnool district, the rocks have the same general characteristics as their counterparts in the Tadpatri taluk of the Anantapur district. The Pulivendla quartzites overlie the Vaimpalli limestones perfectly conformably, which in their turn conformably overlie the Gulcheru quartzites. They all dip easterly at gentle angles. The Vaimpallis here are remarkably free from basaltic or doleritic intrusions. There is soon a change in the direction of the strike, which becomes E.–W., and the change is accompanied by large dislocations, especially noticeable in the vicinities of Ramapuram (57 E/15 ; 15° 17′ : 77° 52′) and Dhone (57 E/15 ; 15° 23′ 30″ : 77° 52′ 30″). The faulting probably accompanied the intrusion of trap sills of large size, which are particularly abundant in the vicinities of Malkapuram (57 E/15 ; 15° 20′ 30″ : 77° 59′) and Mudduletiswami (57 I/3 ; 15° 21′ 30″ : 78° 5′ 30″). Abundant faulting also must have taken place in the neighbourhood of Rangapuram (57 I/3 ; 15° 24′ 30″ : 78° 4′ 30″), but the covering layer of Banganapallis and Jammalamadugus of the Kurnool series has effectively masked the structure.

[1] *Rec. Geol. Surv. Ind.*, LXII, p. 360 (1930).
[2] *Op. cit.*, LXV, p. 383, (1932).
[3] *Op. cit.*, LXVI, p. 320, (1933).

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From Rangapuram, the Vaimpallis trend E. N. E. by way of Balapalapalle (west of Betamcherla :—57 I/3 ; 15° 27′ : 78° 9′) to Gattimanikonda where they are cut off by a very important fault, the Gattimanikonda fault. They are to a large extent covered by sandstones and quartzites which, as will be seen, have been referred to the Banganapallis.

North of this fault, there is the very curious and extremely interesting structure named by Foote the 'Kalava (Calwa) wall'.[1] This structure has been described in detail by the present author in a separate paper[2] and is mentioned briefly in the description of the barytes occurrences of the Kurnool taluk (*see* p. 80). North of the Kalava wall, there is another large spread of trap which stretches up to the Tungabhadra river, east of Kurnool town (57 I/1 ; 15° 50′ : 78° 3′). The Vaimpallis are largely masked by a covering of Banganapallis and Jammalamadugus.

I.—Dhone Taluk.

The barytes deposits of the Dhone taluk of the Kurnool district are the best known in the Madras presidency, chiefly through the continued export of barytes from the mines at Balapalapalle in the neighbourhood of Betamcherla. For descriptive purposes, they may be subdivided as under, the order of mention (except for Veldurti) being that in which they are met if one follows along the strike of the Vaimpallis from the trijunction of Gooty, Tadpatri and Dhone taluks :—

Subdivision for descriptive purposes.

25. Nallamekalapalle (57 E/16 ; 15° 7′ 30″ : 77° 47′).
26. Narayanapuram (57 E/16 ; 15° 9′ 30″ : 77° 47′).
27. Peddapaya (57 E/16 ; 15° 10′ : 77° 50′).
28. Chandrapalle (57 E/16 ; 15° 12′ 30″ : 77° 49′).
29. Hussainpuram (57 E/16 ; 15° 14′ : 77° 49′ 30″).
30. Rangapuram (57 E/15 ; 15° 16′ ; 77° 49′).
31. Ramapuram (57 E/15 ; 15° 17′ : 77° 52′).
32. Kochcheruvu (57 E/15 ; 15° 19′ : 77° 51′ 30″).

[1] King, *op. cit.*, pp. 65-66 (1872). Kalava (15° 37′ : 78° 12′) is on one-inch sheet 57 I/1.

[2] A. L Coulson, *Rec. Geol. Surv. Ind.*, LXVI, pp. 438-448, (1933).

33. Dharmavaram (57 E/15 ; 15° 21′ 30″ : 77° 53′).
34. Karanapikunta (57 E/15 ; 15° 21′ : 77° 54′ 30″).
35. Kamalapuram (57 E/15 ; 15° 21′ : 77° 56′).
36. Erragunta (57 E/15 ; 15° 23′ : 77° 56′).
37. Valasala (57 E/15 ; 15° 23′ 30″ : 77° 58′ 30″).
38. Chinna Malkapuram (57 E/15 ; 15° 22′ : 77° 58′ 30″).
39. Kottapalle (57 I/3 ; 15° 22′ 30″ : 78° 2′ 30″).
40. Bukkapuram (57 I/3 ; 15° 23′ : 78° 2′).
41. Rahimanpuram (57 I/3 ; 15° 24′ : 78° 3′).
42. Ambapuram (57 I/3 ; 15° 23′ : 78° 5′ 30″).
43. Gutupalle (57 I/3 ; 15° 25′ 30″ : 78° 3′).
44. Husainpuram (57 I/3 ; 15° 26′ 30″ : 78° 3′).
45. Tapasikonda (57 I/3 ; 15° 27′ 30″ : 78° 3′ 30″).
46. Papasanikottala (57 I/3 ; 15° 27′ 30″ : 78° 4′ 30″).
47. Komururikottala (57 I/3 ; 15° 26′ : 78° 5′).
48. Balapalapalle (57 I/3 ; 15° 27′ 30″ : 78° 6′ 30″).
49. Musalayyacheruvu (57 I/3 ; 15° 29′ 30″ : 78° 4′).
50. Kolumalapalle (57 I/3 ; 15° 28′ 30″ : 78° 8′).
51. Gattimanikonda (57 I/2 ; 15° 32′ : 78° 11′).
52. Boyanapalle (57 I/2 ; 15° 32′ 30″ : 78° 8′).
53. Veldurti (57 E/14 ; 15° 33′ : 77° 56′).

25. Nallamekalapalle (57 E/16 ; 15° 7′ 30″ : 77° 47′).

Nallamekalapalle is a small village very near the trijunction of the Dhone, Gooty and Tadpatri taluks. It is just over four miles E. N. E. of Jakkulacheruvu railway station (57 E/12) at mile 250 from Madras on the broad-gauge line ; it is about 5½ miles north-west of Rayalacheruvu station.

No. 49.—Barytes occurs in a few thin veins in siliceous limestones at the 1,500 feet contour on the shoulder between the two summits of the hill, three furlongs N. N. E. of Nallamekalapalle. No pits have been dug. There are very frequent signs of brecciation in this hill, but they generally trend W. N. W.–E. S. E. The barytes vein seems to strike N.–S.

It is interesting to note that there is apparently a big dislocation in the strata in this vicinity, inasmuch as a fault seems to run from just north of Nallamekalapalle in a W. N. W. direction, passing south of the small village of Ramapuram.

The author was shown veins of calcite in the lowest members of the Vaimpallis at Jakkasanikuntla (57 E/16 ; 15° 8′ 30″ : 77° 46′ 30″), which were incorrectly believed locally to be barytes. He was also informed of the presence of barytes to the south-west of Nallamekalapalle, but was unable to trace this.

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26. Narayanapuram (57 E/16 ; 15° 9′ 30″ : 77° 47′).

Narayanapuram[1] is a village some 2¼ miles north of Nallamekalapalle. It is distant 5½ miles from Jakkulacheruvu railway station.

No. 50.—A vein of barytes of indefinite width occurs in crushed Vaimpalli limestones 1¾ miles south-east of Narayanapuram in the Peddapaya reserved forest. Two shallow pits, overgrown with grass at the time of the author's visit, said to have been dug by M. R. Ry. B. P. Sesha Reddy Guru of Betamcherla,[2] give but little information as to the economic possibilities of the occurrence. The vein is of fair width, pure in its central part, but containing much limestone in its marginal portions. The path from the village of Boyanapalle (57 E/16 ; 15° 8′ 30″ : 77° 49′ 30″) to Narayanapuram[3] more or less follows the course of a fault, which runs a short distance to the north of the barytes occurrence.

There is a very old deep well of a tortuous nature at the temple three-quarters of a mile east of Narayanapuram. The excavators appear to have followed a definite line of crushing and it is possible that the hole was originally made in following a vein of barytes.

27. Peddapaya (57 E/16 ; 15° 10′ : 77° 50′).

Peddapaya, or Devagudipad, though a small village, gives its name to a reserved forest, situated to the west and south-west of the village, in which there are several occurrences of barytes. All of these except one (No. 50) have been classified under this heading. M. R. Ry. B. P. Sesha Reddy Guru of Betamcherla held 16 acres 75 cts. under prospecting license in 1920, and later blocks of 22 and 7 acres respectively ; H. M. D. Ashroff Hussane Khan of Kurnool held one acre under a prospecting license.

The barytes deposits described hereafter are about ten miles from Jakkulacheruvu station on the Madras-Bombay broad-gauge line, and 17 miles south of Dronachellum junction (Dhone) station on the Guntakal-Bezwada metre-gauge line (Dronachellam junction is the commencing station of H. E. H. the Nizam's Guaranteed State Railway line to Secunderabad). They are rather inaccessible and there are no roads that can be utilised. The bullock-cart tracks here are bad inasmuch as there is abundant wind-blown sand in the vicinity of Narayanapuram and Jakkasanikuntla, which villages lie between the deposits and the station.

Road and railway communications.

[1] Narayanapuram also rejoices in the names of Paisanrangarreddipalle and Pachmanipallo. Though the inhabitants speak of it as Narayanapuram, this name is not generally used by those of other villages. Accordingly, there is occasionally great confusion as to which village is meant.

[2] *See* notes under Peddapaya on page 49.

[3] There is a good exposure of the basal members of the Vaimpallis and of the Gulcherus to the north of Narayanapuram and near Gudipadu (57 E/16 ; 15° 11′ : 77° 46′ 30″). The Gulcherus here consist of some ten to 12 feet of very coarse conglomerates at their base, followed by about 15 feet of finer, gritty, ferruginous conglomerates, and then by ten feet of a gritty sandstone, all overlain conformably by Vaimpalli shales.

No. 51.—A shallow pit, overgrown with grass at the time of the author's visit, has been dug at about the 1,800 feet contour and about three-quarters of a mile west of the summit on the western shoulder of the large hill, 2,070 feet, in the Peddapaya reserved forest. This is approximately 2⅛ miles W. S. W. of Peddapaya village. Barytes occurs in a vein in siliceous Vaimpalli limestones which here dip easterly. There are present quite a number of fragments of a reddish, very ferruginous, fine-grained silicified rock which appears to be an altered, metasomatised limestone that has entirely lost its calcareous nature. The top of the hill is crowned by Pulivendlas, Vaimpallis forming its base and sides. The barytes seems to occur along a fault course. Its apparent small size does not offer promising possibilities.

Frequent signs of brecciation were noted along the northern flanks of the hill ; also a small vein of barytes of indefinite width and extent which cropped out on a path a quarter of a mile W. N. W. of the summit.

A number of pits have been dug[1] a short distance away at a place about a quarter of a mile north-west of hill station 2,070 feet. On the one-inch map, the locality is between the Ā and Y of 'PEDDAPĀYA R.F.' (the topography shown on the sheet is not good). It is about 1½ miles W. S. W. of Peddapaya and 3¾ miles due south of Chandrapalle. The barytes vein exposed by the pits varies from a few feet to a few inches in thickness. The barytes (N 563) is of fair quality and a considerable amount has been excavated and carted, it was said, to Dhone, which is 17 miles to the north.

These three occurrences all lie along the same general line which bears at 240°. The two former appear to be along a fault line with abundant brecciation ; but the last occurrence, which is the most important, is apparently not along a fault course, though it is along the continuation of the same general line of the fault. No brecciation was noted in its vicinity. It is quite possible that the barytes vein is continuous from the first to the third occurrence, as occasional fragments of barytes were noted when tracing the veins. But the situation and apparently small quantity present at the first and second occurrences are not encouraging.

No. 52.—Very irregular veins of greyish barytes, obviously replacement deposits, were seen in pits dug in siliceous Vaimpalli limestones in the Peddapaya reserved forest, slightly more than one mile W. N. W. of Peddapaya village. If anything, they have a general north-easterly trend, but it is exceedingly indefinite. No signs of brecciation were noted. The occurrence is not promising.

28. Chandrapalle (57 E/16 ; 15° 12′ 30″ : 77° 49′).

Chandrapalle is some ten miles north-east of Jakkulacheruvu railway station but, as in the case of the Peddapaya occurrences,

[1] Said to have been dug by M. R. Ry. B. P. Sesha Reddy.

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barytes excavated in its neighbourhood appears to have been carted generally to Dronachellam (Dhone) station, though that station is some 2½ miles further distant. Dronachellum station is apparently more favourably situated for marketing the barytes than is Jakkulacheruvu station.

As has been noted previously (p. 43), the existence of barytes in the vicinity of Chandrapalle has been known for a very long time.

Geology of the area.

The geology of the country east of Chandrapalle is very interesting. Between this village and Kommamarri (57 E/16; 15° 12′: 77° 52′),[1] there is a small flat-topped hill which is capped by Banganapalli rocks, the basal members of the Kurnools, resting unconformably upon the Tadpatri shales[2] and associated doleritic sills. To the west of this plateau, erosion has exposed Vaimpalli limestones and Pulivendla quartzites which here are very much shattered and faulted, presumably in pre-Kurnool times. The general trend of these faults is E.–W. Two occur in the hill 1¼ miles S. S. E. of Chandrapalle. Dolerites underlie the Pulivendla quartzites to the east and south-east of the village. These sills become increasingly important as the rocks are followed along their strike towards Malkapuram (57 E/15; 15° 20′ 30″: 77° 59′) and Betamcherla (57 I/3; 15° 27′: 78° 8′ 30″) and have been described in detail in the author's asbestos report.

No. 53.—Seven furlongs east of Chandrapalle, on the western side of the large hill rising to 2,050 feet, and situated within the Jaladurgam reserved forest, barytes may be seen in an exposed shallow pit dug at about the 1,850 feet contour. The top of the hill is crowned by Pulivendlas, which conformably overlie Vaimpalli limestones and trap sills. It appears from the frequency of the occurrence of boulders of trap on the grass-covered slopes immediately below the pit that the barytes deposit is itself in trap. It extends for about 150 yards in a N.–S. direction. Some signs of brecciation were noted further to the north of the barytes and it is possible that the deposit is along the continuation of a fault line. The barytes has been used locally to a small extent.

A quarter of a mile S. S. W. of the above occurrence and situated seven furlongs E. S. E. of Chandrapalle, on a little knoll just inside the reserved forest boundary,

[1] *See* footnote on page 51.

[2] The curious concretionary markings of the Tadpatri shales are very interesting. Specimens (43·903) from two miles E. N. E. of Chandrapalle, in the valley running towards Siddanagatta (57 E/16; 15° 13′ 30″: 77° 51′), appear to contain immature brachiopods; but the markings are concretionary in origin (see W. King, *op. cit.*, pp. 187-188). They may be compared with the larger concretions (44-53) collected by Dr. Fox from flaggy beds in the Tadpatris, six miles S. S. W. of Muddanuru in the Jammalamadugu taluk of the Cuddapah district.

another vein of barytes was noted in siliceous Vaimpalli limestones. No pits have been dug, but it does not appear from surface indications that the deposit is promising. Trap occurs nearby.

29. Hussainpuram (57 E/16; 15° 14′: 77° 49′ 30″).

Hussainpuram is some 11 miles south of Dhone along bad bullock-cart tracks.

Geology of the area.

There has been much faulting east of the village between it and Siddanagatta. The most conspicuous fault is that occurring in the spur running E. S. E. from hill station 1,535 feet. A N.–S. fault and also an E. N. E.–W. S. W. fault may be seen near the dam on the path between the two villages—the effect of both of these on the outcrops of the Pulivendlas capping the Vaimpallis is very noticeable.

No. 55.—The barytes deposit described hereafter has importance as it is considered the type example of the mode of occurrence of very many barytes veins in the Kurnool district. It occurs just without the Jaladurgam reserved forest, seven furlongs E. N. E. of Hussainpuram and about the same distance south (a little east) of Bhavipadu.[1] Apparently the deposit occurs in land belonging to both villages. The survey numbers of the blocks held on a mining lease by M. R. Ry. B. P. Sesha Reddy Guru of Betamcherla, however, are 592/1 B and 522/1 of Kommamarri.[2]

The lessee has concentrated work chiefly on one pit at the north-eastern end of the vein, where he has dug to a depth of some 20 feet. The other pits tracing the vein towards the village are relatively shallow.

The barytes occurs in grey Vaimpalli limestones which dip eastward from 10° to 20° and which gradually become yellowish in colour on exposure on account

[1] Known locally as Bypalle and Bhavipalle. The name must not be confused with that of the large village of Pyapalli, five miles west of Hussainpuram. Pyapalli is shown on the old maps as Paipully, and in the Post Office Guide as Peapully. No. 55 is spoken of locally as Bypalle barytes; but to avoid confusion, it is better that it be referred to Hussainpuram.

[2] Kommamarri is a smaller village than either Bhavipadu or Hussainpuram and inevitably confusion must result when a village, the name of which is taken for subdivisional purposes, is further distant from a block than a larger village.

It is interesting to note here that a prospecting license for block No. 747 of 4 acres 12 cts. was granted to H. M. D. Ashroff Hossane Khan Mandoji of Kurnool; and in 1921, for block No. 633 of 6 acres 67 cts. to M. R. Ry. B. P. Sesha Reddy Guru. The positions of these blocks are unknown.

In this connection, it may be mentioned that many prospecting licenses for barytes have been issued for blocks in the Jaladurgam reserved forest. Some of these are the occurrences described under Chandrapalle (pp. 50–51). Ramapuram (pp. 54–55) and Kocheheruvu (p. 55). The acreage alone of these blocks was given to the author, and further correspondence was unsuccessful in obtaining their exact positions. Licenses, however, have also been issued for plots of Jaladurgam village. The author was informed that Nos. 52/1 and 2, 68/2, 66/1 and 2, 83 and 1153 of Jaladurgam are at a distance of nearly five miles to the west of the village. It is probable, therefore, that the baryets occurrences in these plots are those discussed in the Ramapuram area (*see* pp. 54–55).

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of the oxidation of the ferruginous matter in them. The excavated strata show a certain amount of movement to have taken place, but the occurrence does not occur along any well-defined fault course. It is extremely irregular in nature and its sinuous, though generally N. E.–S. W., course suggests that the barytes has been deposited from solutions following a tortuous path in their percolation through the limestone.

The deposit varies in width. The pit is some 15 feet broad, but some of the base exposed at the time of the author's visit was limestone and not barytes. The amount of movement that has taken place is insufficient to account for the thickness of the deposit and this gives added weight to the view that replacement of the limestone walls by barium-containing solutions has taken place.

The barytes (N 564) is pure and of good quality. A very interesting feature is the occurrence of large vugs in the vein into which hemihedral crystals of barytes (N 565) project. These vugs are frequently up to 12 inches in length and four to five inches wide. Others are much smaller.

Though a considerable amount of barytes has been excavated from this pit, and there is much more available, yet its reserves are far from inexhaustible. The pits already dug indicate good reserves, but it is considered that more prospecting, especially towards the north-east, should have been undertaken before a mining lease was taken out. It will be interesting to learn as mining progresses whether or not a connection has been traced between the trap and the barytes.

30. Rangapuram (57 E/15 ; 15° 16′ ; 77° 49′).

The Rangapuram under which these barytes deposits are classified is a small village between miles 4 and 5 from Pyapalli on the Pyapalli-Banganapalle third-class road,[1] and must not be confused with the larger village (57 I/3 ; 15° 24′ 30″ : 78° 4′ 30″) of the same spelling which gives its name to a railway station on the Guntakal-Bezwada metre-gauge line. The Rangapuram in question is some ten miles S. S. W. of Dhone (Dronachellum) station. It is also known locally as Rangapalle.

The first two occurrences of barytes are interesting in that the Vaimpalli limestones and shales in which they occur are much lower in the stratigraphical scale than is commonly the case. The last occurrence has an intimate relation with the Ramapuram fault described later (*see* p. 53 ; also Pl. 4, fig. 2).[2]

No. 56.—Barytes was noted in a cultivated field a quarter of a mile S. S. E. of Rangapuram. No pits have been dug and it is impossible to state the

[1] *See* Plate 4, fig. 2.

[2] Prospecting licenses for barytes for plots Nos. 21 A, 54/1 E and 231 of Mettupalle, a larger village to the north of Rangapuram, have been issued by the Collector. The position of the first two plots was stated to be 'four miles from Mettupalle to the south' ; that of block 231 to be 'four miles to the east of Mettupalle'. Thus it is possible that the first two plots are those in which the Rangapuram deposits occur.

probable amount present. The amount of debris was large. The soil indicates the barytes vein to occur in siliceous Vaimpalli limestones.

No. 57.—Barytes was also noted a quarter of a mile N. N. E. of Rangapuram, just outside the Mettupalle reserved forest. Again no pits had been dug, but it is thought that there is no large quantity of barytes available. The vein is in siliceous Vaimpalli limestones, low down the stratigraphical scale.

No. 58.—A few very shallow pits have exposed a vein of barytes one mile E. N. E. of Rangapuram, where much faulting has taken place. The deposit occurs to the west of the low ridge separating Bhavipadu from Rangapuram, which is capped by Pulivendla quartzites and faulted on its western and eastern sides. A sketch section of the relationships is given as figure below. It is not thought that the possibilities of the deposit are large.

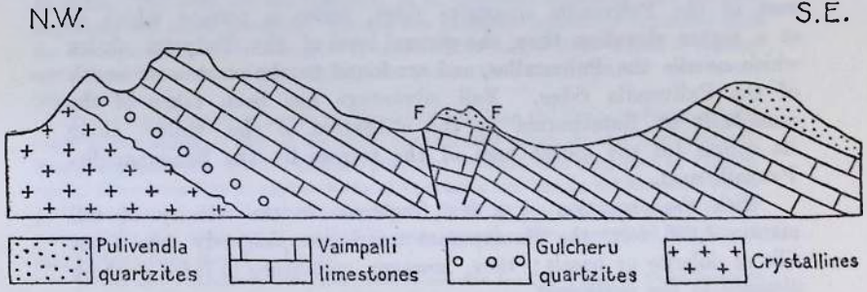


FIG. 2.—Sketch section showing the relationships of the ridge, capped by Pulivendla quartzites, which trends N. E.-S. W. between Rangapuram and Bhavipadu (sheet 57 E/15).

31. Ramapuram (57 E/15 ; 15° 17′ : 77° 52′).

Ramapuram is a small village between miles 8 and 9 on the Pyapalli-Banganapalle third-class road. It is some 7½ miles south of Dhone, but it appears that most, if not all, of the large quantity of barytes which has been removed from its near vicinity, has been carted to Malkapuram station, which is some nine miles distant to the north-east. The area is extremely interesting on account of the intense barytisation that has taken place in this region of much faulting.[1] The chief fault, which has been termed the Ramapuram fault, trends N. E.–S. W. to the west of the village, and crosses the Pyapalli-Banganapalle road in the neighbourhood of mile 7 and more or less follows the western boundary of the Madhavaram reserved forest. It is undoubtedly continuous with the dislocations referred to previously

Geology of the area.

[1] *See* Plate 4, fig. 2.

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as being on either side of the ridge between Bhavipadu and Rangapuram.

An important cross-fault runs E.–W. along the road a quarter of a mile north of Ramapuram. There are numerous other small faults here trending in various directions.

Attention must be drawn here to that important physiographical feature, called by King[1] the Pasupula (old spelling, Puspulla) terrace, which, to all intents and purposes, may be considered as commencing here. The country formed of Vaimpalli limestones and intrusive sills of basalt and dolerite, which is to the north and west of the Pulivendla quartzite ridge, forms a terrace which is at a higher elevation than the general level of the Tadpatri shales which overlie the Pulivendlas, and are found to the east and south of the Pulivendla ridge. Full advantage has been taken of the cross-fault at Ramapuram by the utilisation of the valley along its course for the ascent here of the terrace by the Banganapalle-Pyapalli road.

With the exception of a few fragments in the vicinity of hill station 1,696 feet, the Ramapuram area is conspicuously free from sills of dolerite or basalt; they, however, commence in force a short distance to the north-east.

No. 59.—Within the Madhavaram reserved forest, between half and one mile north of Ramapuram village, many pits have been dug for barytes and a considerable quantity of that mineral (over 100 cart-loads) excavated and carted, so the author was informed locally, to Malkapuram railway station.[2] Practically all the pits have been refilled and all traces of their previous existence, and also of the barytes, will shortly be lost through vegetation covering the ground. Their sites were, however, plainly visible at the time of the author's visit in February, 1932 (probably about a year after the pits were filled in), and he was also fortunate enough to obtain the services of a cooly from Kocheheruvu who was cognizant of their localities.

The author is not in a position to state whether or not the deposit is worked out. It is thought that only the easily accessible material has been removed and that if the pits were reopened, abundant more barytes, admittedly more difficult to work, would be available. It is a great pity that the area has not been worked systematically in a workmanlike manner.

[1] *Op. cit.*, p. 164. Pasupula (57 I/3; 15° 19′ 30″: 78° 1′) is in Banganapalle State.

[2] The Collector's list notes that a prospecting license for barytes for blocks of 7 acres, 3 acres 20 cts. and 31 acres in the Madhavaram reserved forest, and for plots Nos. 289 and 374 of Madhavaram village, the two last totalling 73 acres 17 cts., were granted to H. M. D. Ashroff Hussano Khan Mandoji of Kurnool. Other occurrences of barytes in this reserved forest will be given, but it is thought that the blocks mentioned above are those in which the barytes deposits at present described occur.

The intensive faulting in the area is shown by the contortion of the Vaimpalli limestones and shales, and also by the ubiquity of the outcrops of Pulivendla quartzites which cannot be explained on the grounds that these quartzites are unconformable upon the Vaimpallis. The general dip of the limestones is to the south-east, but there are frequent changes to the south and even west. The main deposit seems more or less to follow the Ramapuram fault along the western boundary of the Madhavaram reserved forest; the veins which lie within the forest in the acute angle between this fault and the cross-fault running E.–W. may be considered as stringers in less disturbed siliceous Vaimpalli limestones. There are also traces of a few pits which have been dug outside the forest on Ramapuram lands.[1]

No. 60.—Numerous veins of barytes have been exposed by pits to the west and south-west of Ramapuram within a radial distance from the village of 1½ miles. The veins are too numerous to be described separately, but the most important are noted hereafter. Certain are probably intimately connected with the Ramapuram fault, but the general nature of the bulk of them is that of replacement deposits, some being strikingly similar to the Hussainpuram occurrence (pp. 51–52).

Just over a quarter of a mile south-east of mile 7 on the Pyapalli-Banganapalle road, at the southern end of the little uncultivated patch on the Kocheheruvu-Hussainpuram track, several shallow pits, two to three feet deep and of varying width, have been dug to expose veins of barytes a few feet in thickness in Vaimpalli limestones. The limestones dip E. S. E. at 20°; the general trend of the veins is E.–W. Staining of malachite was noticed. The excavated barytes is said to have been carted to Dhone.

In the same uncultivated patch, but nearer the road and two or three furlongs east of mile 7, other E.–W. veins of barytes have been slightly worked, but the barytes is not of as good quality as that described above, nor are the veins so thick. There is also more malachite present. However, in a few pits adjacent to the road, the quality of the barytes is better. These occurrences are about 1½ miles west (a little south) of Ramapuram.

In the cultivated ground on the northern side of the road, there is abundant evidence of the presence of Pulivendla quartzites.[2] Judging by the abundant debris of barytes here, it is possible that there are large deposits of this mineral.

About 1½ miles south-west of Ramapuram, there are numerous little faults which have given rise to small fault breccias. Associated with these are many replacement deposits of barytes.

The amount of barytes in this area west and south-west of Ramapuram must be large. As has been the case for the deposits north of the village, much has already been removed and the pits refilled. It is considered, however, that there are large untapped reserves of the mineral still awaiting exploitation.

No. 61.—A trench some 12 yards long and a few feet broad has been dug to expose barytes occurring as a replacement deposit of the Hussainpuram type in Vaimpalli limestones on Kocheheruvu lands, 1¼ miles N. N. W. of Ramapuram.[3] The strata in its vicinity are little disturbed, but it is thought that the

[1] *See* footnote with reference to the Jaladurgam lands under Hussainpuram (p. 51).

[2] It is possible that these outcrops are continuous with those on the ridge between Bhavipadu and Rangapuram (*see* pp. 52–53).

[3] The deposit is 1½ miles S. S. W. of Kocheheruvu. *See* footnote on page 56.

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deposit is an offshoot of the Ramapuram fault which lies half a mile to the south-east. A small quantity of barytes has been removed.

32. Kochcheruvu (57 E/15; 15° 19′: 77° 51′ 30″).

Kochcheruvu is an important village about five miles south of Dhone.

Geology of the area.

The relationships of the traps occurring to the south-east of the village with the Pulivendlas and Vaimpallis have been described by the author in his asbestos report. It is interesting to note, however, that the basal Vaimpallis and Gulcherus to the west and south-west of Kochcheruvu are very brecciated.[1]

No. 62.—A small vein of barytes of no great importance occurs in grey Vaimpalli limestones in the Madhavaram reserved forest, two miles east of Kochcheruvu.[2] It strikes at 250° and dips at 80° to the north-west. The vein is very irregular and intermittent. A nearby fault runs N. N. W.—S. S. E. to the trap hill 2½ miles E. S. E. of Kochcheruvu. The barytes vein is half a mile S. S. W. of the deserted village of Pachkanama (or Pardeshbhai).

33. Dharmavaram (57 E/15; 15° 21′ 30″: 77° 53′).

Dharmavaram is a small village two miles S. S. E. of Dhone.

Geology of the area.

Its vicinity is unimportant from the barytes point of view, but is interesting inasmuch as it is situated near where the flexing movements affecting the Cuddapahs dislocated them. There appears to be a large dislocation, the Dhone fault, which is between Dhone and Dharmavaram along a line through Gonivanipalle (57 E/15; 15° 21′: 77° 52′) and Chintalapalle, trending N. N. E.-S. S. W. The extremely silicified Gulcherus and Vaimpallis to the west of the fault have a general E. S. E. dip; those to the east of the fault dip to the S. S. E.

[1] The faults here have no prevailing trend. There is a very important one trending E.-W., 1¼ miles north-west of the deserted village of Krishnapuram, which has its effects on the Gulcherus underlying the Vaimpallis. Another trends E. S. E.-W. N. W. through hill station 2,017 feet, west of Kochcheruvu, and is crossed by another (N.-S.) fault at the hill station. The Dhone fault, which trends S. S. W. to Kochcheruvu, has been described under Dharmavaram.

[2] Block No. 294 A/1 A of Kochcheruvu of 21 acres 20 cts. was held under a prospecting license by H. M. D. Ashroff Hussane Khan Mandoji of Kurnool, and an unsurveyed block of 6 acres 25 cts. by H. M. D. B. Abdul Nabi Sahib of Dhone; but it was not possible to ascertain the exact positions of these blocks.

Another definite, but less important, fault trends N. N. W.-S. S. E. through the valley south-east of the small village of Bugganipalle.[1]

No. 63.—Barytes occurs on the western side of the hill three-quarters of a mile west of Dharmavaram and about the same distance S. by E. of the deserted village of Periked.[2] There are a few shallow pits now filled with debris, from which some person in Dhone has excavated the barytes. The western side of the hill is extremely silicified and at times ferruginous. The barytes is intimately mixed with impurities and it would be difficult to work. There is no large quantity available.

A few thin veins of the replacement type were noted on the summit of the hill. It is thought that the first deposit is more or less along the line of the Dhone fault, and that the veins on the summit are stringers from this main fault channel.

34. Karanapikunta (57 E/15; 15° 21′: 77° 54′30″).

Karanapikunta is a small village about four miles south-east of Dhone and slightly more than this distance W. S. W. of Malkapuram station.

No. 64.—A thin replacement vein of barytes occurs in yellowish Vaimpalli limestones 1⅜ miles S. S. E. of Karanapikunta[3] in the Madhavaram reserved forest. A small pit indicates that the deposit has no economic value.

35. Kamalapuram (57 E/15; 15° 21′: 77° 56′).

Kamalapuram is a small village 2½ miles south-west of Malkapuram station and gives its name to a small reserved forest to its north.

[1] The Bugganipalle in question (57 E/15; 15° 23′: 77° 53′ 30″) must not be confused with the more important village (57 1/3; 15° 28′ 30″: 78° 10′ 30″) with a station of the same name (at mile 303·5 on the Guntakal-Bezwada metre-gauge line).

The small fault in question is near mile 279 on the Guntakal-Bezwada railway. King's mapping of the area near Bugganipalle is incorrect. He shows the Gulcherus as extending across the railway line to Bugganipalle (old spelling, Bookapully) and Dharmavaram (Durmaverum), whereas in point of fact, the Gulcherus do not extend south of the line. King also shows Chintalapalle (Chintalpetta) as being on the junction between the Gulcherus and Vaimpallis, whereas it is well on Vaimpallis and the Gulcherus crop out a considerable distance to the west.

[2] Block No. 702/Z of Dhone has been held successively by various gentlemen since 1918. The Collector's list also shows block No. 703 of Dharmavaram as being held under prospecting license in 1927 by H. M. D. Ashroff Hussane Khan Mandoji of Kurnool, but enquiry elicited the information that it is 'three miles south-east from Dhone'. Block 702/Z was stated to be '2½ miles due east from Dhone'. It is thought that both these positions are incorrect.

[3] *See* Plate 4, fig. 2.

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The bordering southern range in this forest is capped by quartzites which appear to be of two ages, Banganapalli and Pulivendla.

Geology of the area.

The younger Banganapalli quartzites and sandstones crop out in force a short distance to the north-east (*see* pp. 59-60). Three faults are conspicuous—one trends N. N. W. and its course has been followed by the path from the village to Bugganipalle[1]; another trends at right angles and is situated to the north-west of hill station 1,765 feet; and the third is parallel to the latter, but runs at the foot of the boundary ridge, north-east of the village.

Numerous prospecting licenses for barytes in the Kamalapuram area have been granted.[2]

No. 65.—A N.–S. vein of barytes occurs in yellowish of grey Vaimpalli limestones five furlongs north of Kamalapuram and just outside the reserved forest. Deep pits have been dug but were refilled prior to the author's visit. The occurrence is of the replacement type, similar to that at Husainpuram. A dolerite (43·891, 21806) of rather spotted appearance crops out nearby.

A similar N.–S. trending vein of braytes occurs a short distance to the west. The barytes here appears to be rather grey in colour. The pits were also filled at the time of the author's visit and so here, as in the previous case, it is not possible to give an idea of the potentialities of the deposit. Both, however, are probably related to the last fault mentioned above.

The barytes excavated from these deposits was carted to Malkapuram station.

No. 66.—A few thin veins of barytes, striking N.–S., were noted in Vaimpalli limestones just inside the reserved forest at the southern foot of hill station 1,765 feet, about one mile W. N. W. of Kamalapuram village.

No. 67.—The path from Kamalapuram village to Bugganipalle village follows the course of a N. N. W.–S. S. E. fault along which, about $1\frac{1}{4}$ miles north-west of the former village, there has been deposition of a large quantity of iron oxide and a certain amount of barytes. The barytes is generally reddish-grey in colour and is of such poor quality (N 570) that though many shallow pits have been dug, very little barytes seems to have been removed from this vicinity. Calcite (N 571) is associated with the barytes.

No. 68.—A small replacement vein of barytes in Vaimpalli limestones crops out just south of the cultivated field on the path from Kamalapuram to Bugganipalle, $1\frac{5}{8}$ miles north-west of Kamalapuram.

[1] *See* footnote on page 57.

[2] Blocks of 3 acres 50 cts., 4 acres, 10 acres, 12 acres and 18 acres 3 cts. were granted to M. R. Ry. V. V. Subbiah Pantulu of Vuyyuru Kistna district, and of 5 acres 4 cts. and 8 acres to M. R. Ry. S. P. Ranga Rao of Kurnool. The former gentleman has had an interest in the barytes of this locality since 1925. As long ago as 1916, the late Mr. A. Ghose of Gooty held a prospecting license for barytes for a block of 3 acres 5 cts. in the Kamalapuram reserved forest.

36. Erragunta (57 E/15; 15° 23′ : 77° 56′).

Erragunta is a small village situated just north of the railway line and midway between Dronachellam (Dhone) and Malkapuram stations. The deposits classed under this head occur south-west of the village and to the north of the Kamalapuram reserved forest but south of the railway line.[1] There are at least two important faults in this region, both approximately E.–W., along which there appears to have been deposition of barytes.

No. 69.—There is much barytes in a vien trending E.–W., situated about three-quarters of a mile south-west of Erragunta, which can be traced for a distance of more than half a mile by means of occasional pits which have been dug along its course. The barytes occurs in siliceous and chalcedonic Vaimpalli limestones, just north of a very crushed zone in which there has been much silicification. The amount of silica present will undoubtedly hinder any working of the barytes, which appears to be of fairly good quality. A vein exposed half a mile S. by W. of the village may be connected with this deposit.

No. 70.—Several other occurrences of barytes were noted in this vicinity. A single pit has been dug about one mile S. W. by W. of Erragunta, exposing a replacement vein of barytes. There are also several veins of a similar nature on the north-westerly slopes of the range bordering the forest, roughly about $1\frac{1}{8}$ miles south-west of Erragunta. One also occurs on the south-westerly slopes of the central peak of the range, but is of no great extent.

37. Valasala (57 E/15; 15° 23′ 30″ : 77° 58′ 30″).

Valasala is a small village $1\frac{1}{4}$ miles N. by E. of Malkapuram station.

The geological structure of its neighbourhood is especially interesting inasmuch as the basal members of the Kurnools (the Banganapallis) are developed in force and can be seen overlying unconformably the barytes-containing Vaimpalli rocks.[2] They crop out at about the 1,750 feet contour horizontally or with gently rolling (generally easterly) dips; their elevation descends gradually as they are traced into sheet 57 1/3. It also appears that the original land surface on which the Banganapallis were deposited must have been very irregular in

Geology of the area.

[1] *See* Plate 5, fig. 1. The hills to the north of the village were not visited, but they appear to be composed of Gulcherus capped by Vaimpallis, all with a general south to S. S. E. dip.

[2] *See* Plate 5, fig. 1.

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nature.[1] Occasional small traps were noted in the hills north of the station.

No. 71.—Several veins of barytes can be seen to the south-west of Valasala within a distance of 1¼ miles from the village. They are mostly of the replacement type in Vaimpalli limestones. One vein, however, 1¼ miles south-west of the village, is in very crushed and ferruginous shales and limestones. Its quality is not good (N 569) nor does the available quantity of barytes appear to be large. The other veins are situated as follows :—in a cultivated field five furlongs W. S. W. of the village ; 300 yards due south of the foregoing and in the bed of a stream running S. S. W. to cross the railway line between miles 284 and 285 ; and on the cart track to the station from Valasala, three-quarters of a mile S. S. W. of the village.[2]

No. 72.—A crushed area of intense barytisation has its centre about three-quarters of a mile north-west of Valasala, north of hill station 1,811 feet, and extends just inside the North Dhone reserved forest.[3] It continues around the slopes of the Valasala hill to the headwaters of the tributary of the Erragunta stream, five furlongs west of Valasala. There seems but little doubt that this area extends under the capping of Banganapallis towards Valasala village, and is probably continuous under that capping with barytes No. 73 described hereafter. The small vein of dark grey barytes exposed on the path from Valasala to Erragunta (about a quarter of a mile west of Valasala) is probably part of the deposit. It is unfortunate that this barytes is generally of poor quality, being greyish in colour, as there is undoubtedly a large amount present. The occurrence is very similar to deposit No. 59 at Ramapuram (*see* pp. 64-65).

No. 73.—A quarter to half a mile E. N. E. of Valasala, in the headwaters of and on the eastern side of the Malkapuram stream, there are numerous veins of barytes striking E.–W., with stringers trending N.–S. The Vaimpalli limestones in which they occur dip south at a gentle angle and, across the river, are overlain by almost horizontal Banganapalli ferruginous sandstones and grits. It is thought that this barytes is probably continuous with the barytised area described previously.

No. 74.—A small vein of barytes, striking approximately E.–W., the same strike as that of the Vaimpallis in which it occurs, was noted a quarter of a mile south-east of Valasala. It crops out just below the covering of Banganapalli sandstones on the southern scrap of the plateau.

No. 75.—A vein of barytes was noted three-quarters of a mile east (a little south) of Valasala in a cultivated field. The pits dug previously were refilled prior to the author's visit. Several trap boulders were noted in their near vicinity, but none actually *in situ*. The possibilities of the vein are not large.

No. 76.—A considerable amount of barytes has been excavated from pits just inside the North Dhone reserved forest, just over 1¼ miles east (a little north) of Valasala. The area is one of intense crushing and silicification appears to have taken place. The barytes does not appear to be of much better quality than that north-west of Valasala (p. 72).

No. 77.—Other barytes veins were noted in the North Dhone reserved forest to the south and S. S. E. of the last occurrence. Thus 1⅝ miles E. S. E. of Valasala, five pits have exposed a small vein of barytes (N 568) with the exceptional strike of N. N. W.–S. S. E., which was traced for about a quarter of a mile up the dip slope of the Vaimpallis. This is of fair quality and deserves attention. Yet another vein crops out between this last and deposit No. 76 to the north.

38. Chinna Malkapuram[1] (*57 E/15 ; 15° 22′ : 77° 58′ 30″*).

Chinna Malkapuram lies half a mile E. N. E. of Malkapuram station and two miles N. N. W. of the village of Malkapuram.

No. 78.—The single deposit of barytes described here crops out to the north of mile 287 on the bend of the Guntakal-Bezwada railway line some 1¼ miles E. S. E. by E. of Chinna Malkapuram. It is less than 20 yards from the line, in yellowish Vaimpalli limestones which are crushed and brecciated a short distance north of the vein. It appears that the vein, which is of fair quality, runs parallel to a fault which trends E. N. E.-W. S. W.[2] It can be traced at least as far as telegraph pole 287/5.[3]

39. Kottapalle (*57 I/3 ; 15° 22′ 30″ : 78° 2′ 30″*).

Kottapalle[4] is three furlongs south-east of mile 290 of the Guntakal-Bezwada metre-gauge line, and just over 2½ miles S. S. W. of Rangapuram station. All the barytes classed under this head

[1] King's field maps and his published map do not show these Banganapallis. He has failed to recognize that they extend as far west as Valasala. The high hills in the Dhone reserved forest to the north of Valasala are probably formed of Gulcherus and Vaimpallis, capped by Banganapallis.

[2] There are signs of dislocation in the vicinity of this last vein.

[3] The author was informed that the pits on Valasala lands were dug by the Jagirdar of that village, and that those dug in the North Dhone reserved forest were made by M. R. Ry. B. P. Sesha Reddy Guru of Betamcherla. Numerous applications have been granted for prospecting licenses for barytes in the North Dhone reserved forest and the author has been unable to find the exact localities of the areas in question. As long ago as 1916, Messrs. A. Ghose and Co. of Gooty held a prospecting license for barytes. M. R. Ry. B. P. Sesha Reddy held under prospecting licenses at various times during the years 1918-1923 blocks Nos. 13, 14, 18, 28, 29, 32, and 34-40 of the reserved forest. He has also held plots subsequently to 1923, but M. R. Ry. S. P. Ranga Rao of Kurnool and M. R. Ry. V. V. Subbiah Pantulu of Vuyyuru, and, also, but to a lesser extent, H. M. D Ashroff Hussane Khan Mandoji of Kurnool, have been the chief holders of such licenses.

[1] In Telegu *chinna* means small ; *pedda* means large. It is commonly found that there are two villages or hills of the same name and so distinguished, *viz.*, Pedda Yeckaluru and Chinna Yeckaluru, Peddagummani Konda and Chinnagummani Konda (*konda* means a hill).

[2] There is possibly a cross-fault near mile 287 on the southern side of the line.

[3] Prospecting licenses for barytes have been held for plots of Malkapuram by M. R. Ry. V. V. Subbiah Pantulu of Vuyyur, M. R. Ry. B. P. Sesha Reddy of Betamcherla and Mr. A. Ghose.

[4] *See* Plate 5, fig. 1. It must not be confused with Kottapalle (57 J/7 ; 14° 22′ : 78° 21′ 30″) in the Pulivendla taluk of the Cuddapah district (*see* p. 18), near which there are large deposits of barytes. *Kottapalle* literally means ' new village ', and so the name is very commonly met in Telegu-speaking districts.

It is thought by the author that the survey numbers of Kottapalle held under prospecting license for barytes are those containing deposits Nos. 83 and 84 of Bukkapuram (*see* p. 63 and footnote No. 2).

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occurs south of the railway line and mostly within, or near, the very irregularly-shaped Block A of the Rangapuram reserved forest, which follows the boundary between the Dhone taluk and Banganapalle State.[1]

Geology of the area.

The geological structure of the country south of Malkapuram has been discussed in detail in the author's asbestos report. Its eastward continuation to the south of Kottapalle is very similar in nature. Immediately south of the village, the Vaimpallis have gently rolling dips, generally southerly in direction. Doleritic and basaltic sills, which are continued into the Malkapuram traps to the west and the Muddulettiswami rocks to the east, have been intruded into the Vaimpallis just below the Pulivendlas, which form the E.–W. running border ridge with Banganapalle State. Also faulting appears to have taken place here, one fault trending north-east from just north of hill station 1,835 feet. Younger Kurnool rocks, Banganapalli in age, crop out near Kottapalle village.

No. 79.—A vein of barytes crops out in yellowish ferruginous Vaimpalli limestone five furlongs E. by S. of Kottapalle. It is not of good quality and varies largely. A certain amount has been excavated but most of it has been left at the pit's mouth as it is of too poor quality to remove. The pit was filled prior to the author's visit. It was apparently some ten yards long and of no great depth. The limestones here have a gentle south-easterly dip; the vein strikes N. E.–S. W.

No. 80.—Just inside the western end of Block A of the Rangapuram reserved forest, $2\frac{3}{8}$ miles south-west of Kottapalle and five furlongs W. N. W. of the border peak 1,835 feet, barytes (N 576) of good quality occurs as a replacement deposit, striking E.–W. in ochreous Vaimpalli limestones. Surface indications do not show the vein to extend for any appreciable distance.

No. 81.—Another vein, striking E. N. E.–W. S. W. for about a quarter of a mile and more or less parallel to the fault previously mentioned was noted $1\frac{1}{2}$ miles S. S. W. of Kottapalle in Block A of Rangapuram reserved forest. A considerable amount of barytes has been removed but the pits were refilled prior to the author's visit.[2] The vein occurs in ferruginous and siliceous Vaimpalli shales and limestones.

No. 82.—Mr. P. N. Mukerjee noticed two exposures of barytes a short distance apart, about $1\frac{1}{4}$ miles S. by E. of Kottapalle just north of the Rangapuram reserved forest boundary. The two small exposures are in limestone and are probably connected with each other and allied to a fault noticed by the author striking N. by E. just west of hill station 1,741 feet. The strike of the barytes veins, however, is E. N. E.–W. S. W.

[1] *See* Plate 5, fig. 1.

[2] In 1922, M. R. Ry. B. P. Sesha Reddy Guru of Betamcherla held block No. 34 of the Rangapuram reserved forest under a prospecting license for barytes. He has since held blocks of acres 8 acres 95 cts., 7 acres 50 cts. and 6 acres 51 cts. in the same reserved forest.

40. Bukkapuram (57 I/3; 15° 23′: 78° 2′).

Bukkapuram is three-quarters of a mile N. N. W. of Kottapalle, but is on the northern side of the railway line.[1] It is about $2\frac{1}{2}$ miles south-west of Rangapuram railway station.

Geology of the area.

The village itself is on Banganapalli sandstones, which extend south-west along the railway line and north-east towards Rangapuram, where they are overlain conformably by Jammalamadugu limestones and flags. The Banganapallis have rolling dips, especially noticeable in the neighbourhood of the deserted village of Somapuram. They also crop out in that part of the North Dhone reserved forest to the north-west of the village of Bukkapuram.

The deposits described hereunder all occur to the north of the railway line, and are in plots which, for revenue purposes, have been subdivided as part of Kottapalle.[2]

No. 83.—A vein of barytes occurs in yellowish Vaimpalli limestones in uncultivated land two miles W. S. W. of Bukkapuram and about a quarter of a mile N. N. W. of mile 288 on the Guntakal-Bezwada line. It is associated with calcite (N 567). Specimens of the latter mineral with smooth rounded faces where they meet the wall rock (limestone) have a pseudo-nodular appearance when they are weathered out of the enclosing vein. The amount of barytes present may be considerable, but the pits, dug, it is said, by the Jagirdar of Valasala, indicate a vein of varying thickness and uncertain extent, but with a general E.–W. trend.[3]

No. 84.—A small vein, also with an E.–W. trend, crops out in Vaimpalli limestones about a quarter of a mile W. N. W. of the last deposit (roughly about $2\frac{1}{2}$ miles W. S. W. of Bukkapuram). It has no economic value.

No. 85.—Pits have been dug by the Jagirdar of Valasala three-quarters of a mile N. N. W. of Bukkapuram, just outside the North Dhone reserved forest, exposing a vein of barytes striking E. N. E.–W. S. W. for about three furlongs or so. There has been considerable crushing and silicification of the Vaimpalli limestones in which it occurs.

[1] *See* Plate 5, fig. 1.

[2] As long ago as 1918, the late Mr. A. Ghose held block No. 849 of Kottapalle, totalling 116 acres, under prospecting license for barytes. M. R. Ry. B. P. Sesha Reddy of Betamcherla held block No. 776/1 in 1923 and No. 210 B/1 in 1927. Since then, the latter gentleman, H. M. D. B. Abdul Nabi Sahib of Dhone, Khan Sahib K. Abdul Hye of Bellary, M. R. Ry. Jayaram Reddy of Betamcherla and M. R. Ry. S. P. Ranga Rao of Kurnool have held various blocks of Kottapalle under prospecting licenses for barytes. The author was unsuccessful in ascertaining the exact positions of the various blocks.

[3] The author was informed of the existence of another vein of barytes between this and Bukkapuram village; but though diligent search was made, it was not found, though its existence is not doubted. The country was very grass-covered at the time of his visit.

Many other pits have been dug along the continuation of this vein to the E. N. E., some in lands belonging to Rahimanpuram village in the *jagir* of Gutupalle, but classified here for convenience. The barytes is of good quality. The occurrences are of the replacement type, very reminiscent of the Hussainpuram occurrence.

41. Rahimanpuram (57 I/3; 15° 24′ : 78° 3′).

Rahimanpuram is a small village half a mile W. S. W. of Rangapuram station.[1]

Geology of the area.

It is situated on Banganapalli sandstones, which are overlain by greenish flaggy Jammalamadugu limestones. The barytes deposits classified hereunder occur to the west and W. S. W. of the village, in Vaimpalli limestones which have been exposed by the erosion of their covering of Kurnool rocks.

Two prominent faults may be noticed, one striking E.-W. in the high ground west of the village; and the other crossing this and striking N. E.–S. W. Traps were seen along each of these faults, one $1\frac{3}{8}$ miles W. by S., and the other just under a mile W. by W., of Rahimanpuram.

No. 86.—There is an area of intense barytisation with its centre about $1\frac{3}{8}$ miles W. S. W. of the village of Rahimanpuram. Numerous pits have been dug by, so the author was informed, M. R. Ry. B. P. Sesha Reddy of Betamcherla and a fair quantity of barytes removed to Rangapuram station; but the pits were refilled prior to the author's visit. The barytes is of good quality and the quantity remaining must be considerable. The occurrence is just outside the eastern boundary of the North Dhone reserved forest.

No. 87.—There is a series of deposits of barytes of the Hussainpuram replacement type in Vaimpalli limestones (43·901) due west of Rahimanpuram. A considerable amount of the mineral of good quality (N 578) has been excavated and carted to Rangapuram railway station. The largest vein occurs $1\frac{3}{4}$ miles west of the village[2] land can be traced for 75 yards or more; it strikes E. N. E.–W. S. W. Other veins were noted $1\frac{1}{2}$ and $1\frac{5}{8}$ miles west of Rahimanpuram. All of them are connected, it is thought, with the E.–W. fault mentioned above which can be traced to the south of the occurrences along the summit of the ridge until it is covered by Banganapallis.

[1] Many prospecting licenses for barytes for blocks of Rangapuram have been issued. There are, however, no veins of barytes in the neighbourhood of this village and it is thought that the survey numbers of Rangapuram refer to plots in the vicinities of either Rahimanpuram (to its west and W. S. W.) or Komurikottala (*see* p. 68). M. R. Ry. B. P. Sesha Reddy of Betamcherla has had an interest in these as far back as 1920. Since then, he, M. R. Ry. V. Venkata Subbiah of Vuyyur, M. R. Ry. S. Jayaram Reddy of Betamcherla, Khan Sahib K. Abdul Hye of Bellary and H. M. D. B. Abdul Nabi Sahib of Dhone have held prospecting licenses for barytes for plots of Rangapuram.

[2] It is approximately $1\frac{1}{8}$ miles E. S. E. of Nagamallakunta.

No. 88.—Small veins of barytes were seen along the N. E.–S. W. fault mentioned previously, one mile west (a little north) of Rahimanpuram. They have not been worked, nor do they appear promising.

40. Ambapuram (57 I/3; 15° 23′ : 78° 5′ 30″).

Ambapuram is $2\frac{3}{4}$ miles S. E. by E. of Rangapuram railway station.

Geology of the area.

There have been several dislocations of the Papaghnis and Cheyairs and their associated traps in its vicinity, but they are largely masked by the covering of Banganapalli and Jammalamadugu rocks. Just over one mile to the south of the village, the Mudduletiswami traps crop out in force. They have been described elsewhere.

No. 89.—Barytes occurs on the western side of the unmade road from Rangapuram to Mudduletiswami, just past the second milepost. The area is one of much crushing. The same mineral was noted on the eastern side of the same road, just before the second mile post, as a replacement deposit of the Hussainpuram type. Both these deposits are approximately three-quarters of a mile W. S. W. of Ambapuram. They are probably interrelated. No pits have been dug.

43. Gutupalle (57 I/3; 15° 25′ 30″ : 78° 3′).

Gutupalle is rather an important *jagir* village, $1\frac{3}{4}$ miles north-west of Rangapuram railway station.

Geology of the area.

The Vaimpalli limestones to the north and north-west of the village are much faulted. In places, the covering of Banganapalli sandstones has not yet been removed by denudation and the structure is obscure. It appears, however, that the strong ridge trending N. E.–S. W., which culminates in the peak of 1,700 feet, to the north of the village, is composed of highly crushed Pulivendla quartzites situated along a fault line. It contains many veins of reef-quartz and a certain amount of iron oxide. It is thought that this ridge formed an 'island' in the Banganapalli sea. A parallel fault, but less important, occurs less than half a mile to the north-west of the ridge. Other minor faults trend north and south.[1]

No. 90.—Barytes occurs in the cultivated field of Syed Daza Mya Sahib, just north-east of the village of Gutupalle, probably along the line of a N.–S. fault. There appears to be no great amount present.[2]

[1] *See* Plate 5, Fig. 2.

[2] The author was informed locally that the deposit was seen by some 'Company Sahib', but that nothing further had been heard.

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No. 91.—Just W. N. W. of Gutupalle, along the track to Hanuman taraidu, several exposures of barytes of the replacement type were noted in Vaimpalli limestones. They have a general W. N. W. trend. The barytes is of good quality, but little of it appears to be present.

No. 92.—Approximately 1⅛ miles N. W. by W. of Gutupalle, slightly to the east of the North Dhone reserved forest boundary, barytes occurs in fair quantity as a replacement deposit which, however, is intimately connected with a N.–S. fault.[1] The quality of the barytes varies greatly but the majority is of poor quality.

No. 93.—A larger deposit of barytes, and of better quality, occurs seven furlongs N. N. W. of Gutupalle, mostly as a replacement deposit in Vaimpalli limestones; but a fair quantity is found in crushed rocks (N 579, 21814) caused by the N. E.–S. W. fault mentioned previously (p. 65). This area does not appear to have been prospected thoroughly and merits attention.

44. Husainpuram (57 I/3; 15° 26′ 30″ : 78° 3′).

Husainpuram[2] is a small village three miles N. N. W. of Rangapuram railway station. It is 3⅛ miles north of Gutupalle.

Geology of the area.

The geological structure in its vicinity is largely masked by the covering of Banganapalli sandstones which here overlie the Vaimpallis unconformably. The rolling nature of these sandstones and grits is well seen in the hills between Husainpuram and Tapasikonda.

No. 94.—On the cart track from Gutupalle to Husainpuram, a furlong from the latter village, barytes was noted in a cultivated field apparently occurring as impersistent veins in Vaimpalli limestones. More was noted about the same distance north-east of the village. The two occurrences are possibly connected.

No. 95.—A considerable quantity of barytes, apparently of good quality, occurs half a mile N. N. E. of the village of Husainpuram. The locality is to the west of the southernmost quartzites on the edge of the cultivation, W. N. W. of hill station 1,751 feet. The barytes is apparently associated with a N.–S. fault and does not appear to have been prospected.

45. Tapasikonda (57 I/3; 15° 27′ 30″ : 78° 3′ 30″).

Tapasikonda is four miles due north of Rangapuram railway station, but it is situated about five miles from it by bullock-cart tracks. The village has been built on a hill formed of Vaimpallis capped by sandstones believed to be Banganapallis. Similar sandstones are developed in force in the Betamcherla reserved forest to the north-east on sheets 57 I/3 and I/2 (*see* p. 70).

[1] The deposit is on the eastern side of the *nala* near boundary pillar No. 293.

[2] Husainpuram must not be confused with Hussainpuram (57 I/16; 15° 14′; 77° 49′ 30″), the site of the occurrence of barytes that has been taken as the type replacement deposit. It will be noted that the spelling is not quite the same.

No. 96.—Barytes occurs in a cultivated field just over half a mile south-east of Tapasikonda to the east of the path running from that village to Komururikottala. Some barytes is said to have been carted to Rangapuram by M. R. Ry. Jayaram Reddy of Betamcherla. The pits were refilled previous to the author's visit, but it was apparent that the barytes is of good quality and is of the nature of a replacement deposit. The amount still remaining is indefinite.

No. 97.—M. R. Ry. Jayaram Reddy is also said to have excavated barytes from another cultivated field just under half a mile E. S. E. of Tapasikonda and between that village and Papasanikottala.[1] There is, apparently, still a fair quantity of barytes remaining in this locality.

46. Papasanikottala (57 I/3; 15° 27′ 30″ : 78° 4′ 30″).

Papasanikottala is 5¼ miles W. by N. of Betamcherla station and four miles N. by E. of Rangapuram station. Such barytes excavated from the deposit described hereafter appears to have been carted to Betamcherla station.

There is a strong N. W.–S. E. trending fault between Papasanikottala and Musalayyacheruvu (57 I/3; 15° 29′ 30″ : 78° 4′), situated in the Betamcherla reserved forest, and along which there has been deposition of iron oxide and silica.

No. 98.—Barytes occurs just to the north of the fault mentioned above approximately three-quarters of a mile N. N. W. of Papasanikottala, in crushed Vaimpalli shales and limestones, along what is apparently a minor fault with the same trend (N. W.–S. E.). The quantity of barytes present is not large, nor is it of good quality.

No. 99.—A larger deposit of barytes and of better quality (N 587) occurs just inside the Betamcherla reserved forest a little over half a mile north-east (a little east) of Papasanikottala. At the time of the author's visit, there was a considerable pile of barytes excavated from the pit, which itself had been filled in. It was understood that the excavations were made by M. R. Ry. B. P. Sesha Reddy Guru of Betamcherla who held a prospecting license for the block.[2] Surface alluvium masks the geological structure, but it is thought that the deposit was of the replacement type in grey Vaimpalli limestones. The occurrence is more or less along the continuation of the major N. W.–S. E. fault, mentioned previously, which here forms a minor watershed. An interesting feature of the barytes is the occasional presence of a certain number of inclusions (N 588).

47. Komururikottala (57 I/3; 15° 26′ : 78° 5′).[3]

Komururikottala is 4½ miles W. S. W. of Betamcherla railway station.

[1] The author is ignorant of the survey numbers of these occurrences worked by M. R. Ry. Jayaram Reddy.

[2] Reference may be made to the notes on the Balapalapalle deposits (p. 71), most of which are in the Betamcherla reserved forest.

[3] *See* Plate 5, fig. 2. The Komururikottala, Balapalapalle and Kolumalapalle areas may be conveniently grouped as the Betamcherla occurrences. All the deposits classed under these areas lie within a radius of 4½ miles from Betamcherla railway station.

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The village is apparently on Banganapalli sandstones and grits, but Vaimpalli limestones and Pulivendla quartzites are exposed to the north-east and east of it. The Banganapallis are overlain conformably by the Jammalamadugus between Komururikottala and Hanumantharayakottala. At times, the Jammalamadugus (Narjis) appear to overlie the Vaimpallis directly, the basal bed being a breccia.[1] Other examples of 'islands' in the Banganapalli sea have been mentioned previously (*e.g.*, p. 65), and it appears that many such 'islands', occurring to the west of Betamcherla, were submerged in the Jammalamadugu sea. The coarse nature of many of the Banganapalli deposits is mentioned later (p. 82; also footnote p. 83).

Geology of the area.

The Jammalamadugus crop out in force to the east of Betamcherla where they are extensively quarried for use as a building stone.[2]

There is a strong E.–W. fault to the east of Komururikottala and it would appear that the quartzites to the north of this fault are Pulivendlas, and are not to be referred to the Banganapallis.

No. 100.—Erosion of the covering of Banganapalli sandstones has exposed a deposit of barytes in very chalcedonic Vaimpalli limestones, one mile south-east of Komururikottala village. A fair amount has been excavated and carted to Betamcherla station by M. R. Ry. S. Jayaram Reddy of Betamcherla. The veins are of the replacement type and strike more or less E. S. E.–W. N. W. The barytes is dirty white in colour and is not of good quality. It is thought a moderate amount still remains.

No. 101.—A quarter of a mile E. N. E. of Komururikottala, just east of the *bund* and along the *nala* barytes occurs partly in veins of the replacement type, and partly as a fissure deposit in siliceous Vaimpalli limestones. The veins strike E. N. E.–W. S. W. M. R. Ry. B. P. Sesha Reddy of Betamcherla has excavated and carted some of the barytes to Betamcherla. It is mostly white and of good quality (*N* 580).

Another pit has been dug exposing barytes half a mile E. N. E. of the village along the same line. Yet another deposit of barytes occurs just over half a mile north-east of Komururikottala.

No. 102.—A small amount of barytes has been removed from a pit 1¼ miles east of Komururikottala.[3] This is situated more or less along the line of the major fault referred to previously.

[1] *Cf.* King, *op cit.*, pp. 76-78. The same breccia is common near Rangapuram.

[2] King has mentioned the utilisation of the Narji limestones (*op cit.*, p. 70 *et seq.* and p. 282). There is a very thriving trade in building stones and flags at Betamcherla. The sides of the Paniam-capped plateau to the east of the village and of Bugganipalle contain many quarries.

[3] About the same distance W. S. W. of Hanumantharayakottala.

48. Balapalapalle (57 I/3; 15° 27′ 30″ : 78° 6′ 30″).

The Balapalapalle deposits of barytes are the best known in the Kurnool district and, in fact, in the Madras Presidency. Certain of them have been extensively mined within the past two decades. Balapalapalle is a small village 2¾ miles W. by N. of Betamcherla railway station. It is separated from the important village of Betamcherla by a N.–S. trending range which is very interesting geologically.

The range is composed chiefly of Pulivendla jasperoid quartzites (43·904, 21816), which at times are very hæmatitic. Certain of the rocks in the ridge appear to be alteration products of Vaimpalli limestones, and it seems probable that the ridge marks the site of a major fault, trending N.-S. A smaller cross-fault runs N. E.–S. W. to the south-east of Balapalapalle. Another, trending S. S. E.–N. N. W., can be seen in the cultivated fields S. S. E. of the village.

Geology of the area.

The whole region east of Balapalapalle is one of immense disturbance, but, as is usual in these parts, the structure is partly masked by the covering of Banganapalli and Jammalamadugu rocks, especially in the vicinity of Hanumantharayakottala. The large expanse of Betamcherla trap (43·906, 21823; 43·905, 21817) beginning near this village extends up to the Gattimanikonda fault on sheet 57 I/2. This basalt (for most of it is basaltic in texture) though continuous in outcrop, is not constant in stratigraphical position. It appears to be a gigantic sill, the intrusion of which was accompanied by faulting. East of Balapalapalle, it overlies, and, also, is apparently faulted against, quartzites which have been referred to the Pulivendla stage of the Cheyair series. North of Bugganipalle, in the region at present masked by Banganapalli sandstones and grits, there must be a change in the stratigraphical relations of the trap sill because still further north, in the neighbourhood of Gattimanikonda, the basalt clearly underlies the Pulivendlas and has been intruded between them and the Vaimpallis.[1] Further reference has been made to this basalt in the description of the Gattimanikonda barytes.[2]

[1] North of the village, the trap is cut off by the Gattimanikonda fault. Reference may be made to p. 77 and, also, to the paper by the author on the Kalava wall of Paniam quartzites [*Rec. Geol. Surv. Ind.*, LXVI, pp. 442-443, and Plate 26, (1933)].

[2] P. 77.

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As, however, the chief deposits of barytes in its vicinity occur to the west of Balapalapalle in the Betamcherla reserved forest, the structure of that area should be grasped at the present juncture.

The Betamcherla reserved forest is an eroded plateau area in which Vaimpalli limestones are capped by quartzites and sandstones of doubtful age. It is thought that the rocks in question are not all of one age; some are Pulivendlas and some are Banganapallis, but it is not always possible to state which with certainty.

King failed to recognize the presence of the Banganapalli rocks, not only in this region, but in their continuation northwards as far as Kurnool town. He regarded these plateau rocks as Pulivendlas and, indeed, cited them as evidence of the unconformable nature of the Pulivendlas on the Vaimpallis.[1] The author, however, holds that there is no large, if any, unconformity between the Pulivendlas and the Vaimpallis, and that the great majority of the sandstones, grits, breccias, and even quartzites, in the Betamcherla reserved forest are Banganapalli in age, being perfectly continuous with the undoubted diamond-bearing Banganapalli plateau grits and sandstones which overlie the Gattimanikonda fault near that village.[2]

As is to be expected, on account of the masking effect of the younger Kurnool rocks, the structure is far from clear in many places. Erosion, however, has proceeded sufficiently far to indicate the existence of several major faults in that part of the forest area W. N. W. of Balapalapalle. The chief of these appears to be a N.–S. one, with which are associated the main deposits of barytes. Other less important faults trend approximately E.–W. All these faults have been discussed in the description of the barytes deposits.

Fragments of trap were seen in the fields south-west and west of Balapalapalle, but the traps here are of no great size and are not comparable with those at Betamcherla and Mudduletiswami.

No. 103.—During part of 1931 and 1932, barytes was quarried by M. R. Ry. S. Jayaram Reddy of Betamcherla from pits dug in a cultivated field three quarters of a mile south of Balapalapalle.[3] The deposit seems to be of the replacement type in very chalcedonic Vaimpalli limestones. Trap fragments are common nearby, but no trap was seen actually *in situ*. On the other (eastern) side of the adjacent ridge, however, there is the large expanse of Betamcherla trap from which the fragments were possibly derived. The limestones to the north-west of the deposit are very crushed, and it appears that the barytes occurs at the

[1] Pp. 169-170.
[2] *See* A. L. Coulson, *Rec. Geol. Surv. Ind.* LXVI, pp. 442-443, (1933).
[3] The occurrence is the same distance north-west of Hanumantharayakottala.

south-eastern end of a N. W.–S. E. striking fault. Further exploratory work is necessary before an estimate can be given of the amount of the deposit.

No. 104.—The deposit that has been worked most in India is situated just over 1½ miles N. W. by W. of Balapalapalle in the Betamcherla reserved forest. According to information received by the author, Messrs. Beardsell and Co. of Madras worked it in 1908 and exported barytes from Murmugoa in Goa (Portuguese West India) Messrs. Turner, Morrison and Co. of Shalimar, Calcutta, are stated to have worked the deposit during the period 1911-1916. The late Mr. A. Ghose of Gooty and Calcutta held it from 1916 to 1928.[1] And finally, M. R. Ry. B. P. Sesha Reddy Guru of Betamcherla has mined barytes from this locality since 1929.

Unfortunately at the time of the author's visit, there were few sections exposed which gave much information concerning the structure of the rocks. The old, winding galleries from which so much barytes has been won in the past, have been allowed to fall into a state of disrepair, as M. R. Ry. Sesha Reddy has commenced the excavation of a new pit from which galleries were to be made. This new pit, however, had not reached the deposit at the time of the author's visit.

Earth has blocked the entrance of the largest of the old pits, but as far as could be gathered, drives radiated in a westerly direction from it to the west, south-west, north-west, W. S. W., W. N. W., etc. The same is probably true of the other pits of which there are several. These drives followed the courses of the veins of barytes, the general direction of which, as far as they may be said to possess one, is more or less E. S. E.–W. N. W. The general dip of the Vaimpalli limestones in this neighbourhood is south-east to S. S. E., but there are many local inversions. Indeed certain north-westerly dips were noted.

There is no doubt that the area is one in which intense faulting has taken place. As the author was unable to traverse the galleries, he cannot state whether or not the barytes has been deposited actually along the line of the fault. The surface evidence, and that of such pits as he was able to visit, is far from clear, but the author is of the opinion that the deposits of barytes may be considered as partly fissure and partly replacement (pp. 104-105). The general trend of the major fault is N.–S., and so the veins usually trend almost at right angles to the fault.

There is an extreme abundance of ochreous material in the rocks and it is considered that ferruginous solutions accompanied the barium-containing liquor as has

[1] These dates are uncertain and reference may be made to the brief history of the barytes industry in the Kurnool district given on page 44.

Unfortunately there is now no record of which particular block was held by the gentlemen referred to therein. Moreover it will be remembered that mention was made in the Quinquennial Review for 1909-1913 [*Rec. Geol. Surv. Ind.*, XLVI, p. 237, (1915)] of this deposit 'on information supplied by Mr. A. Ghose'. However, Mr. Ghose held prospecting licenses for barytes in the Betamcherla reserved forest in 1916 and 1917 [*see also op. cit.*, XLVIII, p. 90, (1918); XLIX, p. 107, (1919)]. M. R. Ry. B. P. Sesha Reddy Guru held prospecting licenses for blocks in the forest from 1918 onwards [*op cit.*, p. 199, (1919)]. Dates have been given (*see* p. 44) for his taking out of mining leases but it is not known which are the respective dates for the three blocks of 86 acres, 16 acres and 10 acres. Other gentlemen who have held prospecting licenses in the Betamcherla reserved forest are M. R. Rys. S. P. Ranga Rao of Kurnool, S. Jayaram Reddy and Gunda Singaruyya Chetty, V. V. Subbiah Pantulu of Vuyyuru, Khan Sahib K. Abdul Hye of Bellary and H. M. D. Ashroff Hussane Khan Mandoji of Kurnool.

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been noted for several deposits of barytes described previously.[1] The barytes, however, is generally of very good quality (N 582), but there are numerous interesting modifications. Thus certain specimens are reddish (N 551), others greyish (N 584), yet others contain numerous inclusions (N 583). The author's colleague Mr. W. D. West, has been kind enough to identify the inclusions as minute needles of hæmatite which, on weathering, are altered to brownish yellow limonite. At times the number of inclusions is so large that the barytes is dark in colour. Mention has been made elsewhere (*see* p. 118) of a valuable specimen (N 618) of crystal-clear barytes forwarded by M. R. Ry. Sesha Reddy from these Balapalapalle mines.

The surface of the ground near the pits is covered with numerous boulders of quartzite, the exact age of which is uncertain. It is thought that some of these blocks are fragments of Pulivendla quartzites, jasperoid in nature; others are secondary, due to the replacement of limestones by siliceous, and in many cases, ferruginous, solutions; and yet others appear to be fragments of the Banganapalli or 'plateau' sandstones and breccias which overlie the Vaimpallis and Pulivendlas in this neighbourhood. If the fragments referred to the Pulivendlas are correctly identified, then it is apparent that there must have been very considerable faulting before the deposition of the Banganapallis,[2] because the normal position of these rocks is some two miles or more to the south-east.

No. 105.—The N.-S. fault near deposit No. 104 has already been mentioned. Another fault appears to run along the cart track E. S. E. from this deposit and along this fault, there has been considerable deposition of ferruginous matter, including hæmatite. A cross-fault runs N. N. E.–S. S. W. along the river bed a quarter of a mile to the east, and approximately 1¼ miles north-west of Balapalapalle. Just to the east of this fault, there is another deposit of barytes in grey Vaimpalli limestones which is said to have been worked by M. R. Ry. S. Jayaram Reddy of Betamcherla. It occurs in the Betamcherla reserved forest and is of the replacement type; though a little distance away from the last-mentioned fault, it is probably connected with it. It is not thought that the reserves of barytes in this deposit are abundant.

The structure of the area is largely masked by sandstones (? Banganapalli) which overlie the S. S. E. to southerly dipping Vaimpallis.

No. 106.—Yet another fault trends slightly north of west along the *nala* W. N. W. of Balapalapalle. Barytes occurs in very crushed Vaimpalli limestones along this fault, 1⅜ miles W. N. W. of Balapalapalle. A moderate amount of barytes has been excavated by M. R. Ry. S. Jayaram Reddy and the pits dug have fallen into disrepair. One cannot give an idea of the amount of mineral present. It is quite possible that the deposit is connected with the large deposit (No. 104) worked by M. R. Ry. Sesha Reddy, being along the continuation of the direction of the major N.–S. fault by this latter deposit. There are, however, no exposures of Vaimpallis between the two occurrences.

The surfaces of both banks of the *nala* in which the barytes occurs are covered by sandstones and quartzites, rather rolling in dip, which the author believes to be Banganapalli in age.

[1] To mention but one example, No. 67, 1¼ miles north-west of Kamalapuram, is associated with abundant ferruginous matter.

[2] *See* A. L. Coulson, *Rec. Geol. Surv. Ind.*, LVXI, p. 444, (1933).

49. Musalayyacheruvu (57 I/3; 15° 29′ 30″ : 78° 4′).

Musalayyacheruvu is 6¼ miles N. W. by W. of Betamcherla railway station.

The Musalayyacheruvu deposit of barytes occurs in the Betamcherla reserved forests north-west of the Balapalapalle occurrences, and so the geological structure of the country does not differ greatly from that in their neighbourhood.[1] There are several N. W.–S. E.-trending faults here, none of any great magnitude, but the plateau capping of Banganapalli sandstones and grits probably masks many important ones.

Geology of the area.

It is convenient to refer here briefly to the geology of the area to the north of Musalayyacheruvu and Muddavaram on sheet 57 I/2. There are two strong E.–W. faults to the north of the former village, just on sheet 57 I/3. The more northern of these faults has abundant iron oxide along its course. The Vaimpallis here are very siliceous and chalcedonic, being reminiscent of those west of Kochcheruvu (p. 56). The chief interest, however, lies in the great abundance of steatite (*bulpum*) on the northern side of the range of hills, 1⅜ miles S. by E. of Marrikunta (57 I/2; 15° 31′ : 78° 4′) on either side of the tract from that village to Musalayyacheruvu. Such exposed sections as are now visible in the disused quarries and mines appear to show that the steatite (N. 589-591, 21819, 21820) is probably due to the infiltration of magnesian solutions from some hidden trap as the veins of this mineral trace a very sinuous course in the Vaimpalli shales and siliceous limestones. It was stated that the steatite had been mined by the late Mr. A. Ghose and latterly by M. R. Ry. B. P. Sesha Reddy Guru of Betamcherla.

Geology of the area north of Musalayyacheruvu.

King apparently did not notice this occurrence of steatite, but he has recorded that between Venkatagiri (57 I/2; 15° 31′ : 78° 5′) and Muddavaram (57 I/3; 15° 30′ : 78° 6′), stating (*op. cit.*, p. 166) that

'the shales of this (Papaghni) series are very magnesian, some of the layers being nothing else but fine grey and greenish steatite. There are also seams of the finer form, or "French Chalk", which is here called, and known over South India, as "Bulpum". This is the quarrying place for steatite in this district.'

[1] *See* Plate 5, fig. 2.

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He adds a footnote regarding the uses to which it is put, and the designs into which it is carved, by the local people.

This occurrence is on the path between Venkatagiri and Muddavaram, and is situated some three-quarters of a mile S. S. E. of the former village. The Vaimpalli shales and limestones in which the steatite occurs have a general S. S. E. dip of about 10°-15°. There is more 'French chalk' in this locality than in the Marrikunta occurrence. As there, however, the quality of the steatite varies greatly (N 592-594, 21821). These mines, if they may be called that by courtesy, were disused at the time of the author's visit and apparently had not been worked for some very considerable time.

The author does not agree that the primary cause of this occurrence of steatite is the fact that the shales are magnesian. It is thought by him that the magnesian character is largely acquired, being imparted by the magnesian solutions which accompanied the intrusive sills of basic igneous rocks (see author's asbestos report).

There is an E.–W. fault just south of the hamlet of Muddavaram, between it and the *bund* of the 'tank'. Another fault of similar trend crosses the path to Muddavaram a quarter of a mile south of Venkatagiri. North of this latter village, there is yet another fault which trends N. N. E.–S. S. W. It is possible that this is a post-Kurnool fault, much younger than those previously mentioned.

Numerous diamond diggings may be seen in the vicinities of Balapuram, Repalle and Virayapalle to the north of Venkatagiri. These are in the Banganapalli sandstones and grits which overlie unconformably the Vaimpallis in this region. The basal Banaganpalli rock here is usually a gritty conglomerate, with pebbles the size of peas. The late Mr. A Ghose dug pits for diamonds a quarter of a mile east of Balapuram, but it was stated that none were found. The pits noted by the author were dug in crushed and faulted Vaimpalli limestones and shales, and not in Banganapalli rocks. Banganapallis cap the hill to the W. N. W. of the village.[1]

No. 107.—Inside the Betamcherla reserved forest, 1⅛ miles south-east (a little south) of Musalayyacheruvu,[2] barytes occurs partly as a replacement deposit (N 586) and partly along a line of crushing in Vaimpalli limestones. It occurs just south of the path from the village to Balapalapalle which follows the course of the main N. W.–S. E. fault in this region (*see* p. 73). The trend of the

[1] It is interesting to note that the local word for stone, *viz.*, *rawal*, is used for diamonds

[2] M. R. Ry. B. P. Sesha Reddy Guru of Betamcherla has held prospecting licenses for barytes for plots Nos. 330 (1 acre 45 cts.), 528 (3 acres 47 cts.), and 528 B (2 acres) of Maddavaram, which village is 1¾ miles north-east of the deposit described. It is thought these survey numbers refer to the locality in question.

barytes is N.–S. M. R. Ry. B. P. Sesha Reddy has excavated a certain amount of the mineral which has been carted by a track, not shown on the map, to the big deposit described previously (No. 104, pp. 71-72), and thence to Betamcherla. The pits were refilled prior to the author's visit, and so it is hazardous to estimate the probable quantity present.

50. Kolumalapalle (57 I/3; 15° 28′ 30″: 78° 8′).

Kolumalapalle is 2½ miles N. W. by N. of Betamcherla railway station. All the deposits described hereunder lie on sheet 58 I/3.

The village is situated on Vaimpalli shales and limestones of which there are some good exposures in its near vicinity. Trap however, crops out for most of the distance between it and Betamcherla. To its north and west is the Betamcherla reserved forest, with the usual rolling 'plateau' sandstones of the Banganapalli stage of the Kurnool series, found in other parts of this forest and described previously.

Geology of the area.

The Vaimpallis in the neighbourhood of Kolumalapalle generally have a south-easterly dip, but they vary locally. North of the ridge which runs to the north of the village, the Vaimpallis are not far removed from horizontality, but if anything, they have a slight E. S. E. dip. This ridge is the site of a fault, trending W. N. W.–E. S. E., along which there has been considerable silicification accompanied, it will be seen, with slight barytisation.

Mention may also be made of what appear to be post-Kurnool faults affecting the Banganapallis in the Betamcherla reserved forest on the track between Kolumalapalle and Muddavaram. There is a steep ascent as one passes from the former to the latter village, probably the site of a fault, and also a less steep descent on the other side of the watershed. Also, nearer Muddavaram, there seems to be a parallel dislocation passing through hill 1,590 feet, half a mile E. S. E. of the village.

No. 108.—About half a mile N. by E. of Kolumalapalle, pits dug by M. R. Ry. S. Jayaram Reddy of Betamcherla[1] show a replacement deposit of

[1] Survey numbers of Kolumalapalle have long been held under prospecting license for barytes. Thus in 1917, M. R. Ry. B. P. Sesha Reddy Guru of Betamcherla held plots Nos. 571 A and 599 A; Nos. 589, 651 C and 768 in 1918; No. 575 A in 1919; and Nos. 175 and 575 in 1920; after which he discontinued his licenses. M. R. Ry. B. Pullareddy of Betamcherla held Nos. 12 and 149 A in 1919. H. M. D. Abdul Nabi Sahib of Dhone has held No. 209; M. R. Ry. Gunda Chinna Aswarthani Chetty No. 35/5; M. R. Ry. S. P. Ranga Rao of Kurnool Nos. 149 A and B, 164 and 187; and M. R. Ry. S. Jayaram Reddy of Betamcherla Nos. 475/C and 617. The author was unable to ascertain in which of these respective plots the deposits hereinafter described are situated.

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barytes in Vaimpalli limestones. The occurrence is very near the E. S. E. trending fault previously mentioned as making the ridge north of the village. Indeed stringers of barytes were noted nearby in the crushed rocks on the top of the ridge.

No. 109.—Two pits for barytes have been dug on the northern side of the ridge, three-quarters of a mile north-east of Kolumalapalle. The deposit is not of any great size.

No. 110.—Several pits have been dug for barytes seven furlongs E. N. E. of Kolumalapalle by M. R. Ry. Gunda Chinna Aswarthsni Chetty. The barytes occurs in veins of the replacement type, striking E. S. E., a short distance away from the parallel fault which forms the backbone of the ridge south of the occurrence. The quartzites on this ridge are of doubtful age, some probably true Pulivendlas faulted into their present position, others are thought to be true metasomatic quartzites formed by the replacement of Vaimpalli limestones by siliceous solutions.

No. 111.—A vein of barytes occurs 1¼ miles due north of Kolumalapalle in the Betamcherla reserved forest, just below the northern limit of sheet 57 I/3. The vein has an elongation of some hundreds of yards N. 20° W. and is along the course of a minor fault. The larger part of the deposit, however, seems to be of the replacement type. Such pits as were excavated by M. R. Ry. B. P. Sesha Reddy were refilled prior to the author's visit, but it appears that a fair quantity of the mineral has been removed.

An isolated occurrence of bartytes was noted a furlong or so E. S. E. of the main vein. The ridge to the north of the latter is capped with Banganapalli sandstones with rolling dips. Strong faulting was noted to the W. S. W. and south-west, where Pulivendla quartzites occur.

No. 112.—Barytes occurs in crushed Vaimpallis along an E.–W. fault 1¾ miles N. E. by N. of Kolumalapalle, just below the northern limit of sheet 57 I/3 where it has been excavated by M. R. Ry. B. P. Sesha Reddy of Betamcherla. The barytes is of fairly good quality but does not appear to be present in any considerable amount.

No. 113.—Barytes occurs just within the Betamcherla reserved forest 1⅜ miles W. N. W. of Kolumalapalle in a thin, irregular vein of no great magnitude which trends a little north of west. The occurrence is just north of the cart track from Kolumalapalle to Muddavaram. One pit has been dug just outside the forest.

51. Gattimanikonda (57 I/2; 15° 32': 78° 11').

Geology of the area.

Gattimanikonda[1] is a small village, pleasantly situated on a plateau six miles N. N. E. of Betamcherla railway station and about 3½ miles N. N. W. of Bugganipalle station. It is, however, connected with the former station by a third-class road for most of the distance and most of the barytes that has been excavated from the deposits hereinafter

[1] Known locally as Gooramankonda, its old name, and that of the hill station 1,647 feet immediately east of the village.

described appears to have been carted to Betamcherla and not to the nearer Bugganipalle. The main structural feature of the Gattimanikonda area is the Gattimanikonda fault.[1] This very important pre-Kurnool E.–W. fault has dislocated the strata to such an extent that while south of it, the Pulivendla quartzites cap the hill immediately east of the village, the same rocks north of the fault crop out some three miles further west. Even assuming a uniformly easterly dip of the Pulivendlas of only 5°, the throw of the Gattimanikonda fault to the north is little less than 1,400 feet. Further details may be obtained by reference to the author's paper on the Kalava wall of Paniam quartzites, which has been published separately.[2]

Reference must be made here, however, to the Banganapalli sandstones and grits that cap the Vaimpallis and to a certain extent mask the Gattimanikonda fault in the neighbourhood of the village. They crop out in force in the Betamcherla reserved forest near the hill called Dara Kanama. Sometimes there have been silicified, but not to the same extent as the Pulivendlas where these are typically developped. There seems little doubt that these rolling sandstones, grits and, in places, quartzites are mostly Banganapalli in age.

There is a large spread of basalt (43·905, 21817; 43·906, 21823) injected as a sill between the Vaimpallis and Pulivendlas, which stretches from Gattimanikonda to Betamcherla. This has been mentioned previously (*see* p. 69).

No. 114.—There is an area very rich in baryte with its centre about three-quarters of a mile W. S. W. of Gattimanikonda. The veins of barytes are of the replacement type in Vaimpalli limestones, not very far distant from the spread of basalt mentioned above, which have a gentle south-easterly dip. This area persists south of the road between miles 4 and 5 on the Betamcherla-Somayajulapalle third-class road, and even into the Betamcherla reserved forest. The barytes (N 595) is usually of good quality.

It appears that there is a considerable quantity of barytes available here. This it may be noted, was the sole area in which prospecting for barytes was being carried out at the time of the author's visit, except for the deposit mined at Balapalapalle (No. 104, p. 71). It is understood that the work was being done for H. M. D. Ashroff Hussane Khan Mandoji of Kurnool.[3]

[1] *See* Plate 5, fig. 2.

[2] *Rec. Geol. Surv. Ind.*, LXVI, p. 442, (1933).

[3] The Collector's list shows that several prospecting licenses for barytes have been issued to various gentlemen for plots of Bugganipalle. Thus H. M. D. Ashroff Hussane Khan Mandoji of Kurnool has held No. 755 C; M. R. Ry. S. Jayaram Reddy of Betamcherla Nos. 550/1 and 529/1; and M. R. Ry. S. P. Ranga Rao of Kurnool Nos. 625 A and 625 B-1, 2 and 3. It is understood by the author that the barytes deposits described in this section occur in plots of Bugganipalle village.

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No. 115.—The structure to the south-east of the last occurrence is rather vague inasmuch as the basalt sill appears to be faulted against, and to be dipping under, the Vaimpalli limestones near mile 5; whereas further to the north it overlies the limestones. A fault can be seen trending N.-S. in crushed limestone, and as this is traced to the south, a thin basalt appears along its line. A little to the east of this, about one mile S. by W. of Gattimanikonda, another fault trends N. E.–S. W. Barytes (N 601), reddish grey in colour, has been deposited partly along its course and partly as a replacement deposit in altered limestones. The vein dips vertically and is 1½ feet thick. The amount present is not large, nor is it of good quality.

No. 116.—Perhaps the most interesting exposure of barytes noted in the Kurnool and Anantapur districts is that 1⅝ miles S. by W. of Gattimanikonda.[1] Its interest lies in the fact that the barytes is clearly partly in trap and partly in Vaimpalli limestones. It will be remembered that in these districts, though certain deposits have been thought to occur in trap, definite evidence has been wanting. In the Cuddapah district, however, the largest deposits of barytes occur in trap.

The pits dug here were refilled prior to the author's visit, but specimens (N 596, 21824) were collected showing barytes in basalt. The barytes vein trends N. W.-S. E., probably along a fault course. The north-western part of the vein is in Vaimpallis, the south-eastern in basalt. There is apparently a small amount of barytes present, but as the pits were refilled, it is difficult to state with certainty the amount of the mineral.

No. 117.—Barytes occurs as a replacement deposit in the Betamcherla reserved forest, immediately east of hill station 1,403 feet, one mile south-west of Gattimanikonda. There is no large amount present. There is another exposure in the adjacent valley.

No. 118.—Barytes occurs as a replacement deposit in Vaimpalli limestones, 1⅝ miles south-west of Gattimanikonda in the Betamcherla reserved forest. This deposit and the succeeding one are probably related to a N.–S. fault which strikes between them. The quality of the barytes is not very good.

No. 119.—A number of pits have been dug to expose replacement veins of barytes in Vaimpalli limestones 1¾ miles south-west (a little south) of Gattimanikonda. The deposit is 1¼ miles due west of the *Lambadi* huts marked on sheet 57 I/2, south of Gattimanikonda. The general trend of the veins of barytes, as shown by the pits, is a little south of east. The Vaimpallis here have a gentle dip to the south-east or E. S. E. Further to the north and west, they are capped by sandstones, probably Banganapalli in age. There also seem to be some Pulivendla quartzites of the western side of the fault mentioned above.

No. 120.—Another replacement deposit of barytes occurs 2⅜ miles south-west (a little south) of Gattimanikonda, or 1¾ miles due west of the deserted village of Chinnamandlakonda. Pits have been dug here on either side of the valley. Little barytes has been excavated, nor is it thought that the possibilities of the deposit are good. It is quite possible, however, that the deposit may be proved to extend towards the previous one under the capping of Banganapalli sandstones which cover the Vaimpallis in this neighbourhood.

[1] The topography of the one-inch sheet 57 I/2 in this region is not up to the usual high standard.

52. *Boyanapalle* (*57 I/2*; *15° 32′ 30″ : 78° 8′*).

Boyanapalle is a small village situated about six miles north-west of Bugganipalle railway station as the crow flies, but a few miles more than that by road. It is just within the Dhone taluk, being half a mile from the boundary with the adjoining Kurnool taluk. Boyanapalle lies to the north of the Gattimanikonda fault, whereas Gattimanikonda is to its south. Boyanapalle is situated in the acute angle between this E.–W. pre-Kurnool fault and the N. E.–S. W. post-Kurnool Somayajulapalle fault, which accompanied the formation of the Kalava wall.[1]

Geology of the area.

East of the village, there is a large spread of Pulivendla quartzites dipping E. N. E. at a gentle angle. These overlie Vaimpallis and are in turn overlain by Tadpatri shales which culminate in the peak 1,657 feet. It is probable that the post-Kurnool Somayajulapalle fault curves around the Pulivendla outcrop between the hill and the village. Its exact position could not be located. The country near the village consists of Vaimpallis which are overlain by Banganapallis. These Banganapallis are at a much lower elevation than the Pullivendlas to the east, which are not covered by Kurnool rocks. Thus it seems probable that there is a fault which has lowered the country to the west.

Further north-east, as, *e.g.*, west of hill station 1,460 feet, the Jammalamadugu limestones can be seen overlying the Banganapallis.[2]

No. 121.—Three furlongs E. S. E. of Boyanapalle, barytes was noted in Vaimpalli limestones in a cultivated field. The occurrence apparently has not been noticed by the local villagers as no pits had been dug. Its possibilities, however, do not appear to be promising.

No. 122.—There are a few veins of barytes in Vaimpalli limestones in a disturbed region five furlongs south-east of Boyanapalle. The small hill to the west of the occurrence is capped by Pulivendla quartzites which dip south. This

[1] *See* A. L. Coulson, *Rec. Geol. Surv. Ind.*, LXVI, p. 447, (1933).

[2] It is interesting to compare the elevations above sea-level at which the Banganapallis are found on one-inch sheet 57 I/2, *e.g.* :—

	feet.
Virayapalle	1,500
Boyanapalle	1,350
Dara Kanama	1,600
Gattimanikonda	1,500
Sukkala Moru	1,700

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southerly dip cannot be acquired from the drag of the Gattimanikonda fault, the throw of which is to the north. Basaltic rocks crop out between these Pulivendlas and the Vaimpallis in which the barytes occurs. The occurrence does not appear to have any possibilities, and no pits have been dug.

53. Veldurti (57 E/14 ; 15° 33′ : 77° 56′).

Veldurti is a large village with a station situated at mile 12 from Dronachellam on H. E. H. the Nizam's Guaranteed State Railway from Dronachellam to Secunderabad. The village itself is situated on crystallines and from the train, a fine view of the scarps of the eastward-dipping Gulcherus may be seen. The Gulcherus appear to be capped by Banganapallis. It must be remembered that there has been a very large dislocation of strata east of Veldurti, caused by the Ramallakota-Gani fault[1].

Geology of the area.

No. 123.—The Collector's list states that block No. 865, comprising 77 acres 56 cts., of Veldurti was granted under a prospecting license for barytes to M. R. Ry. V. V. Subbiah Pantulu of Vuyyuru. This occurrence of barytes was not visited by the author, but he believes that it exists. The block is stated to be 2½ miles to the north-east of Veldurti village.

J.—Kurnool Taluk.

The barytes deposits in the Kurnool taluk of the Kurnool district have no great importance. None has been recorded previously and therefore this description has more interest than otherwise, inasmuch as it traces the existence of barytes in the Kurnool district almost as far north as the Tungabhadra river, which divides it from the Nizam's Dominions (Hyderabad).

Subdivision for descriptive purposes.

For descriptive purposes, the barytes occurrences have been subdivided as under :—

54. Uyyalavada (57 I/2 ; 15° 37′ 30″ : 78° 5′).

55. Gadidemadugu (57 I/ ; 15° 46′ 30″ : 78° 9′).

The deposits near Gani (Nos. 130 and 131, p. 86) in the Nandyal taluk of the Kurnool district may be considered as somewhat intermediate in position between those at Gattimanikonda and those at Uyyalavada, lying *en echelon* to the east. Between Gattimanikonda and Uyyalavada, also, there is that very important structural feature, described in detail elsewhere,[1] known as the Kalava wall.

[1] A. L. Coulson, *Rec. Geol. Surv. Ind.*, LXVI, p. 442, (1933).

[2] *See* W. King, *op cit.*, pp. 65-66 ; also A. L. Coulson, *Rec. Geol. Surv. Ind.*, LXVI, pp. 438-448, (1933).

The Kalava wall is an example of post-Kurnool monoclinal folding, accompanied by faulting, probably along the line of an older, pre-Kurnool, 'doubly-hinged' fault,[1] which has been termed the Ramallakota-Gani fault. The two main faults which accompanied the formation in post-Kurnool times of the Kalava wall have been termed the Gunnygull[2] fault and the Somayajulapalle fault.[3]

54. Uyyalavada (57 I/2 ; 15° 37′ 30″ : 78° 5′).

Uyyalavada is 13 miles by third-class road from Veldurti station. It is, however, only 7½ miles by bullock-cart tracks from Ulinakonda station. These stations are at miles 12 and 20 from Dronachellam (Dhone) on the metre-gauge line from there to Secunderabad. Uyyalavada is just within the Kurnool taluk.

The older Cuddapah rocks in the neighbourhood of Uyyalavada are almost entirely masked by the covering of younger Kurnool rocks comprising Banganapallis, Jammalamadugus and Paniams. The hill to the immediate west of the village is capped by Paniams which conformably overlie Jammalamadugu limestones and Banganapalli sandstones, grits and breccias.

Geology of the area.

Further to the north-west and north, in the vicinities of Yaparlapadu,[4] Bodduvanipalle,[5] Tadankapalle (57 I/2 ; 15° 43′ : 78° 2′) Vamasamudram (57 I/2 ; 15° 43′ 30″ : 78° 2′), etc., a 'sweep' of Gulcherus, Vaimpallis and trap sills is exposed, the rocks being uncovered as far north as Kurnool and the Tungabhadra river. This sweep of country has been described in detail in the author's asbestos report.

[1] The downthrow of its western end is to the north ; that of its eastern end is to the south.

[2] Modern spelling, Ganni Ghattu. Its downthrow is to the north. King's name for this fault has been retained. He did not recognize the Ramallakota-Gani and Somayajulapallo faults, nor do his sections or Foote's notes, as quoted by him, give a true idea of the nature of the wall.

[3] Downthrow to the north.

[4] The author heard of the probable existence of barytes near the village of Yaparlapadu (57 I/2 ; 15° 39′ : 78° 0′) but was unsuccessful in locating it. It is thought, however, that barytes does occur in this locality. The Vaimpallis east of the village are normal grey siliceous limestones. The higher ground to the south-east, north, and the high hill to the west (on sheet 57 E/14) are covered with Banganapallis. King's mapping of this area is incorrect for he shows Pulivendlas and trap. The former do not crop out and the latter is masked except for a small outcrop near Bodduvanipalle.

[5] There is an interesting fault south of Bodduvanipalle (57 I/2 ; 15° 39′ 30″ : 78° 2′) along the course of the Saddara *vagu*. Abundant breccias, dipping at 45° to the E. S. E., appear to have been developed *in situ* by movements in the chalcedonic Vaimpalli limestones, which are overlain unconformably by approximately horizontal Banganapallis.

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No. 124.—A few fragments of barytes were noted in a cultivated field 1⅛ miles north-west of Uyyalavada. From the surface debris, it appears that the deposit is of no great size and is of the nature of a replacement deposit in Vaimpalli limestones.

The author was shown another field, seven furlongs N. N. W. of the village, where barytes was said to occur. He was unsuccessful in finding any, but noted a thin vein of calcite in purplish shales which possibly had been mistaken for barytes.

No. 125.—Barytes fragments were noted in another cultivated field 1⅜ miles north of Uyyalavada.[1] This again appears to be a small replacement deposit of no great value.

55. Gadidemadugu (57 I/1 ; 15° 46′ 30″ : 78° 9′).

Gadidemadugu[2] is an important village 8½[3] miles from Kurnool on the third-class road to Nandikotkur. It possesses a two-roomed bungalow and post office, and gives its name to a reserved forest which lies to the north-west and north of the village.

Geology of the area.

The village of Gadidemadugu is built on Jammalamadugu flags and limestones, conformably underlain by Banganapalli sandstones and breccias, which, in their turn, unconformably overlie chalcedonic and siliceous Vaimpalli limestones. The breccias at times are extremely coarse and appear to be fragments of Vaimpalli limestones and the chalcedonic bands, which characteristically are associated with them, resorted *in situ*. King holds that these breccias are Pulivendla in age. He remarks[4] that the fragments in the breccias are of

> ‘ various pale-coloured jaspers and cherts, with others of a peculiar white or buff silicious chert, which is made up of countless minute spheroids, giving quite an oolitic structure to weathered fragments. These contained fragments of oolitoid silicious chert are common to the lowest breccias and conglomerates of nearly the whole extent of the western outcrop of the Poolavaindla (Naggery) quartzites. They are evidently derived from beds of such rock in the subjacent group. In the Gardymuddoo hills, east of Kurnool, the quartzites are full of fragments.’

[1] There is an interesting post-Kurnool fault along the southern margin of the Loddipalle reserved forest, a short distance to the north-west of this occurrence. Paniams here are faulted against Banganapallis, the intermediate Jammalamadugus not being exposed. North-west of hill station 1,476 feet, however, the Jammalamadugus are seen to be in their normal position underlying the Paniams.

[2] Literally, donkeys’ drinking pool. It is interesting to note that ‘ Kurnool ’ is a corruption of two words which meant ‘ oiling place ’, the site of Kurnool town being in olden days the resting place at which bullock-carts, carrying stones for the building of a nearby fort, stopped for oiling of their axles.

[3] The mileposts on the road are different from those shown on the latest (1923) one-inch sheet 57 I/1.

[4] *Op cit.*, p. 170.

He adds (p. 171) that

> ‘ of these same chert bands, the slopes of the hills being covered with a very hard angular debris of the same rock.’

These statements are in direct disagreement with Foote’s notes, quoted by King, ‘ with which in great part ’ he was ‘ inclined to agree ’. (*op cit.*, p. 90) :—

> ‘ To the north-north-westward of the Oondootla (Undutla, 57 I/6) plateau, no rocks belonging to the diamond-bearing series of the KARNULS occur till we reach the west side of the Gardymuddagoo (Gadidemadugu, 57 I/1) valley, where similar pebbly quartzite beds are met with near Bapulcotoor (Brahmanakotukuru) cropping out from under the *Jammulmudgoo* (Jammalamadugu) limestones and rising westward till they form the top of a low ridge of hills running along the right bank of the Toongabudra (Tungabhadra). On the west side of these hills conglomerates of the series are underlaid by a set of highly altered silicious breccias and calcareous rocks, but their exact boundary has not been fully determined. The pebble beds appear to continue north-westward into the hilly ridge south of Sultanpoor (Sultanpur in Hyderabad). On the south side of this ridge, the silicious breccias and associated limestones and a large sheet of intrusive trap are seen to crop out from under pebbly quartzite beds which apparently form the base of the *Banayanpilly* (Banganapalli) group. These pebble beds are remarkable for containing numerous small pebbles of pink and reddish felspar undistinguishable from much of the felspar occurring in vein-granite of the adjoining granitic or rather syenitic region. The other pebbles consist of quartzite, grey chert and red and brown jasper with occasional pebbles of quartz. Along the top of the ridge south of Sultanpoor, these pebble beds are well seen dipping east at a low angle with two or three intercalated beds of greenish grey and pale pinkish quartzite.’

The author agrees with Foote and contends that these breccias are Banganapalli in age. They can be traced southwards into diamondiferous grits and sandstones in which pits have been sunk for diamonds. It is considered to be extremely unreasonable, unnecessary and incorrect to suppose, as King has done (p. 169) that the Pulivendlas, after being apparently quite conformable ‘ for miles and miles of their outcrop’ should suddenly lie ‘ on the acutely bevelled edges of the lower beds ’. These breccias are of very variable thickness and extent and are considered by the author to be a shore deposit of the ancient Banganapalli sea, the irregular nature of the floor of which has already been noted.[1]

[1] It is interesting to note that at the present day, the weathering of the Vaimpalli limestones with their siliceous and chalcedonic bands gives rise to extremely coarse debris. On the gently sloping hills north-west of Gadidemadugu, this layer is about six inches thick, but most of the larger fragments have been removed by hand to allow the cultivation of the land. Another cause contributing to the abundance of these coarse fragment is the existence of large numbers of fault-or crush-breccias in the chalcedonic Vaimpallis. It frequently happens that these fragments on the surface have been recemented in a siliceous matric, and it is at times rather difficult to state whether the resultant breccia is recent or Banganapalli in age.

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In all the exposures visited by the author in his journey along the strike of the Cuddapahs from Cuddapah to Kurnool, he saw nothing in disagreement with his previously expressed view that the Pulivendlas are to all intents and purposes more or less completely conformable with the Vaimpallis. If any unconformity exists between the Papaghnis and the Cheyairs, then the author is convinced it is of no great magnitude.

The erosion of the covering of Banganapalli sandstones, breccias grits, etc. in the Gadidemadugu hills has exposed the underlying Vaimpallis in which barytes has been noted. The Vaimpallis are very much faulted, the trend of the faults varying greatly. Some miles to the west of Gadidemadugu, there is a large E.-W. fault, the Siddireddipalle fault, the existence of which seems to be necessary in order to explain the dislocations of strata which appear to have taken place in this region. Abundant fault-breccias occur to the south of mile 6 on the Kurnool-Nandikotkur road, trending W. N. W.-E. S. E. About seven furlongs north-west of Gadidemadugu, there is an important N. E.-S. W. fault. Whilst in the Gadidemadugu reserved forest, the general trend of one fault is the same, but that of another is N. W.-S. E.

No. 126.—About seven furlongs north-west of Gadidemadugu, barytes (N 599) occurs along a line of brecciation in Vaimpalli limestones which have been exposed by the removal by weathering of the covering of Banganapalli breccias. A fair number of pits have been dug here, but no large quantity of barytes has been removed, nor is it thought that much is available. This occurrence is not in the forest area.[1]

No. 127.—Thin veins of barytes were noted one mile W. N. W. of Gadidemadugu along the same line of fracture as the previous deposit. There does not appear to be any great amount present and the matric is so siliceous that extraction would be difficult. This site is interesting inasmuch as there is a very good example of the formation *in situ* of a crush-breccia in the Vaimpallis.

No. 128.—Barytes occurs in very crushed and silicified chalcedonic Vaimpalli, limestones along a fault running N. E.-S. W. to the north-east of hill station 1,055 feet, $1\frac{3}{4}$ miles N. N. W. of Gadidemadugu and in the reserved forest. A few shallow pits have been dug but since filled in. The amount of barytes present is probably small. The locality is to the north-west of the ridge. A small trap exposure was noted on the south-eastern side of the hills.

No. 129.—Another small deposit of barytes was noted in a very crushed and silicified area, $2\frac{1}{4}$ miles N. N. W. of Gadidemadugu, likewise along a fault

[1] The Collector's list does not note the granting of prospecting licenses for baryets for any plots of Gadidemadugu village, though blocks in the reserved forest have been granted. Thus M. R. Ry. S. Jayaram Reddy of Betamcherla has been granted a block of 20 acres and M. R. Ry. S. P. Ranga Rao of Kurnool a block of 79 acres 33 cts. in the Gadidemadugu reserved forest.

coarse which runs, however, N. W.—S. E. The fault-rock forms the backbone of the ridge which runs to meet the Kurnool-Cuddapah canal near mile 26·5.

K.—Nandyal Taluk.

The barytes deposits in the Nandyal taluk of the Kurnool district are unimportant, but the occurrence at Basavapuram has been known for a very long time. They have been sub-divided as under :—

56. Gani (57 I/6 ; 15° 40′ : 78° 19′).
57. Basavapuram (57 I/11 ; 15° 24′ 30″ : 78° 38′).

Collector's list.

The Collector's list shows that a prospecting license for barytes for 200 acres of the Nandyal reserved forest was granted to Khan Sahib K. Abdul Hye of Bellary, but the author has been unsuccessful in locating this block. It is unknown whether or not the Khan Sahib found barytes in this forest.

56. Gani (57 I/6 ; 15° 50′ ; 78° 19′).

Gani is an important old village in the north-western corner of the Nandyal taluk, near its trijunction with Kurnool and Nandikotkur taluks, all of which are in the Kurnool district. As the crow flies, it is 11 miles north of Paniam, and 17 miles north-west of Nandyal railway stations respectively on the Guntakal-Bezwada metre-gauge line of the Madras and Southern Mahratta Railway.

Geology of the area.

Gani itself is on horizontal Khondair limestones and shales, but the village is situated just over one mile north of that very interesting structure, the Kalava wall of Paniam quartzites. The structure of this region may be seen in Plate No. 26 accompanying the author's paper on the Kalava wall.[1]

There is a small outcrop of Vaimpalli limestones south-east of Gani, which is faulted against Paniam quartzites to the north and against Tadpatri shales of the Cheyair series to the south. The latter fault is the easternmost part of the pre-Kurnool Ramallakota-Gani fault. The downthrow of which is to the south. The Vaimpallis here have rolling dips, generally however to the south. They are overlain conformably by the Pulivendlas at hill station 1,148 feet, where these latter dip westwards under Tadpatris, and south of Chennakkapalle, where both Pulivendlas and Vaimpallis are covered

[1] *Rec. Geol. Surv. Ind.*, LXVI, pp. 438-448, (1933).

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by Banganapalli sandstones and grits in which pits have been sunk for diamonds.[1]

There are frequent traps in the Vaimpallis, all with an E. N. E.-W. S. W. to E.-W. trend. It is possible that the intrusion of the traps accompanied the faulting.

It is interesting to note the occurrence in the Tadpatris of quartz-reefs, certain of which contain copper-ores.[2]

No. 130.—At the junction of the Vaimpallis and Pulivendlas, but, strangely enough, chiefly in the Pulivendlas and not in the Vaimpallis, reddish grey barytes (N 597) was noted in thin veins at hill station 1,148 feet, 1¼ miles S. S. E. of Gani. A few pits have been dug, but the barytes has been used only locally for 'washing' door-steps. The amount present is possibly small.

No. 131.—There are a few thin stringers of barytes in the Vaimpallis near the road from Gani to Paibagala, 1⅜ miles south-east of Gani.

57. Basavapuram (57 I/11; 15° 24′ 30″: 78° 38′).

Basavapuram is a small hamlet of, and is situated one mile E. N. E. of, the larger village of Gazulapalle, which is near the boundary of Nandyal taluk with Sirvel taluk. Confusion is likely to arise inasmuch as both villages give their names to railway stations, which are situated at miles 333·5 and 339·5 respectively on the Guntakal-Bezwada metre-gauge line of the Madras and Southern Mahratta Railway. The villages are on the plains west of the Nallamalai hills.

No. 132.—King noted the occurrence of barytes as a gangue for galena in veins in what were known as the Gaxulapalle or Basavapuram mines which are [3]

[1] These pits are five furlongs S. by E. of Chennakkapalle. They were not mentioned by King in his list of diamond localities (*op cit.*, p. 106). It may be added here that the 'Gooramanconda' in King's list is the village Gattimanikonda in the Dhone taluk, mentioned previously (p. 76).

[2] See King, *op cit.*, pp. 268-269. King noted two in the deep bay in the hills east of 'Somadulpilly (Somayajulapalle)'. The author found that the southern of these is just over two miles S. S. E. of Kalava. It strikes at 250°, has uncertain dip, and is from six to eight feet thick. It contains a little chalcopyrite and pyrite. The other reef is less than two miles from Kalava and strikes more north to north-west. No trace of chalcopyrite was noted in this reef.

Secondary malachite was noted by the author in thin quartz veins in trap, 1¼ miles south-east of Kalava.

The author did not visit the old workings visited by Foote in the 'Gooman Conda' (Gummani Konda) valley. These appear to be about 2¾ miles south-west of Gani (about half a mile west of Peddagummani Konda). He did note, however, that old pits for copper ores had been dug along the course of a quartz-reef striking W. N. W.–E. S. E., intricately mixed up with trap 1⅝ miles S. S. E. of Gani. Secondary malachite and azurite (N 598) with a little primary chalcopyrite were seen in the quartz.

All these occurrences have scientific interest only [*see Rec. Geol. Surv. Ind.*, LXVII, (*in the press*)].

[3] King, *op cit.*, p. 273.

'in the wide valley, on the western flanks of the Nallamullays, where crossed by the Nundycunnama (Nandikanama, 57 I/11) pass, at about two miles north of the fifth mile on the high road from Buswapoor (Basavapuram) or Gazulpully (Gazulapalle) which villages are on the edge of the Khond-air (Kunderu) valley'.

The exact position of these mines cannot be made out from King's description inasmuch as the Gazulapalle-Giddalur road has since been rebuilt and the mile-stones changed. His field maps indicate them to be within the Nallamalais, some two miles north of Chelima railway station, which is at mile 345 on the Guntakal-Bezwada line. It was not posible for the author to visit and check this locality.

This is unfortunate as Newbold states [1] the mines are 'about six miles east of Gazoopilly' (Gazulapalle). The locality two miles north of Chelima is some 7½ miles north-east of Gazulapalle.

It appears from King's maps that the veins are in the Cumbum slates, which form the upper stage of the Nallamalai series of the Cuddapahs. These Cumbum slates with which the barytes is associated are far younger than the Vaimpalli shales and limestones which form the upper stage of the Papaghni series of the same system and in which and the traps associated with them practically all the previously described deposits of barytes occur. Between them there are the Cheyair series and, also, the Bairenkonda sandstone which forms the lower member of the Nallamalais.[2]

L.—Sirvel Taluk.

The deposits of bartytes in the Sirvel taluk of the Kurnool district have been classed under the following head:—

58. Tallalingamdinne (57 I/12; 15° 11′ 30″: 78° 36′).

In addition to information concerning the above, the list forwarded to the author by the Collector of the Kurnool district states that prospecting licenses for barytes have been granted as under to:—

Collector's list.

1. Khan Sahib K. Abdul Hye of Bellary, for 54 acres in the Rudravaram reserved forest.
2. M. R. Ry. B. P. Sesha Reddy Guru of Betamcherla for 50 acres in the Sirvel reserved forest.

[1] *Journ. As. Soc. Beng.*, XV, pp. 389-390, (1846). *See* also *Mad. Journ. Lit. Sci.*, XIII, Pt. 1, pp. 218-219, (1845).

[2] Recently Mr. T. P. Shiva Ram of Gazulapalle forwarded to the Geological Survey of India specimens of galena, embedded in dolomite and associated with barytes, said to have been taken from a depth of between two and three feet 'in a block near Pacherla in the Nallamalais'. Pacherla (57 I/11; 15° 24′: 78° 43′) is a hamlet just within the Sirvel taluk, situated on the Gazulapalle-Giddalur road which forms the boundary between Sirvel and Nandyal taluks. It is highly probable that the samples forwarded by Mr. Shiva Ram were obtained from the old Basavapuram (Chelima) mines just described.

It is also interesting to note that as long ago as 1917, the late Mr. A. Ghose of Gooty held a prospecting license for barytes for a block of 97 acres in the Gazulapalle reserved forest. The author has been unsuccessful in tracing the position of this block.

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3. M. R. Ry. B. P. Sesha Reddy Guru of Betamcherla for 20 acres in the Sirvel reserved forest, near the village of Thuvvapalle.

The author has been unable to ascertain the positions of these blocks. Rudravaram (57 I/12; 15° 14′ 30″: 78° 36′ 30″) is a large village situated near the northern boundary of sheet 57 I/12. The 'Rudravaram reserved forest' referred to is probably the 'Sirvel reserved forest, Extension 2', which lies to the east of Rudravaram. The Sirvel reserved forest is very large, and so it is impossible to locate item No. 2 without further information. The same is true of item No. 3, as enquiry and diligent search of the one-inch maps has failed to locate the village of Thuvvapalle.

58. Tallalingamdinne (57 I/12; 15° 11′ 30″: 78° 36′).

Tallalingamdinne is a small village, three miles south of the larger village of Rudravaram. It is badly situated as regards transport, as it is 16 miles almost due south of Gazulapalle railway station at mile 333·5 on the Guntakal-Bezwada metre-gauge line of the Madras and Southern Mahratta Railway.

King's field map shows the village of 'Lingumdinny' to be on Jammalamadugu linestones on the plains west of the Nallamalai hills, the western members of which are composed of Bairenkonda quartzite and Cumbum slates, the constituent stages of the Nallamalai series of the Cuddapah system.

Geology of the area.

No. 133.—The Collector's list states that M. R. Ry. B. P. Sesha Reddy Guru of Betamcherla was granted a prospecting license for barytes for survey No. 463 of Tallalingamdinne, which block comprises 30 acres. Enquiry elicited the information that this block is '2½ miles south-east of Rudravaram', *i.e.*, about the same distance north-east of Tallalingamdinne. This means that the barytes here is in the tract marked by King as being composed of Bairenkonda quartzites; but it is more than probable that it is a small occurrence in Cumbum slates, mixed up with these quartzites. No information is available as to the quality or quantity of the barytes.

M.—Cumbum Taluk.

No mention of barytes in the Cumbum taluk was made in the Collector's list. The occurrence of that mineral described hereunder were not visited by the author, who gained the information concerning them whilst at Kurnool and on his return to Calcutta.

The barytes occurrence in this taluk is classed as follows:—

59. Janapalacheruvu (57 M/3; 15° 28′ 30″: 79° 9′ 30″).

Janapalacheruvu is a small village about nine miles S. E. by S. of Cumbum, which town possesses a station at mile 388 on the Guntakal-Bezwada metre-gauge line.

King's original map shows the village of Janapalacheruvu (Junnapalcheroo) to be on Cumbum slates in which are limestone bands and quartz-reefs. The Velikonda hills to the east are composed chiefly of Bairenkonda quartzites. Both stages of the Nallamalais are thus present.

Geology of the area.

No. 134.—M. R. Ry. B. P. Sesha Reddy Guru, M.L.C., of Betamcherla, personally informed the author in Calcutta that on the 8th April, 1931, he was granted a mining lease for barytes for a block of 10 acres in the North Velikonda reserved forest between Janapalacheruvu and Malapuram villages.[1] This would make the block lie to the north-east of the former village.[2]

The mine is called the 'Apralethoka Barytes Mine'. The length of the vein is stated to be about one furlong and the thickness varies from three to six feet. Trial pits have been dug to a depth of 20 feet, indicating the vein to continue in depth below this. M. R. Ry. Sesha Reddy expects it to continue to about 40 feet. The stock of barytes at the minehead in early May, 1932, was 1,000 tons.

A sample of 'pure white barytes' submitted by Messrs. the South Indian Mining Co. (B. P. Sesha Reddy, Proprietor) to Messrs. Hughes and Davies of Bombay was analysed with the results given below in Column I. A sample of reddish barytes, termed 'off-coloured barytes', was analysed by the same firm with the results given in Column II.

	I. Per cent.	II. Per cent.
$BaSO_4$	99·25	96·30
SiO_2	0·45	2·82
Fe_2O_3	..	0·21
Al_2O_3	..	0·30
Loss on ignition	0·30	0·37
	100·00	100·00

I. White barytes, Apralethoka Barytes Mine, near Janapalacheruvu, Cumbum taluk, Kurnool district, Madras (analysts, Hughes and Davies).

[1] Prior to this, when in Kurnool, the author was shown by Khan Sahib J. Hussane Khan specimens of barytes from Janapalacheruvuagraharam, which was described as a hamlet of Pitikayagulla. This is obviously the same locality.

[2] The 'Velikonda North Extension reserved forest' does not actually lie between these villages, being to the east of both. Malapuram (15° 31′: 79° 10′) is on sheet 57 M/2; whereas Janapalacheruvu is on sheet 57 M/3. It appears that the barytes occurs in the latter sheet.

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II. Reddish barytes, same locality and analysts.

These analyses have been published with the kind permission of M. R. Ry. B. P. Sesha Reddy Guru.

Specimens similar to those analysed, kindly presented by M. R. Ry. Sesha Reddy, have been registered in the mineral collections of the Geological Survey of India as N 616 and 646 ; and N 646 respectively.

In a letter to the author dated the 9th April, 1933, M. R. Ry. B. S. Sanjeeva Reddy, son of the above gentleman, gave additional information concerning this deposit. He stated that ' the deposit is of the vein type, dipping almost vertically westwards, the dip and strike coinciding with the country-rock which is schist of the oldest type.—The present working has been carried down to a depth of 25 feet at the junction of two veins. More than 1,000 tons have been taken out from this mine. The deposit so far traced covers a length of about 250 feet, branching off into two veins from the middle. At present the mine is worked by an open excavation but with the continuance of the lode to a greater depth, the stoping method will have to be employed.—This is the only deposit from which we expect good quantities of barytes ; but unfortunately this variety is very hard and as most of the paint manufacturers are not equipped with up-to-date grinding plants, they do not prefer this in spite of its being sold at a much lower price than the soft variety.'

N.—Nandikotkur Taluk.

The following reported occurrence of barytes has been brought to the author's notice :—

60. Musalimadugu (57 1/5 ; 15° 58′ : 78° 26′).

Musalimadugu is an important village about 28 miles E. N. E. of Kurnool.

Geology of the area.

King's original quarter-inch sheet (Atlas of India No. 76) shows the village of 'Moosleemmuddoo' to be on or near the northern limit of Khondair shales and limestones. He has mapped a large expanse of debris to the north of the village, the debris separating the Nandial shales from Pulivendla quartzites, Cumbum slates and Bairenkonda quartzites, which extend on both sides of the Kistna river in this locality.

No. 135.—When he was at Kurnool, the author was informed by Khan Sahib J. Hussane Khan that barytes occurs near Musalimadugu in the Nandikotkur taluk. The author was unable to visit the locality, not did he see any specimens from it. He sees no reason, however, to disbelieve the truth of this statement.

CHAPTER V.

BARYTES IN OTHER PARTS OF INDIA.

Introduction.

In this chapter, a short summary has been given of such other occurrences in India of barytes, known to the author either from published accounts, from records in the office of the Geological Survey of India, or from the work of his colleagues in that service. It has been considered advisable to include this summary in the present memoir inasmuch as La Touche's admirable 'Bibliography'[1] is now, unfortunately, some 14 years behindhand in the recording of new occurrences. A ready market has greatly stimulated the search for barytes within recent years, especially within regions close to Calcutta.

Baluchistan.

Kalat and Las Bela States.

Mr. G. H. Tipper has recorded[2] the occurrence of barytes throughout Kalat and Las Bela States.

'in the Belemnite shales of Lower Cretaceous age. It has also been found in the middle Khirthar shales. The two chief localities are the lower scarps of the Pab range near Pabni chauki (35 K/15 ; 25° 17′ : 66° 58′) and the Sarmowli river between Chad and Anjira. Wherever found the mineral occurs as scattered concretions in association with nodules of pyrites. Of the two localities the Sarmowli river is too remote from any centre : while that near Pabni is very favourably situated, as it is only about two days' march from Karachi..... From the mode of occurrence of mineral it is impossible to estimate the quantity available, but considering the great outcrop of the Belemnite shales in the vicinity there must be a fair amount of the mineral scattered about.'

Mr. Tipper's description has been quoted in full as the method of occurrence of the barytes differs from the majority of Indian occurrences. It may be noted, however, that Du Toit has recorded the occurrence of 'some nodules of pyrite associated by barite' in the

[1] T. H. D. La Touche, 'A Bibliography of Indian Geology and Physical Geography, with an annoted index of minerals of economic value'. Pt. I B (Calcutta, 1918).
[2] *Rec. Geol. Surv. Ind.*, XXXVIII, p. 214, (1909).

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Aptian stage of the Cretaceous on the Changalane river, a tributary of the Tembe river, in Portuguese East Africa.[1]

A specimen of barytes (K 43) from Tanga (34 N) in the Shahrig *tahsil* of the Sibi district of Baluchistan was presented to the Geological Survey of India in 1906 by the Political Agent and District Commissioner, Sibi.[2]

Sibi district.

Bihar and Orissa.

A specimen of barytes (N 655), sent to the Geological Survey of India for identification, was stated to have been collected two miles east of Garpos railway station (73 B/8; 22° 7′: 84° 25′) in the northernmost part of Bamra State where it juts into Gangpur State. It possesses a specific gravity of 4·48.

Bamra State.

Dr. M. S. Krishnan informed the author personally that there is an occurrence of barytes (N 488) within Gangpur State, but barely 50 yards from the Singhbhum boundary, half a mile east of Khatangtola (73 F/3; 22° 22′: 85° 4′). Mr. W. S. Young of Kulunga, Gangpur State, has prospected the area. At the time of Dr. Krishnan's visit in April, 1931, the pit sunk by Mr. Young was only four feet deep, 12 feet long and about six feet wide. The barytes vein is about three feet thick and strikes N. W.-S. E. across the foliation of the mica-schists in which it occurs. The barytes (N 488) is of good quality, but about 50 per cent. of that excavated has to be rejected on account of iron-staining. It is also associated with quartz.

Gangpur State.

The occurrence is only one mile north-west of the outcrop of barytes at Kolpotka in the Singhbhum district, described later (p. 93).

A specimen of the Khatangtola barytes, submitted by Mr. Young to the Geological Survey of India, possesses a specific gravity of 4·3.

Another specimen, submitted by Messrs. John Podger and Co. of Kodarma was stated to have been taken from a hill 'near to Jaraikela railway station (73 F/3; 22° 19′: 85° 7′), on the B. N. Ry., very close to Bisra, about 239 miles, from Calcutta'. It is thought that the locality of this specimen is that of the Khatangtola occurrence.

[1] A. L. Du Toit, 'The Geology of South Africa', p. 315 (Edinburgh, 1926).
[2] Another specimen of barytes (J 759), said to have come from 'Akaphal, north of Sarun between Karachi and Quetta', was presented to the Indian Museum in 1903 by R. Hughes-Butler, Esq. This locality has not been traced.

A specimen of barytes, said to have been collected from Bramjan Hill,[1] near Gaya, was brought to the Geological Survey of India in December, 1923.

Gaya district.

A sample of barytes (submitted to the Geological Survey of India in 1930, and said to have come from near Purulia (73 I/7; 23° 20′: 86° 22′), Manbhum district, was of excellent quality. No particulars concerning the size or exact locality of the deposit are available. However, the author has been informed personally by Mr. V. K. Dave of the occurrence of barytes (N 674) on the Panchhot Raj Estate near the village of Malthole (73 I/7; 23° 26′: 86° 26′). The barytes is associated with a calcium aluminium silicate with rare earths.

Manbhum district.

In his paper on the mineral resources of Bihar and Orissa, Dr. L. L. Fermor states:—[2]

Ranchi district.

'In 1917 the discovery was reported of barytes found as a series of veins aligned roughly east and west through the villages of Silwai (73 E/7; 23° 22′ 30″: 85° 26′ 30″), Bahea (73 E/7; 23° 23′: 85° 29′ 30″), and Bongaibera (73 E/11; 23° 21′ 30″: 85° 31′), some 14 miles east of Ranchi. Mixed with the barytes is a certain proportion of galena, and perhaps on this account attempts that have been made to interest Calcutta firms in the exploitation of these deposits for purposes of paint manufacture have not been successful. The veins appear to lie on the belt of porphyritic granite extending from Ranchi to Purulia. Specimens of allanite also have been received from this locality, but the relationship of this mineral to the barytes is not known.'

Dr. M. S. Krishnan has noted[3] the occurrence of veins of barytes, formed by replacement, in two zones, of sericite-schist about half a mile south-west of Kolpotka (73 F/3; 22° 22′: 85° 6′) in Singhbhum close to the Gangpur border:—

Singhbhum district.

'In the southern band the barytes (M 966) occurs in ramifying veins over a tract 500 yards long and 150 yards wide. The veins conform more or less to the schistosity, the dip being from 70° to 75° in a direction S. 40° E. The barytes is being worked open-cast, and the picked white lumps obtained from about 5 to 7 per cent. of the material extracted. The amount extracted is about 2 to 2½ tons daily and is sent in cooly-loads to Jaraikela for despatch to Calcutta. The northern zone has also been tested, but proved to be too poor in barytes for profitable working.'

In 1929, when at Ghatsila (73 J/6; 22° 35′: 86° 29′) in Singhbhum, Dr. J. A. Dunn was shown specimens of barytes said to have been found in the vicinity. He could obtain no information as to

[1] Possibly the hill on which is Gaya Brahmjoni temple (72 D/13).
[2] *Rec. Geol. Surv. Ind.*, LIII, p. 253, (1921).
[3] *Op. cit.*, LXII, p. 31, (1928).

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the exact locality. In this connection, it is interesting to note that a specimen of barytes, with malachite (J 781), presented in 1904 to the Indian Museum by Mirza Mohammad Ali Khan of Tollygunge, Calcutta, was said to have been taken from a locality a quarter of a mile distant from Ghatsila railway station.

Burma.

When investigating the antimony deposits south-west of Thabyu (95 I/6; 15° 36′: 98° 29′), Dr. A. M. Heron collected a specimen of barytes (L 336) from a boulder in the bed of the Tele *chaung*. This boulder possibly was derived from one of the deposits mentioned by Mr. Billinghurst and described hereafter.

Amherst district.

In 1925, Mr. P. E. Billinghurst reported to the Geological Survey of India the discovery of large deposits of barytes, with galena and chalcopyrite, at various places in the Amherst district near the Siam frontier.

A hill called Azin *taung*,[1] 15 miles south of Mitan,[2] was said to be composed chiefly of barytes. On being requested to supply further particulars, Mr. Billinghurst kindly wrote:—

'Azin *taung* is a hill some 500 feet in height and is composed of wide bands of limestone and barite. It covers about 200 acres, but hillocks of barite extend easterly from the base of the hill to distances of a mile or more.

The hill on every side is covered by shallow old workings, several hundred being counted. Few of these are more than ten feet in depth, but some are considerable. The ore (galena and chalcopyrite) seems very irregularly distributed and is invariably in the barite. From present information, the ore would carry about 80 per cent. galena and 20 per cent. chalcopyrite. An overburden of a few feet of a reddish soil covers the slopes of the hill, but outcrops are numerous.

Azin *taung* is typical of a number of barite occurrences in the neighbourhood, but these are less mineralised.

Ootee *taung* [3] is divided by the Siam-Burma frontier and occurs at the extreme south-eastern corner of Amherst district. It apparently is a rich deposit of chalcopyrite in barite. It covers about 40 acres and rises 200 feet. The entire surface has been worked. The country rock is massive greyish limestone.

Yetheywa, Tichine, Tilloun, etc.[1] These areas occur in the lower south centre of the district (Amherst). These are lodes running chiefly through hard, white, grey, or pinkish limestone, but sometimes through slate. They vary from narrow veins to lodes over 20 feet wide and appear to run for over ten miles, but are probably not continuous. The strike is north and south. They are represented mostly by heavily mineralised gossans, with frequent bosses of barren barite. The ores are chiefly chalcopyrite and galena, but practically no work has been done. A few old workings exist.

The Tichine *chaung* runs for a mile across the barite lodes, and the lodes are represented at this place by boulders of barite and oxides of iron. There seem to be about 20 lodes of various widths in this mile-wide belt.

Yetheywa is near the site of a deserted village on the Kilakoon river, a tributary of the Kyun river (? 95 I/6). The lodes cover an area of roughly a mile, culminating at the crest of the hill in a huge mass of discoloured barite. The dip at this place is about 35° westward. The occurrence is probably a southern continuation of Tichine.

Other barite occurrences are continuously being reported in this Kyain township of Amherst district. If the barite is of any economic importance, the only large area which can be worked without railways is Azin *taung*. This is only four miles from the Haungtharaw river, navigable for rafts and three-ton boats for five months of the year. At other times, it would have to be carted further up the river to deeper water. A practical estimate for actual working costs would be Rs. 25 F. O. B. Moulmein.'

When mapping the Ye-Yaman tract of the Kyaukse district in the field season 1923-24, Mr. C. T. Barber noted the occurrence of malachite and azurite with barytes (M 466) in Sindetaung shales, two miles south of the village of Yetha (93 C/6; 96° 20′: 21° 35′).[2]

Kyaukse district.

When investigating some argentiferous galena, the late Sir Henry Hayden noted the occurrence of a bed of barytes six to seven feet thick, 'apparently interstratified with the rocks of the country', at Taunggaung[3] in the Mandalay district of Upper Burma.

Mandalay district.

(*a*) *North Hsenwi State.* In December, 1928, Mr. G. V. Hobson noted a barytes vein (N 173), carrying specular iron-ore, in Plateau Limestone which rests on Chaung Magyi beds, just south of hill station Loi Kyaktaw, 6,199

Northern Shan States.

[1] This is probably the Azin shown on sheet 95 I/9 (15° 52′: 98° 31′), which is four miles south-east of Mikwi (95 I/5).

[2] Mitan is a Karen village of 100 houses contiguous with Kyaikdon (94 L/8; 16° 0′: 98° 24′). Reference may be made to Dr. Heron's paper [*Rec. Geol. Surv. Ind.*, LIII, p. 36, and Pl. 1, (1921)].

[3] Not shown on sheet 95 I or the one-inch sheets.

[1] Not shown on the one-inch sheets. Tichine is probably near Kyauktaga Taung on sheet 95 I/6.

[2] Unpublished progress report, 1923-24.

[3] Mss. notes, January, 1896. *See Rec. Geol. Surv. Ind.*, XLVI, p. 237, (1915). Taunggaung is probably that shown on sheet 93 B/8 (22° 8′: 96° 22′). A specimen of barytes in the Indian Museum (I 934) was collected by Sir Henry Hayden from this locality.

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feet (93 E/7 ; 23° 18′ : 97° 22′), in the North Hsenwi State of the Northern Shan States. It seems to have a continuation to the north-east, but in this direction, according to Mr. Hobson[1] the hæmatite occurs in quartz. Barytes veins were also noted on the path about 1½ miles due east of Loi Kyaktaw. Mr. Hobson has registered a specimen of barytes (N 180) from north of Kawng Loi-pek, 4,728 feet (97 E/11 ; 23° 27′ : 97° 35′), also in the North Hsenwi State.

(*b*) *Tawng-peng State.* Mr. La Touche has described[2] occurrences of bartyes (K 200) at Bawdwin (93 E/8) in Tawng-peng State :—

'Beds of massive barytes are also of common occurrence, but they were not found in direct association with the galena. In one spot the barytes occurs in considerable quantity, in fragments up to a foot in diameter, scattered over the surface of a knoll over an area of two or three hundred square yards, and evidently derived from the outcrop of a large mass.'

Dr. J. Coggin Brown[3] adds :—

'It (barytes) has not been found as crystals, but occurs massive in coarsely grained aggregates, which are often full of small cavities. The broken surfaces of some of these masses show a platey structure with curved surfaces and a vitreous lustre.

Owing to the presence of cavities the results of determination of the specific gravity are liable to be slightly low. One specimen from the Amphitheatre gave a specific gravity of 4·4.'

In 1917, when asked kindly to furnish information regarding the quantity of barytes at Bawdwin, the Burma Corporation, Ltd., stated :—

'Sufficient work has been done to determine that there are at least four roughly parallel veins, varying in width from 12 to 36 inches ; all these veins apparently pinch and swell rapidly, but two at least appear to maintain a width of between 24 to 36 inches. In addition, there is generally a variable width along the sides of the veins carrying stringers of barite.'

It was estimated that probably 20,000 tons of barytes (L 733 ; L 849) could be recovered, but most of the deposit will be required by the Corporation.[4]

[1] Diary for December, 1928.
[2] *Rec. Geol. Surv. Ind.*, XXXVII, p. 242, (1908-09).
[3] *Ibid.*, p. 255. Also *see* J. C. Brown, *ibid.*, LXVIII, pp. 168-169, (1918).
[4] The barytes is used as a furnace lining by the Burma Corporation Ltd. *See* A. M. Heron, *Rec. Geol. Surv. Ind.*, LXIV, p. 326, (1930), and page 126 of this memoir.

The following analysis of a representative sample was given :—

	Per cent.
$BaSO_4$	91·36
$CaSO_4$	2·57
$MgSO_4$	1·14
SiO_2	0·97
Fe_2O_3, Al_2O_3	1·76
Pb	*trace*
Mn	*trace*
H_2O + volatile matter	1·30
TOTAL	99·10

Southern Shan States.

Mr. V. P. Sondhi states[1] that barytes is of common occurrence in the neighbourhood of Mawsön (93 D/13 ; 20° 57′ : 96° 50′) in the Yawnghwe State of the Southern Shan States. It is frequently associated with quartz and calcite and found in well-developed veins. An outcrop of barytes was found by Mr. Sondhi east of Konlean (93 D/9 ; 20° 48′ : 96° 39′), about five miles W. N. W. of Taunggyi.

Central India Agency.

Indore State.

Barytes is said to occur at Rheti, in the Nemawar district of Indore State.[2]

Orchcha State.

According to Mr. M. K. Ray barytes (M 949) occurs by the side of a hill called Chakrada, west of Surajpura village (54 P/2 ; 24° 43′ 30″ : 79° 10′ 30″), two miles S. S. E. of Deorda and 40 miles from Man Ranipur on the Great Indian Peninsula Railway.[3]

It is associated with about equal proportions of quartz in a vein striking N. W.–S. E. for about a quarter of a mile in Bundelkhand Gneiss, and is also found in the country rock. A little chalcopyrite is associated with the barytes. A thickness of about eight feet had been proved without reaching the walls at the time of Mr. Ray's visit. The barytes (M 949) has a specific gravity of 4·395.

The estimated cost of transport to Man Ranipur was between Rs. 10 and Rs. 15 per ton.

[1] *Rec. Geol. Surv. Ind.*, LXVI, p. 39, (1932).
[2] This may be the village Rehti (55 B/14 ; 22° 39′ : 76° 51′).
[3] *See* A. L. Coulson, *Rec. Geol. Surv. Ind.*, LX, pp. 431-432, (1928).

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In his own published description of the deposit,[1] Mr. Ray mentions the occurrence of six 'gossan' veins by the neighbouring village of Nygaon and states that

'it seems probable that all these pyritic veins, including the barytes vein, were deposited from solutions emanating from the same igneous magma.'

Rewah State.

Vredenburg[2] found veins of barytes from an inch to over a foot in thickness in the Red Shale series of pre-Vindhyan age near the village of Bharra (63 L/7; 24° 23′; 82° 15′) on the Mohan river in Rewah State.

Mallet[3] mentions the occurrence of stringers of barytes in the Lower Rewahs near Sohagi Ghat (63 H/9; 24° 59′: 81° 42′) and at Ginga Hill, about 40 miles south-west of Allahabad, but the deposits have no commercial value.

Central Provinces and Berar.

Jubbulpore district.

Ball[4] states that barytes occurs in association with traces of copper-ore found on Bijawar quartzite at Sleemanabad (64 A/6; 23° 38′: 80° 15′) in the Sihora taluk of the Jubbulpore district.

At Sleemanabad, also, Dr. L. L. Fermor[5] has noted the presence of barytes as an accessory mineral

'in a series of parallel metalliferous veins striking in a north-north-west direction through dolomitic limestones of Archaean age.'

About 16 tons of barytes from this locality were despatched to Calcutta about the year 1904 for use in the works of the Shalimar Paint, Colour and Varnish Co., Ltd., but the quality was found to be poor and a nominal value of Rs. 7 per ton was assigned to the barytes.[6]

A specimen of barytes with lead and copper (J 653), presented in 1904 to the Indian Museum by P. C. Dutt, Esq., of Jubbulpore, was said to have been taken from Imalia (64 A/6; 23° 36′; 80° 16′), near Sleemanabad.

Another specimen of barytes (J 777), presented in 1904 to the Indian Museum by G. Gianacopolo, Esq., was said to have been found

[1] *Quart. Journ. Geol. Min. Met. Soc. Ind.*, I, p. 130, (1928).
[2] *Mem. Geol. Surv. Ind.*, XXXI, p. 131, (1901).
[3] *Mem. Geol. Surv. Ind.*, VII, Pt. 1, p. 122, (1871).
[4] 'Geology of India, III, Economic Geology', p. 473, (1881).
[5] *Rec. Geol. Surv. Ind.*, XXXIII, p. 62, (1906).
[6] *Rec. Geol. Surv. Ind.*, XLVI, p. 237, (1915).

in the bed of a river six miles from Sihora (64 A/3; 23° 29′: 80° 6′), towards Jubbulpore.

Yeotmal district.

T. W. H. Hughes has recorded the occurrence of a band of barytes, two inches thick, in a 37 feet coal seam at Wun (55 L/16; 20° 3′: 78° 57′) in the tahsil of that name in the Yeotmal district of Berar.[1]

Jammu and Kashmir.

Riasi district, Jammu State.

In 1925, Mr. C. S. Middlemiss presented to the Indian Museum a specimen of barytes with chalcopyrite (M 647) said to have come from Jangal Gali pass[2] (43 O/4; 33° 0′ 30″: 75° 2′ 30″) in the Riasi district of Jammu State.

Madras.

(Other than the Ceded Districts.)

Banganapalle State.

A specimen of barytes, forwarded by Mr. P. Chettiah of Villapuram, South India, through the Director-General of Commercial Intelligence and Statistics to the Geological Survey of India, was stated to come from Banganapalle (57 I/3; 15° 19′: 78° 14′) in the State of that name.

Nellore district.

Mr. H. C. Jones[3] has described veins of barytes occurring in two low hills about three miles east of Narravada (57 N/5; 14° 54′: 79° 26′) in the Kalahasti *zamindari* of the Nellore district. The veins occur irregularly in a band of fine-grained mica-schist, striking N. W.–S. E. and dipping 40° to the south-west, usually following the strike of the band, but cutting obliquely across its strike in some cases.

The barytes is generally of greyish colour, but some pieces are milky white. It has a specific gravity of 4·46.

Specimens of the country rock, taken about ten feet from any visible barytes vein, were found to contain a considerable quantity of barytes, as small grains scattered through the rock. The other constituents of the mica-schist were quartz, biotite, magnetite and a little calcite.

[1] *Mem. Geol. Surv. Ind.*, XIII, p. 47, (1877).
[2] *See* Plate I of *Mem. Geol. Surv. Ind.*, XXXII, Pt. 4, (1904), in which the Gully pass is seen at the south-eastern end of the Ladda coalfield.
[3] *Rec. Geol. Surv. Ind.*, XXXVI, p. 233, (1908).

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La Touche's summary[1] of Sir Thomas Holland's description[2] of barytes occurring at Alangayam (57 L/14; 12° 37′ 30″: 78° 45′) in the Tirupattur taluk of the North Arcot district,[3] may be quoted:—

North Arcot district.

'Holland has described in detail a peculiar and important occurrence of barytes in the neighbourhood of Alangayam. The rocks forming two low hills, lying about a mile S. of the village, consist largely of a network of veins composed entirely of quartz and barytes, traversing porphyritic gneiss. Similar veins are found penetrating the crystalline rocks in the neighbourhood, and have been traced for a distance of 7 miles. The veins vary in thickness from mere strings to dyke-like masses several feet across. They are considered to be intrusions of an igneous rock containing barytes as one of its original constituents.[4]

From the determination of the specific gravity of a large number of specimens, it was found that the average proportion of barytes present in the rock amounts to 30·8 per cent.'

Sir Thomas Holland[5] gives the following analysis by T. R. Blyth of a specimen of barytes from the locality:—

	Per cent.
$BaSO_4$	94·15
$CaSO_4$	4·01
SiO_2	0·63
Fe_2O_3, Al_2O_3	0·93
Moisture	0·04
Loss on ignition	0·26
TOTAL	100·02

A specimen of barytes forwarded by Mr. P. Chettiah of Villapuram, South India, to the Geological Survey of India through the Director-General of Commercial Intelligence and Statistics was stated to come from Manur (58 H/9; 8° 52′: 77° 40′) in the Tinnevelly district.

Tinnevelly district.

Punjab.

In 1893, Mr. C. S. Middlemiss collected a specimen of barytes (I 562) in the Lavender Clay zone of the Speckled Sandstone series, which is probably of Upper Carboniferous age, between the villages of Kathwai (43 D/3; 32°

Shahpur district.

[1] T. H. D. La Touche, 'Bibliography', Pt. I B., p. 19, (1918).
[2] *Rec. Geol. Surv. Ind.*, XXX, pp. 236-242, (1897).
[3] Alangayam was formerly in the Salem district.
[4] Reference may be made to page 116 of this memoir where Clarke's criticism of this mode of origin is given.
[5] *Op. cit.*, p. 241.

29′: 72° 11′ 30″) and Jalhar (43 D/3; 32° 30′: 72° 6′) in the Shahpur district.

Punjab States.

Mr. J. B. Auden has recorded[1] the occurrence of a discontinuous vein of barytes in the Simla slates in the Simla hills near hill 3,901 feet (53 F/1; 30° 58′ 30″: 77° 1′ 15″), two miles E. S. E. of Subathu. Mr. Auden personally informed the author that the vein is about four feet thick, and occurs along a fault plane. It can be traced sporadically to the south-east for about a mile. The proportion of galena is small, and most specimens (N 53) show hardly any galena at all.

Simla.

Kelly[2] and Henwood[3] have described old lead mines not far from this neighbourhood, but have made no mention of barytes.[4] Ball,[5] however, gives three localities at which ores of lead are said to occur. It is thought that the first of these, *viz.*, '$2\frac{1}{2}$ to 3 miles south-east of Huriapur', is the locality for barytes mentioned by Mr. Auden, 'Huriapur' being the village Haripur (31° 1′: 76° 59′) on sheet 53 A/16. Ball adds:—

'Traces of lead ores with barytes are said to occur to the east of the suspension bridge, as far as the Sairan dak bungalow, on the Simla road, but they do not occur to the west.'

'Sairan' is probably Sair (53 E/4; 31° 5′: 77° 3′) on the track from Subathu to Simla.[6]

Rajputana.

Barytes is said to be associated with the veins of lead-ore formerly mined at Taragarh Hill (45 J/11; 26° 27′: 74° 37′), close to the city of Ajmer.[7]

Ajmer-Merwara.

[1] *Rec. Geol. Surv. Ind.*, LXII, p. 31, (1930).
[2] *Min. Journ.*, XXXIX, pp. 59-60, (1869).
[3] *Op. cit.*, pp. 67, 471.
[4] Compare with the statement in La Touche's 'Bibliography', Pt. I B, p. 19, (1918).
[5] Ball, 'Economic Geology', p. 305, (1881).
[6] A specimen of barytes (G 874), said to have come from Subathu, was presented to the Indian Museum by W. L. Willson, Esq.
[7] Ball, *op. cit.*, pp. 299-300, 474, (1881).

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A description of the barytes deposits in Alwar State has been published as a 'Miscellaneous Note' in the Records of the Geological Survey of India.[1] They occur[2] at Bhakhera (54 A/10; 27° 32′ : 76° 36′), 2½ miles south of Alwar city; near Rampur (54 A/12; 27° 9′ : 76° 37′); at Jamrauli (54 A/12; 27° 9′ : 76° 40′), seven miles S. S. E. of Rajgarh railway station; and at Sainpuri (54 A/10; 27° 43′ 30″ : 76° 38′), 3½ miles N. by E. of Parisal railway station.

Alwar State.

All the deposits of barytes (L791; L843-845) occur in the Alwar quartzite series of the Delhi system, but the barytes is not an original constituent of the quartzites. It occurs in veins filling fissures in the less compact and more easily weathered varieties. Except at Jamrauli the strike of the fissure-veins generally agrees with that of the bedding. The junction between the veins and country rock is sharp, and there is no impregnation of the walls.

Until recently, the Sainpuri mines have been the chief source of barytes produced in India.[3] The barytes vein here is pure white in colour, approximately 15 feet thick, and has been traced for 110 feet.

In conclusion, Mr. Roy states :—

'The barytes veins have probably crystallised from solutions at a relatively low temperature, and at no great depth. They belong to a later geological phase than the intrusive granites and pegmatites to which they are probably totally unrelated in origin.'

Barytes is said to occur at Golri (45 E/1; 28° 56′ : 73° 0′) near Gajner, in Bikaner State. R. D. Oldham collected a specimen (H 850) from this locality in the field season 1885-86.

Bikaner State.

United Provinces.

Barytes is said to occur at Rajpur (53 J/3; 30° 24′ : 78° 6′) in the Dehra Dun district. A specimen (F 167) in the Indian Museum was collected 'two miles from Rajpur on the Maturi (? Mussoorie) cart-road'.

Dehra Dun district.

[1] S. K. Roy, *op. cit.*, pp. 238-239, (1923).

[2] The latitudes and longitudes given are not those of Mr. Roy's description, which are incorrect. Also some of the distances and directions given by Mr. Roy are incorrect. His village of 'Ramsinghpur' is not shown on the half-inch map sheet 54 A/S. E. Its coordinates are given as (27° 10′ : 76° 32′), which would indicate it to be on sheet 54 A/12. It is described as being 'ten miles south of Rajgarh station'. It is thought that this is not correct, and that the village in question is Rampur, coordinates as above, which is just inside Jaipur State, and is six miles south of the station.

[3] *See* the production figures given on p. 128.

CHAPTER VI.

THE MODE OF OCCURRENCE AND ORIGIN OF THE BARYTES.

Classification of the Barytes Deposits in the Ceded Districts of Madras.

Having described in detail the numerous deposits of barytes occurring in the districts of Cuddapah, Anantapur and Kurnool, and having referred briefly to all known occurrences in other parts of India (including Burma), it is desirable to analyse these descriptions and references and to summarise the information so gained.

The deposits of barytes in the Cuddapah, Anantapur and Kurnool districts may be classified as under :—[1]

(*a*) Replacement veins—
  (i) in limestones.
  (ii) in crushed rocks, chiefly limestone, but occasionally dolerite or basalt.

(*b*) Fissure veins—
  (i) in limestones.
  (ii) in dolerite or basalt.

The term 'fissure vein' is used in the sense of veins of barytes which appear to have been deposited along some definite line of fracture. According to Lindgren,[2] a fissure vein

Explanation of terms.

'may be regarded as a mineral mass, tabular in form, as a whole, though frequently irregular in detail, occupying or accompanying a set of fractures in the enclosing

[1] There is a remarkable parallelism with the barytes deposits of South-East Alaska where, according to A. F. Buddington and T. Chapin [*U. S. Geol. Surv.*, Bull. 800, p. 333, (1929)] :—

'Barite occurs locally in fissure veins, where it forms practically the whole vein; as replacement deposits in limestone beds; and locally as a common gangue mineral in the gold-silver-lead veins of the Hyder district.

Barite in fissure veins in limestone, conglomerate, and volcanic rocks occurs on Kuiu Island along the north side of the Cornwallis Peninsula and the south side of the Saginaw Bay and in the Ketchikan district at the northeast end of St. Ignace Island. These veins may be 200 feet in length and as much as 2 feet wide, but they have not been prospected because of their small size.

Barite as a replacement deposit in limestone beds occurs on the Castle Islands on Duncan Canal, Kupreanof Island, and at Lime Point, the south end of the peninsula between Hetta and Nutkwa Inlets, Prince of Wales Island.....At the Lime Point locality, according to Chapin, the country rock is semicrystalline blue-weathering white limestone interbedded with schist.'

[2] *Trans. Amer. Inst. Min. Eng.*, XXX, p. 580, (1901).

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rock ; this mineral mass has been formed later than the country-rock and the fracture, either through the filling of open spaces along the latter, or through chemical alteration of the adjoining rock.'

He believes that [1]

'the majority of fissure-veins are genetically connected with bodies of intrusive rocks'.

The author considers that while fissure veins grow by the filling of open spaces and through a certain amount of alteration of the adjoining rock, the crystallisation forces accompanying the deposition of the mineral have assisted the growth of the vein to a certain extent by forcing apart the walls of the fracture.

According to Lindgren :—[2]

'In many fissure-veins, practically all the economically important ore has been formed by replacement, and for these deposits the term *replacement-veins* is especially used. But if we do not confine ourselves to the fluctuating definition of "pay-ore", practically all fissure-veins are, to some extent at least, replacement-veins.'

The term 'replacement vein' is generally used for those in which mineralising solutions have in part metasomatically replaced the country rock.[3] According to Holmes,[4] metasomatism is :—

'the processes by which one mineral is replaced by another of different chemical composition owing to reactions set up by the introduction of material from external sources. *Metasomatic rocks* are those whose chemical composition has been substantially changed by the metasomatic alteration of its original constituents.'

It must be understood, however, that there is no hard and fast limit between these various types. Many deposits, indeed, are of composite nature, being in part replacement, and in part fissure, as, *e.g.*, the very important deposit (No. 104) at Balapalapalle (pp. 71-72). Other veins commence in limestones and can be traced into dolerites or basalts, or *vice versa*, as, *e.g.*, the interesting deposit (No. 116) near Gattimanikonda (p. 78). Some are partly along lines of crushing and partly in undisturbed rocks. Nevertheless it is advantageous to give this broad classification as indicating in a general way the types of deposit commonly met with in the Ceded districts of Madras.

Gradation of types of deposit.

[1] *Op. cit.*, p. 691.
[2] *Op. cit.*, p. 597.
[3] F. Beyschlag, J. H. L. Vogt, P. Krusch (translated by S. J. Truscott), 'The Deposits of the Useful Minerals and Rocks : their origin, form and content', II, p. 885, (London, 1916).
[4] A. Holmes, 'The Nomenclature of Petrology, with references to selected literature', p. 156, (London, 1920).

It will be noted that no replacement deposits have been found in trap. This, however, is not to be wondered at on account of the nature of the replacement process. As Rastall states :—[1]

Replacement deposits.

'As a rule sediments, with some important exceptions, are more previous to solutions than igneous rocks, and more liable to chemical replacement.'

Reference may be made to the Hussainpuram deposit (No. 55, pp. 51-52), which may be considered as typical of the replacement veins in Vaimpalli limestones. It will be remembered that the existence of vugs (or vughs) in the vein was noted, and that these vugas were often of fair size. Vugs are usually not noted in replacement veins, but occur in fissure veins which consist of more than one mineral. (As has been noted, the barytes veins usually consist of that mineral alone). According to Rastall :—[2]

'The filling of veins from solutions is apparently often a slow process and the character of the material deposited may and commonly does undergo changes. Hence such veins usually show layers of different minerals, and sometimes the filling is incomplete, hollows or *vugs* being left, often lined by beautifully perfect crystals.'

With the continued deposition of barytes in a replacement vein, the process will not always be perfectly regular and so vugs are likely to be formed.

A curious feature of the barytes replacement deposits is the sharp, though usually rounded, junction found in many, but not all, cases, between the vein mineral and country rock.[3] Even though the barytes vein has a wandering course through limestone, its junction with this can be clearly seen. There are, however, many cases where the barytes can be seen impregnating the wall rock, and then there is no sharp-cut junction.

In the areas visited, replacement veins in crushed rocks generally have far less importance than those of the same kind in altered limestones and than either of the two types of fissure veins. However, it has frequently happened that a line of crushing is marked

[1] R. H. Rastall, 'The Geology of the Metalliferous Deposits', p. 52, (Cambridge, 1923).
[2] *Op. cit.*, p. 96.
[3] Compare F. T. Emerson, as quoted by W. Lindgren, *Trans. Amer. Inst. Min. Eng.*, XXX, p. 597, (1901), who notes general lack of definition between ore-body and wall rock as one of the criteria for replacement veins.

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by the deposition of a small amount of barytes. It must be understood that a distinction is being drawn here between deposits of barytes in the actual crushed rock, and barytes in areas where there has been much crushing but where the greater part of the barytes deposited is in rocks which themselves are uncrushed. In other words, it is probable that the line of crushing has been the course by which the barium-containing solutions have ascended, but has not been favoured by them as a site of deposition.

In this connection, it may be noted that very frequently deposits of the replacement type have a general elongation bearing at an angle with that of a nearby major fault. This is assumed to be the mode of occurrence of certain of the best deposits of barytes in the Kurnool district, including the deposit cited above as the type of the replacement type of vein (*viz.*, Hussainpuram).

Fissure veins.

The so-called fissure, or fault veins are those where there seems little doubt that the barytes deposit occupies the site of a fault course, or a definite line of fracture. As such, they generally possess a definite hade, usually in the opposite direction to the dip of the enclosing strata. The best example of this kind of vein in limestones is the unimportant but interesting occurrence (No. 46) at Venkatamapalle in the Anantapur taluk of that district (p. 40). As an example of the same type, but in dolerite or basalt, there is the very large deposit (No. 14) at Kottapalle in the Pulivendla taluk of the Cuddapah district (pp. 19-21). It will be remembered, that the existence was noted of mineralised part of the containing rock adjacent to the mineral veins.

Date of Intrusion of, and the Relationship of the Barytes with, the Basalts and Dolerites.

Age of the intrusive trap sills in the Cuddapahs.

It is considered by the author that the barium-containing solutions, responsible for the deposition of that metal in the form of barytes after reaction with sulphate ions (*see* pp. 115-116), were differentiated from the basic parent magma of the basalt and dolerite sills intrusive into the Papaghni and Cheyair series of the Cuddapah system. Moreover, it is thought that the intrusion of these trap sills took place most probably in or about the Nallamalai epoch, certainly

in pre-Kistna times.[1] King has mentioned the intrusive nature of certain of the trap occurrences, but states[2] that 'considered generally, the traps are mostly contemporaneous (with), partly intrusive' into the Cheyairs. There has been a regrettable tendency in the past to speak loosely of these trap sills as 'contemporaneous lava flows.' Dr. C. S. Fox[3] and the author[4] consider that all the traps seen by them in the Papaghnis and Cheyairs are definitely intrusive into these series. Admittedly the author has not seen all the exposures referred to by King; nor, for that matter, has he seen the so-called ash beds described by him.[5] Accordingly he (the author) does not deny the possibility that certain of the traps may be as early as late-Cheyair in age. It is, of course, highly improbable that the individual members of the gigantic series of sills were intruded over the large area in which they are found at one and the same time. Such being the case, it may be taken as more or less certain that the sills in the Papaghnis and the Cheyairs were intruded in late or post-Cheyair, Nallamalai, or immediately post-Nallamalai times.

Ages of the trap dykes in the Crystallines.

It will be remembered that the occurrences of barytes at Mudigubba in the Kadiri taluk of the Anantapur district (p. 42) were supposedly related to certain trap dykes intruding the Crystallines. It is thought that these dykes are of the same age as the sills in the Cuddapah system, but only a small number of the trap dykes in the Crystallines to the west of the Cuddapah rocks are considered to be of such age. The author thus disagrees with King's bald statement that the dykes in the Crystallines 'are not connectable in any way with the traps of the KADAPAHS'.[6] However, in his description of the Nellore portion of the Carnatic, King has noted trap dykes

[1] At first glance, it might appear that there is no necessity to assume the number of separate series demarcated by King; in other words, that possibly the Kistnas and, or, the Nallamalais are really modifications of either the Papaghnis or the Cheyairs. But a thorough study of King's notes and of his original maps show this to be incorrect. The Kistnas are apparently much younger than either the Nallamalais, Cheyairs, or the Papaghnis, and, though folded and involved in earth movements along the eastern border of the basin of deposition, it is more than probable that they never had any great extension to the west, and, also, that the greater part of the earth movement suffered by the Papaghnis and Cheyairs took place before their deposition. In fact, it would appear from King's maps (though his notes and descriptions are not in favour of this), that the break between the Nallamalais and the Kistnas is more comparable to that assumed by King to exist between the Kurnools and the Kistnas.

[2] *Op. cit.*, p. 203.

[3] *Rec. Geol. Surv. Ind.*, LXV, p. 34, (1932).

[4] *Ibid*, LXVI, p. 440, Footnote No. 1, (1933).

[5] King, *op. cit.*, pp. 185-186.

[6] *Op. cit.*, p. 203.

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intruding both Cuddapahs and gneiss, but says nothing regarding their age.[1]

In his Bellary memoir, Foote states that the age of very many of the trap dykes shown on his map is still unsettled.[2] Regarding those in the gneissic area on the eastern coast, the same author states that all were intruded prior to the deposition of the Cuddapahs,[3] but in his Madras memoir, he does not mention the age of the intrusive trap dykes.[4]

Age of the chief earth movements which have affected the Papaghnis and Cheyairs.

The author has been at pains to point out that he considers that the unconformity between the Vaimpallis and the Pulivendlas, stated by King to be large in certain places, is, in point of fact, non-existent; or, if it does occur, then it is so small as to be negligible. In other words, considering the constituent series of the Cuddapah system as given on page and ascending in the time-scale, we meet no unconformity till that between the Cheyairs and the Nallamalais is reached. This unconformity was not examined by the author, but it would appear from King's maps, as well as from his descriptive notes of the feature, that it must exist. However, it is not thought that the break is so large as that between the Nallamalais and Kistnas. The tilting, faulting and folding (rare but existent in places) shown by the Papaghnis and Cheyairs were impressed upon them later than in immediate post-Cheyair times, or, to be precise, in the post-Nallamalai but pre-Kistna epoch.

One need only cite the Gattimanikonda fault, or the immense Ramallakota-Gani fault nearby, to show the extent of faulting of which there is abundant proof of pre-Kurnool age. The field evidence as to the relative age of the traps and the faulting varies. At times, the faulting appears to be post-trap-intrusion, at others contemporaneous; and at yet others, pre-trap-intrusion. However, the general impression left upon one after a few months' study of the traps and their relationships is that the intrusion appears generally to have been *accompanied by, or followed soon after by, faulting*. In other words, the intrusion and cooling of the basic sills was probably

[1] *Mem. Geol. Surv. Ind.*, XVI, Pt. 2, pp. 41, 56-62, (1880).
[2] *Op. cit.*, XXV, Pt. 1, p. 159, (1895). *See* also pp. 160-171.
[3] *Op. cit.*, XVI, Pt. 1, pp. 42-43, (1880).
[4] *Op. cit.*, X, Pt. 1, pp. 130-131, (1873).

largely responsible for the faulting. Accordingly, it is only to be expected that the barium-containing solutions, as they were concentrated from the traps, found easy paths along the various crushed zones and fractures, not only in the traps themselves, but also in the associated limestones and shales.

Theories as to the Origin of Barytes in Various Countries.

When one studies the literature of barytes, one finds some of the deposits of this mineral are supposed to have been formed by the leaching of barium compounds from other rocks, as, *e.g.*, dolomites, limestones, granites, porphyries, etc., and later concentration in another country rock. Thus the views of Winslow of the Missouri Geological Survey concerning the origin of the barytes of Washington county, Missouri, U. S. A., are given by A. A. Steel as under:—[1]

United States of America.

'.....the barite, together with its associated lead and zinc, has accumulated through the agency of descending solutions, gathering the barite from the weathering of the dolomitic rock. In favour of this hypothesis is the presence of appreciable, although very small, amounts of barite in the dolomite (from 0·001 to 0·005 per cent.); the assumed absence of definitely-proved fissures extending to great depths; the long period and considerable amount of denudation; the evidence of the Flat River lead-mines; and the stalactites of barite in Franklin county.'

After analysing the evidence, Steel himself states that:—[2]

'The evidence, therefore, seems conclusive that the barite originally came from below. The barite-bearing granites and porphyrites of Archaean age are not very deeply buried in Washington county, so the faults certainly extend down into them and they afford a convenient source. In pre-Algonkian time these rocks were greatly affected by solutions, and the visible barite may have been then concentrated or brought in from the basic dikes intrusive in them.'

It will be noted that Steel suggests the possibility that the basic dykes intruded into the Archaean granites and porphyrites in Algonkian times were responsible for the original introduction of the barytes.[3] The case is paralleled by that of the Ceded districts of Madras, where the rocks which are intruded by the sills (Papaghnis, Cheyairs and Nallamalais) and the intrusive sills of basalt and dolerite are themselves of (Algonkian Purana) age.

[1] *Trans. Amer. Inst. Min. Eng.*, XL, p. 721, (1909).
[2] *Ibid*, p. 725.,
[3] Reference may also be made to W. A. Tarr's paper on the 'Barite Deposits of Missouri' [*Econ. Geol.*, XIV, pp. 46-67, (1919)]. *See* also the author's description of a vein composed of barite, pyrite and fluorite which cuts granite and is believed to be of magmatic origin. [*Amer. Min.*, 17, No. 9, pp. 443-448, (September, 1932)].

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In the introduction to the memoir on the barytes and witherite deposits of the United Kingdom, it is stated that :—[1]

United Kingdom.

'In this country (Great Britain) barytes is pre-eminently a vein-mineral. It is a common constituent of mineral-lodes, espécially those carrying lead- and zinc-ores, and in these cases is generally associated with varying proportions of calcite, quartz or flourspar, though many veins are known in which barytes occurs practically alone. In Germany (the world's chief producer) most of the spar also comes from mineral veins, but the United States have extensive surface-deposits in which it is a residual product of limestone weathering. These latter deposits can be paralleled on a minor scale at Bradwell Moor, Derbyshire. At Nutfield, in Surrey, barytes occurs in isolated crystalline masses embedded in "fuller's earth".

In Canada, also, the 'barytes occurrences are predominantly vein deposits',[2] except in the case of the Five Islands deposits where a

Canada.

'great deal of barytes occurs as irregular, pockety masses, in an agglomerate of slate and quartzite, filling depressions between ridges of similar rocks'.[3]

Writing about the breccia-filled pipes younger than the Stormberg volcanoes of the Karroo system in the Sutherland district of South Africa, Du Toit states :—[4]

South Africa.

'In places the breccias and tuffs have been strongly impregnated with carbonates of lime and magnesia, barite, limonite, and silica, more particularly in the smaller pipes and in the peripheral portion of the main vent, while the up-tilted sandstones and shales have been similarly impregnated. Doubtless this mineralisation was effected by heated waters ascending through the porus fragmental materials towards the close of the eruptions, as happens during the "solfataric" stage in recent volcanoes.'

Barytes has been noted also in a similar occurrence in the Geitsi Gubib in South-West Africa.[5]

When summarising the information about the quartz-barite-rock at Alangayam in the Tirupattur taluk of the North Arcot district, Sir Thomas Holland states :—[6]

North Arcot district, India.

'This rock forms a large plexus of veins cutting through the pyroxenitic and other gneisses between Alangayam and Andiyappanur..... These veins vary

[1] *Mem. Geol. Surv.*, 'Special Reports on the Mineral Resources of Great Britain', II, 'Barytes and Witherite', 3rd edn., p. 1, (1922).
[2] H. S. Spence, 'Barium and Strontium in Canada', p. 10, (Can. Dept. Mines, Mines Branch, Ottawa, 1922).
[3] *Ibid.*
[4] 'The Geology of South Africa', p. 342, (Edinburgh, 1926).
[5] Du Toit, *op. cit.*, p. 343.
[6] *Rec. Geol. Surv. Ind.*, XXX, p. 242, (1897).

in thickness from mere strings to dyke-like masses several feet across, and through them all the barytes is uniformly distributed. The quartz and barytes are considered to be normal original constituents, which have separated from an injected mobile magma like many commoner pegmatites of a different composition ; but no evidence is forthcoming concerning the temperature of the magma prior to consolidation. There are none of the "banded" and "comby" structures of mineral veins, and no signs of possible derivation by pseudomorphism from ordinary pegmatite.'

However, F. W. Clarke states that Sir Thomas Holland's views regarding the quartz-barite-rock as a segregation from the original magma are chemically improbable :—[1]

'In a molten state quartz (or free silica) would react upon barium sulphate, to form a silicate and set sulphuric acid or sulphur dioxide free. Quartz and barite are magmatically incompatible.'

He adds :—

'Nearly or quite all of the occurrences of barite indicate that it is a mineral of aqueous origin. It may form as a direct deposit from waters, or as a precipitate when different waters commingle, or, as C. W. Dickson has shown, by a reaction between solutions of barium bicarbonate and gypsum. Barium sulphate is also produced, according to Dickson, when the bicarbonate solution is brought into contact with oxidising pyrite ; and its presence in limestones is attributed to a possible coincidence of the two reactions. The oxidizing pyrite is first instrumental in transforming calcium carbonate to sulphate, and the latter then undergoes double decomposition with the percolating barium solutions. The original source of the barium is in the feldspars and micas of the crystalline rocks, from which it is dissolved out during the ordinary process of weathering.'

Results of Analyses.

We may now return to the consideration of the basic sills in the Cuddapah district. The question naturally arises : What is the percentage of barium in the ordinary dolerite or basalt sill injected into the Papaghnis or Cheyairs ? The author here gratefully acknowledges the assistance of Mahadeo Ram, of the Geological Survey of India, who has kindly analysed fully two dolerites for him. The former of these (41·953) was collected by Dr. C. S. Fox from the Brahmanapalle asbestos mines in the Pulivendla taluk of the Cuddapah district. The latter (43·899, 21812) was collected by the author at Malkapuram in the Dhone taluk of the Kurnool district. In neither of these is there any trace of barium.[2] However, in an altered basalt

Dolerites.

[1] 'The Data of Geochemistry', 4th edn., *U. S. Geol. Surv.*, Bull No. 770, p. 592, (1924).
[2] The analyses will be published in the author's asbestos report.

(43·906, 21823) from south-west of Gattimanikonda in the Dhone taluk of the Kurnool district, and in a dolerite (43·911, 21829) from east of Joharapuram in the Kurnool taluk of the same district, distinct but minute traces of barium were found.

Limestones.

On the other hand, the results of analyses by Mahadeo Ram of Vaimpalli magnesian and dolomitic limestones collected by the author[1] do show the presence of barium in slightly more than half of the cases as shown in the following table:—

TABLE I.—*Percentage of baryta in certain limestones.*

Specimen.	43·873	43·876	43·878	43·879	43·894	43·898	43·901
Slide . .	21777	..	21783	..	..	..	..
Percentage of Ba O	0·75	*nil.*	0·15	0·07	*nil.*	*nil.*	1·20

43·873 Magnesian Vaimpalli limestone, one mile south of Ippatla, Pulivendla taluk, Cuddapah district.

43·876 Dolomitic and siliceous limestone, 1¼ miles west (a little north) of Ippatla.

43·878 Purplish, slightly magnesian limestone, one mile south-east of Lopatanutula, Pulivendla taluk, Cuddapah district.

43·879 Magnesian limestone, 1½ miles south of Karnapapayapalle, Pulivendla taluk, Cuddapah district.

43·894 Dolomitic limestone, three-quarters of a mile W. S. W. of Malkapuram, Dhone taluk, Kurnool district.

43·898 Dolomitic limestone, a quarter of a mile south-west of Malkapuram.

43·901 Siliceous limestone (country rock of barytes vein), 1¾ miles west of Rahimanpuram, Dhone taluk, Kurnool district.

With the exception of the last, all the rocks were collected not very far distant from contacts with dolerites or basalts, and so, if the magma responsible for the barium-containing solutions was the parent magma of the traps, it is only to be expected that there is a certain amount of impregnation of the adjoining rocks. The last

[1] These will be published in the asbestos report.

specimen (43·901) is that of the country rock in which the deposit No. 87 has been formed. The rock is almost half a chert as it contains 48·40 per cent. of silica. Possibly the replacement of the original limestone by silica took place at the same time as the infiltration of the small amount of barium.

Baryta in the lithosphere.

One may compare the above results with Clarke's figures giving the average composition of the lithosphere. This author gives[1] 0·055 per cent. Ba O in igneous rocks which form 95 per cent. of the lithosphere; 0·05 per cent. in shales forming 4 per cent.; 0·05 per cent. in sandstones forming 0·75 per cent.; and *nil* in limestones which form 0·25 per cent. of the lithosphere. The weighted average percentage of baryta is given as 0·051.

Association of Barytes with other Minerals in the Ceded Districts.

Association with quartz.

Although possibly generally free from impurities, the barium-containing liquors must frequently have contained silica in solution. In some cases, this silica has been deposited as quartz at the time of the reaction of the barium-containing solutions with sulphate ions to give barytes. At most other times, however, the silica has penetrated into the wall rock and has replaced much of it (usually limestone), forming a rock approaching a chert. The barytes after its formation has remained concentrated as a vein, whilst most of the silica has been dispersed into the country rock. Even though the vein itself be pure barytes, in practically every case there has been silicification of the wall rock. Accordingly, it is only reasonable to suppose that the silica responsible for this silicification accompanied the barium-containing solutions in their passage from the parent magma to the site of the vein.

Association with calcite.

Few cases of the association of calcite with barytes were noted. In any case, little can be inferred from such association in those cases where the veins are in limestones, inasmuch as solution of calcium carbonate and redeposition in the form of calcite is always liable to take place.

[1] 'The Data of Geochemistry', *U. S. Geol. Surv.*, Bull. No. 770, p. 34, (1924).

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Mention must be made here of the abundant quartz-reefs that were noted in the Vaimpallis and Cheyairs, and that are, according to King,[1] apparently very abundantly associated with the Nallamalais. The quartz-reefs in the Vaimpallis must not be confused with the extremely abundant bands of chalcedony of varying colours, common throughout the wide expanse of Vaimpalli limestones. It is thought that this chalcedony may be considered as being the metamorphic product *in situ* of original siliceous bands in the limestones. Whereas the chalcedonic bands are almost invariably parallel to the bedding, the quartz-reefs, almost as invariably, cut across the bedding.

Quartz-reefs.

The author can find no mention by King or Foote of the occurrence of trap dykes in the Nallamalais, nor of any other magma, basic or acidic,[2] to which these quartz-reefs in the Nallamalais may be ascribed. He thinks, however, that the Nallamalai quartz-reefs represent the extreme, acidic, differentiation product of the basic magma responsible for the basic sills intruded into the Papaghnis and Cheyairs, and some of which may also be intruded into the Nallamalais, though they have not yet been exposed by denudation.

The question of certain epidote-quartz-rocks is also relevant. Frequent veins, chiefly composed of epidote and quartz, but with iron-ores occasionally present, were noted associated with the traps.[3]

Epidote-quartz-pegmatites.

[1] *Op. cit.*, p. 235.

[2] Indeed, as regards acidic intrusions, the author knows of no granitic or porphyritic rocks in the Cuddapahs as a whole.

[3] In December, 1928, Mr. P. Venkayya of Mulapeta in the Nellore district of Madras, sent to the Geological Survey of India for identification some specimens of quartz-epidote-pegmatites from Wajra Karur (57 E/8; 15° 2′ : 77° 23′) in the Gooty taluk of the Anantapur district. These specimens revived the interesting question as to the exact source of the diamonds in South India, regarding which the following papers deal: R. B. Foote:—'Notes on the Geology of parts of Bellary and Anantapur Districts', *Rec. Geol. Surv. Ind.*, XIX, pp. 97-111, (1886); 'Notes on the Wajra Karur Diamonds, and on M. Chaper's alleged discovery of diamonds in pegmatite near that place', *op. cit.*, XXII, pp. 39-49, (1889). P. Lake:—'The supposed matrix of the Diamond at Wajra Karur, Madras', *op. cit.*, XXIII, pp. 69-72, (1890). Chaper:—'De la presence du diamant dans une pegmatite de l'Indoustan', *Comptes Rendus Acad. Sci.*, XCVIII, pp. 113-115, (1884); 'Sur une pegmatite à diamant et à corindon de l'Hindoustan', *Bull. Soc. Min. France*, VII, pp. 47-49, (1884); 'Note sur une Pegmatite diamantifère de l'Hindoustan', *Bull. Soc. géol. France*, 3rd ser., XIV, pp. 330-345, (1885-1886). M. Chaper's first two papers are preliminary notes; his main paper is the last. An excellent summary of the controversy is given by La Touche in his 'Bibliography' [Pt. I B, pp. 163-164, (1918)].

Foote has criticised severely and at length Chaper's alleged discovery of diamonds and rubies in a pegmatite near Wajra Karur. He (Foote) was loth to give up the idea that the Wajra Karur 'Blue Rock' was the source of, or one source of, the South India diamonds, and his very plausible solution is as follows:—When the blue rock was intruded from below, that region was covered by a thick mass of sedimentary rocks of which some were sufficiently carbonaceous in character to furnish the carbon necessary to allow of the blue rock (a plagioclase-augite-rock according to Lake) becoming charged on cooling with the carbon crystals as was the case at Kimberley in South Africa. The 'neck' rose to a great height above what now remains; and in the course of time, denuding agencies attacked the diamond-bearing portion of the neck of blue rock and the gems thus set free were washed away and embedded in conglomerates forming at a distance at lower levels from the materials of the neck, and of the sedimentary rocks through which it had risen.

The present author does not consider that the Wajra Karur pipe was responsible for all the diamonds found in the Banganapalli sandstones and grits at the base of the Kurnools. He is of the opinion that these diamonds have been resorted from any of several diamond-bearing basic sills intruded into the Papaghnis or Cheyairs in the near vicinities of the localities at which they were found. He also considers that the Wajra Karur volcanic neck is of the same age as the sills intrusive into the Papaghnis and Cheyairs.

In this connection, reference may be made to Vredenburg's interesting paper on the Panna diamonds [*Rec. Geol. Surv. Ind.*, XXXIII, pp. 254-314, (1906)] wherein he suggests basic dykes of Bijawar (Cheyair) age as the possible *nidus* of the diamonds.

[1] F. Beyschlag, J. H. L. Vogt, P. Krusch and S. J. Truscott, *op. cit.*, I, p. 137, (1914).

This epidote is *not* secondary in nature in the sense that it is derived from the traps by alteration. Its occurrence in the field suggests that the solutions responsible for it and its accompanying quartz were concentrated from the trap magma during the last stages of crystallisation, more or less at the period of faulting.

Some of the traps are extremely epidotic, noticeably certain large sills of basalt which occur stratigraphically just below the Pulivendla quartzites along the asbestos belt near Brahmanapalle, and also near Kottapalle, in the Pulivendla taluk of the Cuddapah district, and again in the vicinities of Kamalapuram, Malkapuram, Mudduletiswami, and Betamcherla in the Dhone taluk of the Kurnool district. The Kottapalle specimens (21772; 21773; N 535, 21774) are characteristic.

The Formation of the Barytes in the Ceded Districts.

The barium-containing solutions responsible for the barium in the barytes have been considered to be derived from the magma responsible for the trap sills in the Cuddapahs. It behoves us to consider the question of the precipitation of that barium in the form of the sulphate, barytes. It is thought that the barium, which was probably in solution as the chloride, was precipitated as barytes on meeting a solution containing sulphuric acid.[1] This sulphuric acid could be another derivative from the trap magma, or, on the other hand, could

Meeting of barium-containing solutions with those containing sulphuric acid.

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have been derived from the oxidation of sulphur originally present in some form in the Cuddapah rocks.

The fact that the majority of the barytes occurrences in the Ceded districts are in Vaimpalli shales and limestones, or in the associated traps, is certainly suggestive that these shales and limestones have a predisposing influence for the precipitation of barytes. Exactly similar basalts and dolerites are intrusive as sills into the Tadpatris, but in not one single case was barytes noted associated with these rocks. The Tadpatris are fundamentally a shale series, with concretionary siliceous limestones of very different character from the limestones found in the Vaimpallis. Therefore it would appear that the Vaimpalli limestones and shales have been in part at least responsible for some of the sulphuric acid which precipitated the barytes. It must not be forgotten, however, that barytes has been recorded from Mudigubba (p. 42) in the Anantapur district, supposedly in gneiss, and from other localities, in the Kurnool district particularly, not in Vaimpallis.

In favour of the assumption that the precipitating sulphuric acid is another derivative of the trap magma, we have the occurrence of metallic sulphide ores in quartz-veins in the Tadpatris, which appear to be definitely associated with basaltic and doleritic sills. But, as Clarke has stated,[1] quartz and barium sulphate are magmatically incompatible, and it therefore appears that the sulphate ions responsible for the precipitation of the barium as barytes probably had an origin different from that of the barium; in other words, in the majority of cases, the sulphate ions were derived from leaching of the Vaimpalli limestones.

[1] *Loc. cit.*

CHAPTER VII.

THE PROPERTIES, MARKETING AND USES OF BARYTES.

Introduction.

This chapter is composed largely of extracts from other writers, but its inclusion is considered desirable in order to facilitate reference to the subjects treated. Incidentally, some of the uses of barytes mentioned hereafter are not very generally known.

Properties of Barytes.

Mineralogical data.

Barytes, barite, heavy spar or barium sulphate ($BaSO_4$) contains 65·7 per cent. of barium oxide or baryta (BaO). It has a high specific gravity of about 4·3 to 4·6, which serves effectually to distinguish it from minerals it might resemble in its other physical properties. Its hardness varies from 2·5 to 3·5. It is infusible, but with great heat changes to baryta. It does not effervesce with dilute acid. According to Larsen, its refractive indices are:—[1]

$\alpha = 1{\cdot}636.$
$\beta = 1{\cdot}637.$
$\gamma = 1{\cdot}648.$

It crystallises in the orthorhombic system, usually in crystals commonly tabular parallel to *c* (001).

Varieties.

According to Dana,[2] there are the following varieties:—

'Ordinary. (*a*) Crystals usually broad or stout; sometimes very large; again in slender needles. (*b*) *Crested*; massive aggregations of tabular crystals, the crystals projecting at surface into crest-like form. (*c*) *Columnar*; the columns often coarse and loosely aggregated, and either radiated or parallel; rarely finely fibroid. (*d*) In globular or nodular concretions, subfibrous or columnar within. *Bologna Stone* (from near Bologna) is here included; it was early a source of wonder

[1] *U. S. Geol. Surv.*, Bull. No. 679, p. 219, (1921).
[2] E. S. Dana and W. E. Ford, 'A Text-Book of Mineralogy', p. 626, (New York, 1922).

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because of the phosphorescence it exhibited after heating with charcoal. "Bologna phosphorus" was made from it. (*e*) Lamellar, either straight or curved; the latter sometimes as aggregations of curved scale-like plates. (*f*) Granular. (*g*) Compact or cryptocrystalline. (*h*) Earthy. (*j*) Stalactitic and stalagmitic; similar in structure and origin to calcareous stalactites and stalagmites and of much beauty when polished. (*j*) Fetid; so called from the odor given off when struck or when two pieces are rubbed together, which odor may be due to carbonaceous matters present'.

The two commonest varieties noted in the Ceded districts were the ordinary and granular types noted above. One instance, *viz.*, at Razampeta in the *taluk* of that name in the Cuddapah district, was an example of fetid barytes. This specimen has been kindly examined for the author by Dr. E. Spencer of Messrs. Bird and Co.'s Research Department, Calcutta, and by Mahadeo Ram of the Geological Survey of India. In this connection, reference may be made to the analyses given on page 26 and to Dr. Spencer's very comprehensive note on that page and page 27. It will be seen that 0·04 or 0·046 per cent. of sulphuretted hydrogen is present.

Colour.

The commonest colour of barytes is white and needless to say, pure white barytes has the most commercial uses. Generally the barytes as quarried or mined in the Ceded districts is iron-stained to quite an appreciable degree. This necessitates considerable waste with the hand-picking methods at present in vogue. (There seems to be no attempt to prepare the barytes as described in the succeeding section.) Other colours commonly noted were grey and red. In many cases, it was observed that the reddish and greyish colours were due to the presence of innumerable inclusions, determined by the author's colleague, Mr. W. D. West, to be minute needles of hæmatite.

One specimen of barytes from the Balapalapalle mines of M. R. Ry. B. P. Sesha Reddy Guru of Betamcherla deserves special mention. This specimen (N 618) is a beautiful example of optically clear and transparent barytes, and is unique in the collections of the Geological Survey of India.

Preparation of Barytes for the Market.

The following notes are taken from pages 5 to 7 of 'Barium Minerals', War Period (1913-1919), issued in 1921 as part of the

'Mineral Industry of the British Empire', by the Imperial Mineral Resources Bureau :—[1]

'The first step in the preparation of crude barytes for use as a pigment is the sorting (on picking-belts or otherwise) of the mineral as received from the mine, this being followed by a more or less coarse crushing, the size of the product being determined by the form in which the impurities are present, whether as superficial stains or disseminated throughout the mineral. In German practice this preliminary crushing is to nut size, or even larger, but it is generally desirable to grind the barytes to much smaller size before bleaching, a process to which the mineral must usually be subjected in order to obtain the requisite degree of whiteness before fine-grinding. This is done by heating the crushed mineral with dilute crude sulphuric acid (commonly one of acid to three of water) to remove oxides of iron, calcium, manganese, etc. The process was formerly conducted in stone tanks, but in modern plants lead-lined wooden or steel vats are employed, the heating and necessary agitation being effected by passing steam into the sludge through a perforated lead coil. In some plants the agitation is performed by mechanical stirrers. When the soluble impurities have been completely removed, the solution is drained from the vat and the sludge is leached with water until free from acid. The mineral, after drying, is then in condition for the extremely fine grinding that is essential for its use in the paint trade.

In British practice this fine-grinding is commonly effected by passing the mineral, thus prepared, through "French" buhr-stone mills, twice or oftener this operation being sometimes preceded by a passage through rolls or revolving ball-mills. In Germany, a much finer state of subdivision has been obtained by a more repeated grinding of the barytes, which may pass through as many as eleven buhr-mills in series. When the grinding is a wet process, the final product must be dried, which is usually done on flagstones set over flues. The pulverized barytes, as marketed, ranges from material that will pass a 200-mesh screen to a grade that will pass 300-mesh. The finest product obtainable is made by supplementing the grinding by water-flotation (levigation), which ensures practically absolute uniformity in grinding. Much of the so-called "floated barytes", however, is merely mineral that has been ground under water instead of in a dry condition.

Pneumatic separation, in which the finely-ground powder is separated from the coarser particles by means of an air-current, has been adopted in recent years, and promises to give good results. In this process the finer particles should not exceed 0·03 mm. in diameter. Experience seems to indicate, however, that it is possible to grind too finely, and thus develop too high an absorptive capacity for oil. This matter is one that deserves attention as a research problem, viz., to find out just what mechanical condition combines in the best way the two desirable qualities of good covering power and low oil-absorption.

It is essential that ground barytes used in the manufacture of paint should be free from compounds of iron, potassium, sodium and calcium. Bleaching to remove iron oxide is effected by treatment with dilute sulphuric acid.'

[1] Reference may be made to the notes by Dr. J. Coggin Brown in this connection :—'Notes on Barytes and Mineral Colours', *Bull. Ind. Indus. Lab.*, No. 22, pp. 6-7, (1922). Also to A. A. Steel, *Trans. Amer. Inst., Min. Eng.*, XL, pp. 734-743, (1909).

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These notes have been given at some length because it is considered that by marketing a purer product, the barytes industry in India will better itself. At present there is only a rough hand-picking, followed by hand-hammering to about nut size. The purification of the barytes is done at the works where the paint is manufactured. It is understood, however, as has been stated previously (p. 9), that Messrs. Tiffin & Co. are erecting a crushing plant for barytes at Cuddapah. The details of this plant are not known, but it is believed that the crude barytes will be merely crushed to facilitate transport, and that there will be no bleaching nor other preparation for the market.

Crushing plant.

The author is indebted to Messrs. Turner Morrison & Co., Ltd., Managing Agents for the Shalimar Paint, Colour and Varnish Co., Ltd.,[1] for the following information concerning barytes in the Indian Stores' Department's 'Specifications for Paints':—

Specifications.

'DRY PIGMENTS.

All dry pigments to be entirely free from grit and equal to their respective standards in fineness of grinding. When barytes is specified, natural barium sulphate containing not more than 5 per cent. of impurities and free from added matter is to be used. Barytes added to white pigments or contained in white paints is to be free from any impurity adversely affecting its whiteness.'

He is also indebted to this Company for the following extracts from the B. E. S. A. 'Specifications for Barytes for Paints (No. 260 of 1926)':—

'DESCRIPTION.

1. The material shall consist of natural barium sulphate, which may have been bleached, in the form of a dry soft powder.

COMPOSITION.

2. The material shall contain not less than 90 per cent. of barium sulphate ($BaSO_4$), unless otherwise agreed between Vendor and Purchaser.

COARSE PARTICLES.

3. The material shall all pass a sieve having 200 meshes to the linear inch I. (M. M. Standard) when tested in the manner described in Appendix A.

[1] *See Trans. Min. Geol. Inst. Ind.*, XXVIII, pp. 64-65, (1933), for a brief note concerning this Company.

OIL ABSORPTION.

4. The oil absorption of the material, when determined in the manner described in Appendix B, shall not be less than 9 and not more than 14, or shall be equal to that of the standard sample, if any, provided by the Purchaser. The comparison shall be made in the manner described in Appendix C.

COLOUR.

5. The colour of the material, when mixed with a medium consisting of four parts refined linseed oil and one part turpentine or white spirit, shall closely match that of the standard sample, if any, provided by the Purchaser. The comparison shall be made in the manner described in Appendix C.

VOLATILE MATTER.

6. The loss on heating the material to constant weight in a water oven at 95°-98° C. (203°— 208·4° F.) shall not exceed 0·75 per cent.

CARBONATES.

7. The material shall not contain carbonates in greater quantity than is equivalent to more than 1·5 per cent. of carbon dioxide (CO_2).

MATTER SOLUBLE IN WATER.

8. The material when examined in the manner described in Appendix D shall not contain more than 2 per cent. of matter soluble in water and the aqueous extract shall be neutral to methyl red.'

For and on behalf of the Shalimar Paint, Colour and Varnish Co., Ltd., Messrs. Turner Morrison & Co., Ltd., added that their experience of the difference between Indian and imported barytes is mainly an experience of their own production as compared with imported material. They are satisfied that the quality of their production is at least equal to that of imported material; *e.g.*, they require their product to leave not more than one per cent. of residue on a 300-mesh sieve.

Uses of Barytes.

Dr. J. Coggin Brown's 'Notes on Barytes and Mineral Colours'[1] are very relevant to the present subject. Reference may be made also to various statistics under the head 'Barium Minerals', published annually by the Imperial Mineral Resources Bureau as part of the 'Mineral Industry of the British Empire and Foreign Countries'.

[1] *Op. cit.*

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The uses of barytes may be divided broadly into three groups :— (*a*) ground barytes ; (*b*) lithopone ; and (*c*) barium chemicals. Of later years, by far the greatest part of barytes produced in the world has been used in the manufacture of lithopone. Thus in 1929, in the United States of America, 52,448 short tons of crude barytes were used for barium chemicals, 58,770 short tons for ground barytes, and 223,188 for lithopone. The total consumption of lithopone in the United States has increased from 124,806,000 lbs. in 1918 to 420,336,000 lbs. in 1929.[1]

Ground barytes.

(*a*) ' Ground barytes is used chiefly as an inert mineral filling in paper, rubber, cloth, linoleum, oilcloth, and similar products, and as a constituent of paint both as a white pigment and as an inert extender. It is especially useful as a filler and surfacing material for playing cards, enamelled paper, and oilcloth, where a highly calendered surface is desired. It is also used as a filler in making artificial ivory and buttons ; as a base for the precipitation of lake colours ; in ceramic glazes and enamels ; as a constituent of some types of glass ; and as an inert filler and body material for many miscellaneous products where a heavy, crystalline filler is desired.'[2]

Use of ground barytes in rotary drilling.

One of the uses of barytes not mentioned in the above quotation is for weighting the mud fluid in rotary drilling.

' The extent to which a mud fluid is " feathered " depends on its viscosity or " thickness ". It is possible to mix a 100 lbs. (per cubic foot) mud fluid using good quality clay and water, but such a fluid is so thick that it is difficult to handle with the rotary pumps and in addition it is readily "feathered". For this reason when heavy mud fluids (anything in excess of 85 lbs. per cubic foot) are required, it is usual to increase their weight by the admixture of some heavy mineral constituent. The two heavy minerals most adapted to this use are barytes and hematite, both of which greatly increase the weight of mud fluids without appreciably increasing their viscosity. In Californian practice, the use of hematite in preference to barytes is attributable to the fact that the former is more readily available, but the majority of technologists believe that barium sulphate, particularly in its amorphous form, is the better substance.

The disadvantages in the use of hematite are :—

(1) Its characteristic red colour, which is liable to mask oil indications in prospecting wells.

[1] Statistics taken from *Mineral Industry*, XXXIX, (1931). The consumption of lithopone in the U. S. A. in 1931 fell to 307,406,000 lbs. (*op. cit.*, XL, p. 65).

[2] ' Barytes : Occurrence, Mining, Uses'. R. B. Ladoo, *Eng. Min. Journ.-Press*, CXV, p. 323, (1923). Reference may also be made to N. Brodie, ' The Manufacture of Paint and Varnish in India ', pp. 14-15, Indian Munitions Board, Calcutta, (1919) ; and to H. A. Gardner and G. B. Heckel, ' Barytes as a Paint Pigment ', *Trans. Amer. Inst. Min. Eng.*, L, pp. 983-985, (1915) ; and *Chem. Trade Journ. & Chem. Eng.*, LXVIII, pp. 203-204, (1921).

(2) It is difficult to obtain entirely free from silica, which acts as an abrasive, causing excessive wear of the casing and drill pipe.

(3) It settles rapidly unless continually agitated, and sometimes " freezes " the drill pipe.

(4) Some authorities claim that it is liable to set up chemical or electrical reactions and so lead to corrosion of casing.

In all four respects, barytes is superior to hematite. The colour of the barytes-weighted mud is lighter than that of ordinary mud fluid. Barytes is more easily obtained in a pure form, free from silica, and it remains in suspension longer than hematite (the amorphous variety of barium sulphate remains in suspension longer than the ordinary clay constituents of mud fluid). Barytes is an extremely inert substance and actually protects the casing from corrosion.

Weighted mud fluids have been extensively employed in Burmese rotary practice, but in several deep tests in the Yenangyaung field their use has proved entirely inadequate to prevent excessive caving or " heaving " of the formation. Similar difficulties have been combated in the United States by the use of " wire line bits ", which obviate the necessity of withdrawing the tools from the hole except at rare intervals ; and by reversing circulation. It is possible that some special technique along these lines might contribute to the successful negotiation of the difficulties met with in Burma.'[1]

The author is greatly indebted to Mr. P. Evans, of the Burmah Oil Co., for permission to publish the following comprehensive note on the use of barytes in rotary drilling, with special reference to Assam.

1. In drilling oil wells by the rotary system, the strata are cut by a bit rotated at great speed at the end of a suitable ' drill-pipe '. In order to keep the bit cool and to remove the ' cuttings ', *i.e.*, the fragments of the strata broken up by the rotating bit, a stream of fluid is pumped down inside the pipe carrying the bit, through suitable apertures in the bit itself and thence upwards in the annular space between the drill-pipe and the wall of the hole. It has been found that the best results are obtained when the fluid consists of a mixture of clay and water forming a thin mud, as such mud-fluid, by plastering up the wall of the hole, makes it less liable to fall in during drilling, and by its viscosity and density facilitates the removal of cuttings. A very important function of this mud-laden fluid is the counteraction of undesirable effects of fluids contained under high pressure in porous strata.

2. During recent years there have been notable advances in the design of drilling machinery and at the same time much attention has been paid to the properties of the mud-fluid ; it has been found that the nature of this fluid has a most important bearing on the success attending deep drilling operations, and it is now appreciated that the properties of the mud-fluid must be the subject of careful investigation in order to ensure that they are suitable to the particular conditions

[1] C. T. Barber, ' Some Aspects of Modern Oilfield Practice ' *Rec. Geol. Surv. Ind.*, LXIII, pp. 392-393, (1930).

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likely to be encountered during drilling. Since drilling difficulties vary very greatly from well to well, the mud-fluid suitable for one well is not likely to be the same as the mud-fluid suitable for another well situated in different territory.

3. It will readily be appreciated that two of the most important properties of the mud-fluid are *viscosity* and *specific gravity*. If the viscosity is insufficient, the mud will not carry up the cuttings nor will it properly plaster up the wall of the hole. If the viscosity is very great, it will be very difficult to pump the fluid down through the drill-pipe in sufficient quantities, and it will be impossible to remove the sand and other cuttings suspended in the fluid. The specific gravity determines the hydrostatic pressure exerted by the mud-fluid at the bottom of the well. If the strata are porous and readily absorb water, the specific gravity of the mud-laden fluid must be kept low. If the strata contain water or other fluids under high pressure, the specific gravity of the mud-fluid must be kept high in order to restrain the high-pressure fluids from entering the well during drilling. In drilling to great depths for oil (particularly in unproved areas) there is the possibility of encountering porous sands containing large quantities of salt water associated with gas under very high pressure. If the hydrostatic pressure exerted by the mud-laden fluid is insufficient, there may be a disastrous 'blow-out': in order to reduce the likelihood of this occurring, it is usual to keep in reserve large quantities of mud of very high specific gravity.

4. The specific gravity of the mud-laden fluid may be increased by the addition of clay or powdered shale, but a point is soon reached at which the mud-fluid becomes too viscous for use. Mud-fluid prepared from clay or shale and water may have a specific gravity between 1·15 and 1·45 or, in exceptional cases, of as much as 1·50 without being too viscous. It has been found that the addition of small quantities of alkali salts of weak acids produces a marked reduction in viscosity, and mud-fluid treated in this way may not be unduly viscous at specific gravities of 1·50 or 1·55.

5. Even a mud-fluid weighing 50 per cent. more than water may be quite inadequate to deal with the pressures encountered in deep wells and it is necessary to add to the mud some 'loading agent'. Barytes is one of the most important of these agents; amongst others are iron oxide and 'concentrates' from metal mines.

6. The preparation of a good barytes mud entails careful laboratory investigation. If the proportion of clay is too small, the mud is unstable—the barytes settles out as a sticky mass at the bottom of the fluid and a layer of water appears on the surface. If the proportion of clay is high, the mud becomes too viscous before the required weight is reached. The addition of viscosity-reducing reagents is therefore necessary and with their aid a fluid of specific gravity exceeding 2·0 can often be obtained. Such a mud contains a very large proportion of barytes —possibly 55 per cent. Although the mud-fluid is used over and over again, a deep well may need many thousands of gallons; for this, several hundred tons of barytes may be required.

7. A mud-fluid of high quality contains a large proportion of colloidal material and the addition of comparatively coarsely ground barytes, sand, etc., destroys the stability of the colloids and brings about a rapid separation of the mud-fluid

into water and thick sticky mud. Consequently it is essential for the barytes to be very finely ground and it is of little use adding barytes which will not pass through a 300 mesh. The presence of silica is also undesirable, both on account of the effect on the colloids of the mud and because it lowers the specific gravity of the barytes and therefore of the mud-fluid. It is usual to specify that the specific gravity must exceed 4·15 and that the barytes must contain 96-97 per cent. $BaSO_4$ and not more than 2 per cent. of silica, and that 99 per cent. must pass through a 300 mesh sieve.

8. The consumption of barytes is very variable; most oil-wells are completed without it being necessary to use any barytes, but exploratory drilling in prospecting areas may call for the use of several hundreds of tons in the course of a few months. It is therefore impossible to predict the quantity of barytes likely to be required in the near future—the use of this material is one of the very recent improvements in drilling technique and it is possible that further improvements will render the use of barytes unnecessary. There are, however, no signs of such changes and it may well be that, as more difficult drilling operations are undertaken, the demand for barytes will increase. In Assam, the consumption has been approximately as follows:—

1929	100 tons
1930	300 tons
1931	200 tons
1932	450 tons (estimated).

9. The Assam supplies have been mainly imported. Hitherto, attempts to obtain the required supplies from Indian sources have not been successful; either the quality has been unsatisfactory, or the price has been higher than that of imported supplies or the quantity that could be delivered has been too small. For wells in Cachar and Sylhet, imported supplies can be obtained *viâ* Chittagong with a freight of about 25 per cent. of the value of the barytes, whereas indigenous supplies coming from or *viâ* Calcutta have to bear a heavier freight, and, unless the Calcutta price is well below Rs. 50 per ton, cannot compete with imported supplies.

The importance of this use of barytes may also be gathered from the details of the imports of the mineral into Sind and Burma as shown in Table VII on page 133. It is thought that the entire amounts of barytes imported into Sind during the years 1930-31 and 1931-32 were so utilized in the oilfields of the Punjab, and that the same is true of the imports of barytes into Burma during the financial years 1929-30, 1930-31, and 1931-32 which found their way to the oilfields of Upper Burma. In this connection, through the courtesy of the management of three oil companies at Yenangyaung, it is known that the following amounts of barytes have been used in Upper Burma during the calendar years 1926-1932 inclusive:—

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TABLE II.—*Amounts of barytes used in the oil-fields of Upper Burma.*

Year.	Amount of barytes. Tons.
1926	100
1927	797
1928	..
1929	1,182
1930	2,719
1931	1,133
1932 (incomplete)	100

Barytes has also been used as a furnace lining. Thus 287 tons of the mineral were used by the Burma Corporation in the year 1929-30 solely for furnace linings. The whole of this amount was produced from the deposits of barytes on the Bawdwin property of the Corporation (*see* p. 96).

Other uses of ground barytes.

Those villagers who cannot afford to use ground-up rice for that purpose, utilise ground barytes for the daily dusting of their thresholds after they have been washed with dung.

(*b*) 'Lithopone, also known by trade names Ponolith, Beckton White, Marbon White, Zincolith, Sterling White, B-J White, Grasselli White, and other designations, is a white pigment consisting approximately of 70 per cent. barium sulphate and 30 per cent. of zinc calculated as zinc sulphide. The zinc sulphide is usually replaced by 1 to 3 per cent. of zinc oxide. The European brands contain zinc sulphide in amounts varying from 11 to 42 per cent. The commercial product is a fine-grained white powder, 98 to 99 per cent. of which will pass through a 300 mesh screen.

Lithopone.

One of the most important steps in the process (manufacture of lithopone) is the purification of the zinc-sulphate solution, for to produce a pure-white product an almost chemically pure zinc-sulphate solution must be used. This process is usually kept secret, but in general it consists of using a powerful oxidizing agent to precipitate iron and other metallic sulphates, filtering, boiling with zinc dust to remove cadmium and cobalt, and refiltering.

To manufacture a ton of lithopone, over one and one-quarter tons of barytes and a total of about four tons of all raw materials, including zinc, barytes, sulphuric acid, and coal, are required.

Lithopone is used extensively in the manufacture of paints, both as a white pigment alone and mixed with other pigments. Another large consumption is in the manufacture of high-grade rubber goods, such as automobile tires, rubber matting fruit-jar rings, and tubing. In rubber it not only acts as a filler but is valuable for the curative effect which the zinc sulphide has on rubber. It is also used as a filler in oilcloth, linoleum, and window-shade cloth, and to a smaller extent in printers' ink, and face powder.'[1]

[1] Ladoo, *ibid.*, pp. 323-324.

(*c*) Barium chemicals may be made either from barytes or from witherite, the carbonate of barium. Reference may be made to the *United States Tariff Information Series* No. 18 for the details of manufacture and the various uses. A useful summary has been given by Coggin Brown.[1] In this connection, however, the distinction between 'blanc fixe' or 'permanent white' and barite must not be forgotten. 'Blanc fixe' is the chemically precipitated form of the sulphate. It is used largely :—

Barium chemicals.

'Where a pure-white pigment or filler is desired, as in paints, rubber goods, linoleum, oilcloth, and glazed paper. It is also used in lithographic inks, as a base for lake colours, and is extensively used as a pigment by the United States Navy in " battleship gray", which contains about 45 per cent. of blanc fixe. Blanc fixe, under the name of chemically pure barium sulphate, is used as an indicator in X-ray photography. It is placed on the market in pulp and as a dry powder. The pulp is a paste containing about 30 per cent. of water, and is used chiefly by the paper and lithographic ink manufacturers. The dry powder is used for pigment purposes.'[2]

[1] *Op. cit.*, pp. 5-6.
[2] Ladoo, *loc. cit.*

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CHAPTER VIII.

THE BARYTES INDUSTRY IN INDIA.

Production of Barytes in India.

The barytes industry in India is yet in its youth. The first production of barytes in India of which statistics are available was in 1918, when 2,724 long tons were produced from the Balapalapalle mines in the Dhone taluk of the Kurnool district of Madras. It was not until 1921 that production is recorded from Alwar State, Rajputana. Kurnool and Alwar were the sole producing centres of barytes from 1921 till 1931 when the quarries at Kottapalle in the Pulivendla taluk of the Cuddapah district of Madras commenced production. Their initial production of 1,335 tons in 1931 may be compared with 4,158 tons from Kurnool and 161 tons from Alwar State in the same year.

From Madras and Rajputana.

The figures of production for the years 1918[1] to 1931 inclusive are given in Table III below. They have been compiled from Annual and Quinquennial Reviews of the Mineral Production of India which are published in the *Records of the Geological Survey of India*.

TABLE III.—*Production of Barytes in India.*

Year.	Madras. Kurnool district.		Rajputana. Alwar State.		Total production of barytes in India.			Rate of exchange
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.		
	Long tons.	Rs.	Long tons.	Rs.	Long tons.	Rs.	£	
1918	2,724	44,215	..	..	2,724	44,215	2,948	*a*
1919	2,590	15,615	..	..	2,590	15,615	1,358	*b*
1920	678	15,528	..	..	678	15,528	1,553	*c*
1921	1,457	47,603	234	4,680	1,691	52,283	3,486	*a*
1922	1,742	41,500	650	6,500	2,392	48,000	3,200	*a*
1923	1,603	22,749	967	20,000	2,570	42,749	2,850	*a*
1924	783	11,341	1,520	20,000	2,303	31,341	2,255	*d*
1925	580	7,760	870	9,900	1,450	17,660	1,328	*e*
1926	350	1,400	1,961	7,844	2,311	9,244	690	*f*
1927	851	5,550	868	4,340	1,719	9,890	738	*f*
1928	620	4,610	2,476	15,000	3,096	19,610	1,463	*f*
1929	802	5,151	2,948	17,588	3,750	22,739	1,697	*f*
1930	5,633	42,578	1,164	6,984	6,797	49,562	3,671	*g*
1931	5,493[2]	42,240	161	966	5,654	43,206	3.200	*g*
1932	2,228[3]	24,000	483	3,381	2,711	27,381	2,059	*e*

[1] It may be noted that there is no recorded production of barytes during the years 1914 to 1917.

[2] Includes production of 1,335 tons of barytes in the Cuddapah district.

[3] Includes 1,278 tons of barytes valued at Rs. 17,786 produced in the Cuddapah district.

Rates of exchange :—
a : £1=Rs. 15.
b : £1=Rs. 11·5.
c : £1=Rs. 10.
d : £1=Rs. 13·9.
e : £1=Rs. 13·3.
f : £1=Rs. 13·4.
g : £1=Rs. 13·5.

It will be noted that production of barytes in Alwar State has latterly begun to decline, whereas fresh life seems to have been given to the industry in the Madras Presidency.

Activity in Madras.

In this connection, the following table (Table IV) may be seen. It compares the production of mines in Madras worked under the Mines' Act with that of 'non-Act' mines and quarries.

TABLE IV.—*Production of barytes in Madras from 'Act' and 'Non-Act' mines.*

Year.	Production from mines in Madras worked under the Mines' Act.			Production from 'non-Act' mines	Total production in Madras
	Pit's mouth value.	Value per ton.	Quantity.	Quantity.	
	Rs.	Rs. A.	Tons.	Tons.	Tons.
1922	23,370	29 9	789	953	1,742
1923	17,000	17 0	1,000	603	1,603
1924	11,341	14 7	783	..	783
1925	7,760	13 6	580	..	580
1926	1,400	4 0	350	..	350
1927	5,550	6 8	851	..	851
1928	4,610	7 7	620	..	620
1929	5,151	6 6	802	..	802
1930	14,971	10 11	1,398	4,235	5,633
1931	7,400	6 11	1,100	4,058	4,158
	12,000	10 0	1,200[1]	135[1]	1,335[1]
1932	4,280	6 13	630	320	950
	17,166	14 2	1,216[1]	62[1]	1,278

The figures for the total production in Madras are those given in Table III on page 128.

It will be seen that the production in Madras from 'non-Act' mines, which includes material removed under a prospecting licence, has latterly far exceeded that if mines worked under the Mines' Act.

The author has noted elsewhere the disproportionate number of mining leases held in the Kurnool district compared with the number

[1] Production from the Cuddapah district. All the other figures are for the Kurnool district of Madras.

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of prospecting licences for barytes which have been issued in that district. It is a legitimate conclusion from this disproportionate ratio that there is no large number of deposits of barytes in the Kurnool district of requisite quality, easily worked, present in sufficient quantity and favourably situated as regards railway transport, such as would warrant the application for mining leases. But the author's survey is not in agreement with this conclusion.

Imports of Barytes into India.

Barytes has been imported into India in ever-increasing amounts. The following table (Table V) gives the amount imported during various financial years (ending 31st March) from 1913-14 to 1930-31. The figures have been taken from the 'Annual Statement of the Sea-Borne Trade of British India with the British Empire and Foreign Countries,' published by the Department of Commercial Intelligence and Statistics, India, at Calcutta. For the years 1913-14 to 1916-17, the various foreign countries were not differentiated as the amounts imported from them, compared with that from the United Kingdom, were small. It will be seen, however, that apart from the years 1913-14 (4,086 cwts.), 1927-28 (20,212 cwts.) and 1928-29 (12,448 cwts.), the amounts imported from the United Kingdom have remained stationary at a low figure.

Imports of barytes increasing.

TABLE V.—*Imports of barytes into British India.*

Financial year	Country from which imported.					Total imported.	
	United Kingdom.	Germany.	Italy.	Belgium.	Other foreign countries.	Quantity.	Value.
	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	£
1913-14	4,086	800	..	..	100	4,986	1,192
1914-15	836	..	..	..	60	896	205
1915-16	910	..	..	..	98	1,008	365
1916-17	218	..	..	..	..	218	150
1917-18	292	..	..	..	600[1]	892	784
1918-19	..	..	..	..	..	..	..
1919-20	..	..	..	..	..	..	..

[1] 600 cwts. from the United States of America.

TABLE V (contd.).—*Imports of barytes into British India.*

Financial year.	Country from which imported.					Total imported.	
	United Kingdom.	Germany.	Italy.	Belgium.	Other foreign countries.	Quantity.	Value.
	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Rs.
1920-21	661	..	..	50	4,211[1]	4,922	64,090
1921-22	320	594	..	..	3	917	7,610
1922-23	107	1,860	..	110	..	2,077	10,624
1923-24	6	8,774	..	..	..	8,780	39,682
1924-25	638	6,330	..	110	..	7,078	28,692
1925-26	449	15,987	5,372	20	..	21,828	91,255
1926-27	556	25,101	6,473	..	198[2]	32,328	1,17,807
1927-28	20,212	7,898	4,449	..	1,303[3]	33,862	1,36,988
1928-29	12,448	14,777	4,790	..	..	32,015	95,591
1929-30	688	75,112	6,255	..	..	82,055	2,40,360
1930-31	369	87,546	4,677	21,649	13,389[4]	127,630	3,19,105
1931-32	321	36,374	7,020	887	10,260[5]	54,862	1,73,658

The United States of America has not been a supplier of barytes to India, except during the years 1917-18 (600 cwts.) and 1920-21 (4,211 cwts.). The first place after the war was taken by Germany and the imports from that country have, with minor exceptions, risen from a modest 594 cwts. in 1921-22 to 87,546 cwts. in 1930-31. Since its appearance as a supplier, Italy has sent roughly about 5,000 cwts. of barytes to India annually. Belgium's exports of the mineral to India rose to 21,649 cwts. in 1930-31, whilst those of the Netherlands attained the large total of 13,389 cwts. It is presumed that the Netherlands' exports are really re-exports of German barytes from Netherlands' ports. There was a large decrease in the imports of barytes in the year 1931-32, due, no doubt, to the financial stringency.

Germany the chief supplier of barytes.

World Production of Barytes.

Are the countries which supply barytes to India the chief barytes producing countries of the world? The following table (Table VI) shows the world's production of barium minerals for the years 1924 to 1930 and has been taken from 'Mineral Industry during 1931'.[6]

Germany the largest producer of barytes in the world.

[1] 4,211 cwts. from the United States of America.
[2] 198 cwts. from the Netherlands.
[3] 1,193 cwts. from the Netherlands and 110 cwts. from Sweden.
[4] 13,389 cwts. from the Netherlands.
[5] 10,235 cwts. from the Netherlands.
[6] *Mineral Industry*, XL, p. 66. (1932).

It will be noticed that pride of place as the largest producer of barytes is held by Germany which country has latterly usurped the position from the United States of America. Whilst the latter country consumes its production of barium minerals, Germany has sufficient surplus to develop a large export trade to India. The Netherlands is not shown as a producing country up to 1930. In this connection it may be added that instructive figures of the production, exports and imports of barium minerals are given on pages 41 to 46 of the Statistical Summary for 1928-1930 of the Mineral Industry of the British Empire and Foreign Countries, published in 1931 by the Imperial Institute.

TABLE VI.—*World's production of barium minerals.*[1]

Country.	1924.	1925.	1926.	1927.	1928.	1929.	1930.
Algeria	500	600	800	500	(a)	1,200	2,403
Australia—							
New South Wales	152	203	203	203	20	154	176
South Australia	1,928	2,040	1,770	1,916	2,404	2,001	1,560
Tasmania	..	4	..	..	..	10	(a)
Austria	1,399	1,363	966	1,924	2,243	300	496
Belgium	20,490	13,190	6,100	1,630	740	(a)	(a)
Canada	137	86	91	51	115	95	60
France	44,189	41,150	38,810	28,300	30,050	41,625	(a)
Germany—							
Bavaria	23,029	21,477	26,955	20,035	23,872	23,406	17,778
Prussia	102,326	151,243	135,319	154,794	232,858	260,811	217,925
Saxony	2,076	968	..	(a)	1,401	(a)	(a)
Great Britain	55,346	49,462	43,462	47,605	50,702	58,011	59,647
India	2,340	1,473	2,348	1,747	3,146	3,810	6,906
Italy	39,568	32,195	31,845	30,677	27,116	24,100	24,420
Rhodesia, Southern	64	36	27	13	77	264	249
Russia[2]	737	4,684	14,389	8,496	3,937	(a)	(a)
Spain	14,450	8,784	7,941	7,716	6,163	5,806	5,552
United States	178,108	206,894	215,795	230,664	244,525	251,533	213,126

(a) Data not available.

It is interesting to note the following remarks by C. Hardy:—[3]

'Lately Russia appeared in the market as a supplier of barite and expects to become a regular factor. For the year 1931, a production available for export of 50,000 tons is contemplated. A typical analysis of Russian barite follows:—

	Per cent.
$BaSO_4$	98·00
Fe_2O_3	0·10
SiO_2	0·40
CaO	0·80'

[1] In metric tons.
[2] Data for year ending 30th September.
[3] *Mineral Industry*, XXXIX, p. 65 (1931).

It is not known whether or not the hopes of Soviet Russia were realised.[1] Certainly it has not captured the Indian market from Germany.

It will be seen that India's production forms an insignificant part of the world's production of that mineral and is little more than one per cent. of the production of either Germany or the United States.

Distribution to Provinces of the Imports of Barytes into India.

Returning to the matter of the imports of barytes into India, the question naturally arises as to where the majority of the imported mineral is consumed.

Table VII below shows the distribution to provinces of barytes imported during the period 1913-14 to 1931-32, the figures being extracted from the 'Annual Statement of the Sea-Borne Trade' issued by the Director-General of Commercial Intelligence and Statistics, Calcutta.

TABLE VII.—*Distribution to provinces of imports of barytes into British India.*

Financial year.	Barytes imported to: Bengal.	Bombay.	Burma.	Madras.	Sind.	Total barytes imported into British India.
	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.
1913-14	4,084	902	..	..	..	4,986
1914-15	736	160	..	..	..	896
1915-16	1,008	..	..	..	..	1,008
1916-17	218	..	..	..	..	218
1917-18	892	..	..	..	..	892
1918-19	..	..	..	..	..	..
1919-20	..	..	..	..	..	..
1920-21	4,673	249	..	..	..	4,922
1921-22	320	594	3	..	..	917
1922-23	107	1,970	..	..	..	2,077
1923-24	6,133	2,647	..	..	..	8,780
1924-25	6,153	925	..	..	..	7,078
1925-26	20,627	1,201	..	..	..	21,828
1926-27	25,878	2,347	4,100	..	3	32,328
1927-28	29,576	3,284	1,002	..	..	33,862
1928-29	22,702	9,215	..	98	..	32,015
1929-30	32,568	7,903	41,379	205	..	82,055
1930-31	15,924	8,216	51,711	196	51,583	127,630
1931-32	5,407	8,327	4,943	749	35,436	54,862

[1] Russia imported barytes, witherite and barium salts during the years 1928-1930 [*see* Statistical Summary, Imperial Institute, p. 45, (1931)].

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It will be seen from the figures in this table that, generally speaking, until the years 1929-30 and 1930-31, most of the barytes has been imported into Bengal, with a smaller, but fairly constant, supply to Bombay. In 1929-30, the large quantity of 41,379 cwts. of barytes was imported into Burma for use in the oilfields of Upper Burma. In 1930-31, 51,583 cwts. of barytes was imported into Sind, presumably to be used in the oilfields of the Punjab, and an almost equal amount (51,711 cwts.) was imported into Burma during the same financial year.[1]

Increasing amounts of barytes used in the oilfields.

Madras has imported very small amounts of barytes since 1928-29.

It is presumed that most of the Bengal imports have been used in local paint works, but a large part of that imported in latter years must have found its way to Assam for use in rotary drilled wells there (*see* p. 125).

Consumption of Barytes in India.

The time is now opportune for noting the total consumption of barytes in India, as indicated by the total imports *plus* production. According to such statistics that are available, there are no records of barytes having been exported from India.[2] Thus it may be presumed that the total production has been consumed locally.

No records of barytes exported from India.

TABLE VIII.—*Consumption of barytes in India.*

Year.	Imports.		Production.		Consumption (= Imports + Production).	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Cwts.	Rs.	Cwts.	Rs.	Cwts.	Rs.
1917	90	42	..	..	90	42
1918	802	742	54,480	44,215	55,282	44,957
1919	..	..	51,800	15,615	51,800	15,615
1920	3,067	40,270	13,560	15,528	16,627	55,798
1921	2,769	31,399	33,820	52,283	36,589	83,682
1922	1,590	8,708	47,840	48,000	49,430	56,708
1923	5,172	25,336	51,400	42,749	56,572	68,085

[1] The first importation into Burma was 3 cwts. in 1921-22, following which there was a pause till 1926-27, when 4,100 cwts. were imported. The jump to 41,379 cwts. in 1929-30 was very sudden.

[2] *See* p. 71. No figures are available of the exports of barytes from Goa.

TABLE VIII (contd.)—*Consumption of barytes in India.*

Year.	Imports.		Production.		Consumption (= Imports + Production).	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Cwts.	Rs.	Cwts.	Rs.	Cwts.	Rs.
1924	9,080	36,704	46,060	31,341	55,140	68,045
1925	19,775	80,712	29,000	17,660	48,775	98,372
1926	26,532	1,03,469	46,220	9,244	72,752	1,12,713
1927	33,374	1,31,564	34,380	9,890	67,954	1,41,454
1928	35,412	1,12,814	61,920	19,610	97,332	1,32,424
1929	56,523	1,74,261	75,000	22,739	131,523	1,97,000
1930	115,695	2,98,200	135,940	49,562	251,635	3,47,762
1931	90,591	2,60,695	113,080	43,206	203,671	3,03,901
1932	43,455	99,615	54,220	27,381	97,675	1,26,996

In the table given above, the figures for the imports of barytes into India are for calendar years, as opposed to those for financial years given in Tables V and VII on pages 130, 131 and 133 respectively. They have been taken from the 'Accounts relating to the Sea-Borne Trade and Navigation of British India', for various calendar years, published by the Department of Commercial Intelligence and Statistics, Calcutta. It will be noted that they are not strictly in agreement with those for the financial years inasmuch as no figures have been listed for the financial years 1913-14 to 1916-17 inclusive. However that may be, the figures, as given, have been included in the table, together with those of production given in Table III in long tons, and now converted into hundredweights.

One striking feature of Table VIII is the fact that since production commenced in India (in 1918), in no single year have the imports of barytes exceeded the total production. However, since 1925, the surplus margin of production over imports has largely decreased, and in the year 1927, the barytes produced in India exceeded that imported only by 1,006 cwts.

Production of barytes greater than imports.

The increase in the consumption of barytes in India has been more or less regular. From an initial consumption in 1918 of 55,282 cwts., it reached the maximum figure of 251,635 cwts., worth Rs. 3,47,762, in 1930. It is thought

Regular increase in consumption.

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that had it not been for the financial depression, the consumption of barytes in India would have remained more or less about that figure. The value of barytes consumed in India in 1931 was over three lakhs of rupees, but there was a great falling off in consumption in 1932.

Values and Prices of Barytes.

Perhaps the most conspicuous feature of Table VIII is the variation in value of the barytes, both imported and locally produced. The 90 cwts. of barytes imported in 1917 had a value of less than Re. 0-8-0 per cwt. In 1920, imported barytes increased in value to an average of about Rs. 13 per cwt. Wide variations in value may be noted in succeeding years, that in 1931 working out at about Rs. 2-14 per cwt.

Variation in value of barytes, imported and produced locally.

The variation in value of the locally produced barytes, though less than in the case of the imported article, shows what difficulties have beset the industry. The initial production (1918) had an average value of approximately Re. 0-13 per cwt. (Rs. 16-4 per ton). The maximum average value of Rs. 1-9 per cwt. (Rs. 27-4 per ton) was attained in 1921. The average value in 1931 was about Re. 0-6 per cwt. (Rs. 7-8 per ton). Reference may also be made in this connection to Table IV wherein the variation in value of barytes produced in the Madras Presidency from mines worked under the Mines' Act has been well shown. The maximum value of Rs. 29-9-0 per ton in 1922 may be compared with the minimum value of Rs. 4-0-0 per ton in 1926. These are pit's mouth prices, but there are no registered sales at the pit's mouth in the Kurnool district at least. Accordingly the values are considerably less than the prices F. O. R. the nearest railway, and much less than those F. O. R. Calcutta.

Different values for Kurnool and Alwar barytes.

A glance at Table III (p. 128) shows that very varying values have been given for Kurnool barytes when compared with barytes from Alwar State produced in the same year. Thus in 1922, barytes produced in Alwar was valued at Rs. 10 per ton, which may be compared with that produced in the Kurnool district, which was valued at just under Rs. 24 per ton; on the other hand, barytes produced in the Kurnool district in 1930 had an average value of Rs. 7-9-0 per ton in 1930, whilst that from Alwar State had an average value of Rs. 6 per ton.

Sale prices of barytes.

Table IX below gives the official sale prices per ton of barytes from 1919 to 1930 for the three grades of barytes produced in the Kurnool district. In this connection, it must be remembered that with the crude marketing methods at present in vogue, approximately 96 per cent. of the barytes produced in the district is classed as third grade. The prices for 1930 are definitely F.O.R. despatching stations and it is thought that the prices for other years are the same.

TABLE IX.—*Sale prices per ton of barytes in the Kurnool district.*

Year.	1st grade.	2nd grade.	3rd grade.
	Rs.	Rs.	Rs.
1919	40	32	30
1920	40	28	10
1921	40	25	10
1922	40	15	10
1923	36	18	10
1924	32	18	10
1925	25	18	10
1926	25	15	10
1927	25	15	10
1928	25	18	10
1929	25	18	14
1930	25[1]	20[1]	15[1]

In 1931 and 1932, the prices per ton F.O.R. despatching stations in the Kurnool district were :—

	1931	1932
A grade	Rs. 25	Rs. 24
B „	10 to 13	10 to 13

In 1932, the prices per ton of Kurnool district barytes F.O.R. Madras were Rs. 36 for first grade and Rs. 21 for second grade.

In Table X below, a statement is given of the sale prices per ton F.O.R. of the various grades of barytes produced in the Cuddapah district during the years 1930, 1931 and 1932.

[1] F.O.R. despatching stations.

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TABLE X.—*Sale prices per ton of barytes produced in the Cuddapah district.*

Year.	Remarks.	1st grade.	2nd grade.	3rd grade.
		Rs.	Rs.	Rs.
1930	(*a*)	68	42	36
	(*b*)	50	40·5	..
1931	(*a*)	58	38	30
	(*b*)	48	..	..
1932	(*a*)	45	32	..
	(*b*)	46	..	..

Prices marked (*a*) were quoted by Mr. Thomas Tiffin and are from Cuddapah to Howrah (Calcutta) and are inclusive of railway freight. Those marked (*b*) were quoted by Mr. A. Krishnappa and are from Cuddapah to Nihatti (Eastern Bengal Railway) and are inclusive of railway freight.

In 1929, Messrs. Hoyle, Robson, Barnett and Co. (India), Ltd., of 26, Middle Road, Entally, Calcutta, stated that the prices of their ground barytes were as under :—

Prices in Calcutta.

Hoyle's White Barytes—Rs. 4 per cwt.
Hoyle's White Seal Snow White Barytes—Rs. 5 per cwt.
Packages. New Gunny Bags free.
Delivery. F.O.R. Sealdah station, Calcutta.

They added that the above prices were for the best qualities of pure barytes only, ground to a fineness that will pass 100 per cent. through a 250-mesh sieve on their Raymond mill. Also that the grinding of their Raymond mill is very much finer than that of the old flat stone mill.

In the same year, Messrs. H. Rolfe and Co. of Post Box 186, Calcutta, quoted Rs. 45 per ton for first-class white barytes in lumps, F.O.R. Calcutta.

Messrs. Turner, Morrison and Co., Ltd., the managing agents of the Shalimar Paint, Colour and Varnish Co., Ltd., have been kind enough to give the following information :—

Prices (September, 1932) F.O.R. Calcutta for untreated lump Indian barytes :—

	Per ton. Rs.
(*a*) Cuddapah district—	
White	45
Coloured	42
(*b*) Kurnool district—	
Assorted (selected and scraped)	45—50
Coloured	30
(*c*) Alwar State—	
Off colour	26

Messrs. The Shalimar Paint, Colour and Varnish Co., Ltd., do not themselves import barytes, but understand that approximate landed costs for the ground material, duty paid, packed in bags, for large quantities, before the departure from the gold standard were :—

	Per ton. Rs.
White	75
Grey	60

The managing agents added that since there is no regular market in India for barytes, it is impossible to give average prices over three years. Roughly speaking, prices of Indian barytes have fallen by Rs. 5 per ton during the last three years owing to the opening of new mines and diminution in demand due to bad trade. They do not know of any barytes imported into India since the departure from the gold standard ; the quotations which have come to their notice have been irregular and do not represent real business.

Prices in the United Kingdom.

According to Coggin Brown[1] :—

'Before the war the best quality of very finely ground German snow-white barytes is said to have been obtainable at about £3-10 per ton c.i.f. United Kingdom ports. It is now (1922) being offered at £11 per ton c.i.f. packed in free casks. Current quotations for ground English No. 1 White barytes are about £11 per ton, delivered in free bags. The lower grades ar worth about £5 to £8 per ton. Brown Belgium barytes ground and packed in casks can be obtained for £4 per ton and medium white grades for about £6 per ton.'

The variation in price of barytes during the past seven years, as quoted by the *Mining Magazine*, may be seen in the following

[1] *Op. cit.*, p. 11, (1922).

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table (Table XI). The *Mining Magazine* gives one price and does not differentiate between the various grades.[1] The *Chemical Trade Journal and Chemical Engineer* gives the limits (as, *e.g.*, for 22nd July, 1932, the price of barytes is given as from £7-10-0 to £9 per ton).

TABLE XI.—*Price per ton of barytes as quoted by the* Mining Magazine.

Month.	1926.	1927.	1928.	1929.	1930.	1931.	1932.
	£ s.	£ s.	£ s.	£ s.	£ s.	£ s.	£ s.
January . .	7 0	6 0	6 0	6 0	5 0	6 15	7 15
February . .	7 0	6 0	6 0	6 0	5 0	6 15	7 15
March . . .	7 0	6 0	6 0	6 0	5 0	6 15	8 5
April . . .	7 0	6 0	6 0	6 0	5 0	6 15	8 5
May . . .	7 0	6 0	6 0	6 0	5 0	6 15	8 5
June . . .	7 0	6 0	6 0	6 0	5 0	6 15	8 5
July . . .	7 0	6 0	6 0	6 0	5 0	6 15	8 5
August . .	6 0	6 0	6 0	6 0	5 0	6 15	8 5
September . .	6 0	6 0	6 0	5 0	5 0	6 15	8 5
October . .	6 0	6 0	6 0	5 0	5 0	6 15	8 5
November . .	6 0	6 0	6 0	5 0	5 0	7 15	8 5
December . .	6 0	6 0	6 0	5 0	6 15	7 15	8 5
Average price per ton.	6 12	6 0	6 0	5 13	5 3	6 17	8 3

Royalty and Import Duty on Barytes.

The present royalty on barytes produced in the Kurnool district of Madras is five annas per ton. Prior to the 20th February, 1930, it was twelve annas per ton. The free allowance of barytes exempt from royalty on each prospecting licence is half a ton. The corresponding figures of the Alwar State are not known.

Royalty on barytes produced in India.

Barytes imported into India is subject to an import duty of 25 per cent. *ad valorem* under 'Painters' materials, all sorts' (Serial No. 91).

Import duty on barytes.

[1] From February, 1932, onwards, the price is that of barytes. Before this date, the price given is that of 'Barium sulphate (94 per cent. $BaSO_4$)'. It is interesting to note that in the *Mining Magazine* for the month of January for the years 1922-25 inclusive, the price of 'barium sulphate' of the same purity is £7 per ton except for January, 1922, when it was £8 per ton.

The Outlook for Indian Barytes.

What of the future? Is the outlook for Indian barytes bright or otherwise? Should local producers try to increase their local market to the detriment of the present import trade of barytes into India? Or should they try to capture, or at any rate invade, foreign markets? Coggin Brown's notes in this connection may be quoted[1]:—

Notes by Coggin Brown.

'It is exceedingly doubtful whether prepared barytes produced in India could compete in the markets of the United Kingdom against material from these nearer sources (United Kingdom, Belgium, France, Italy, Spain, Germay and the United States), owing to the cost of transporting it to the coast and the necessarily higher freights from India.

The possibilities of the large-scale exploitation of the Indian barytes deposits appear to depend, therefore, on the future expansion of the paint and colour industry in India itself. The actual imports of powdered barytes at present do not warrant the expenditure which would be entailed in the erection of a modern milling plant to grind the mineral into suitable condition for industrial purposes. To be acceptable to the paint maker very close control of the milling operations is necessary in order to ensure the essential uniformity of the different grades.

There is no reason to suppose that the Indian barytes deposits are not large enough to meet any demand which is likely to be made upon them in the future.'

The present author agrees with Coggin Brown that it is improbable that Indian barytes could compete in Home markets with the foreign or local product. It therefore behoves the Indian producer to turn his attention to the capturing of the present import trade of barytes into India. There, however, he is up against a fundamental difficulty immediately, *viz.*, long railway distances and consequent heavy freight charges. It is indeed extremely unfortunate that all the main deposits of India appear to be far removed from the consuming centres. Without any doubt, the deposits of the Ceded districts of Madras described in this memoir may be considered as possessing the largest reserves of barytes in India. Their development is at present only in its infancy and there is much scope for further increase. The deposits can supply the needs of India on her present rate of consumption for some years to come. The total barytes consumed in India in 1930[2] was just over 12,580 tons (*see* Table VIII, p. 135), of which over 5,780 tons were imported. Turning to actual figures of the reserves available, it will be remembered that for deposits No. 14, at Kottapalle in the Pulivendla taluk, it was estimated that there were

Disadvantage of long railway transport.

Reserves of barytes.

[1] *Op. cit.*, pp. 17-18, (1922).
[2] 1930 is the year of maximum consumption.

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probably many times 30,000 tons of barytes available according to whether or not the vein there persisted in depth (p. 21). For the Nerijamupalle deposits in the Tadpatri taluk, it was stated that more prospecting would have to be undertaken before one could be sure that there were more than 6,000 tons of barytes available (*see* p. 33). And for the Mutssukota deposit in the same taluk, provided certain assumptions were correct, a quantity of 75,500 tons of barytes was estimated (p. 36). These estimates are for only three important deposits, and there are numerous others (Ramapuram, Nos. 59 and 60, pp. 54-55; Valasala, No. 72, p. 60; Rahimanpuram, No. 86, p. 64; Balapalapalle, No. 104, pp. 71-72; Gattimanikonda, No. 114, p. 77; etc.) for which no figures have been given.

Provincial consumption of barytes.

Where is the barytes consumed in India? There has always been a steady demand for barytes in Bengal and Bombay for the paint industry. It would appear, however, that Coggin Brown's anticipation that the future of the barytes deposits in India will depend on large increases in this industry has not been realised, inasmuch as the new demand for barytes for weighting the mud fluid in rotary drilling has by far surpassed all requirements for the paint industry. The barytes for this new use has to be transported to far away parts of the Punjab, Assam and Upper Burma.

It is most improbable that the Madras barytes will ever be able to compete successfully with foreign barytes in Sind and the Punjab as the railway freights from the producing centres to these places are excessive. Alwar State, Rajputana, is far better situated as regards these markets. However, the Madras barytes has the advantage over the Alwar deposits as regards Calcutta and Assam, but the nearer deposits in Bihar and Orissa are more favourably situated. The Geological Survey of India is continually receiving requests for information as to new deposits of barytes within less than 500 miles from Calcutta; and any such deposit of good quality and present in sufficient quantity would have its future assured.

Apparently the needs of the various oil companies in Burma are being met by importation of barytes. It would appear, however, that the deposits of that mineral in the Amherst district and other parts of India have not received the attention that they deserve. There is no apparent reason why Madras barytes, with a short rail journey to Madras, should not be transported by sea to Rangoon, and sold at a price to compete successfully with the foreign product.

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(Compiled by A. B. Dutt).

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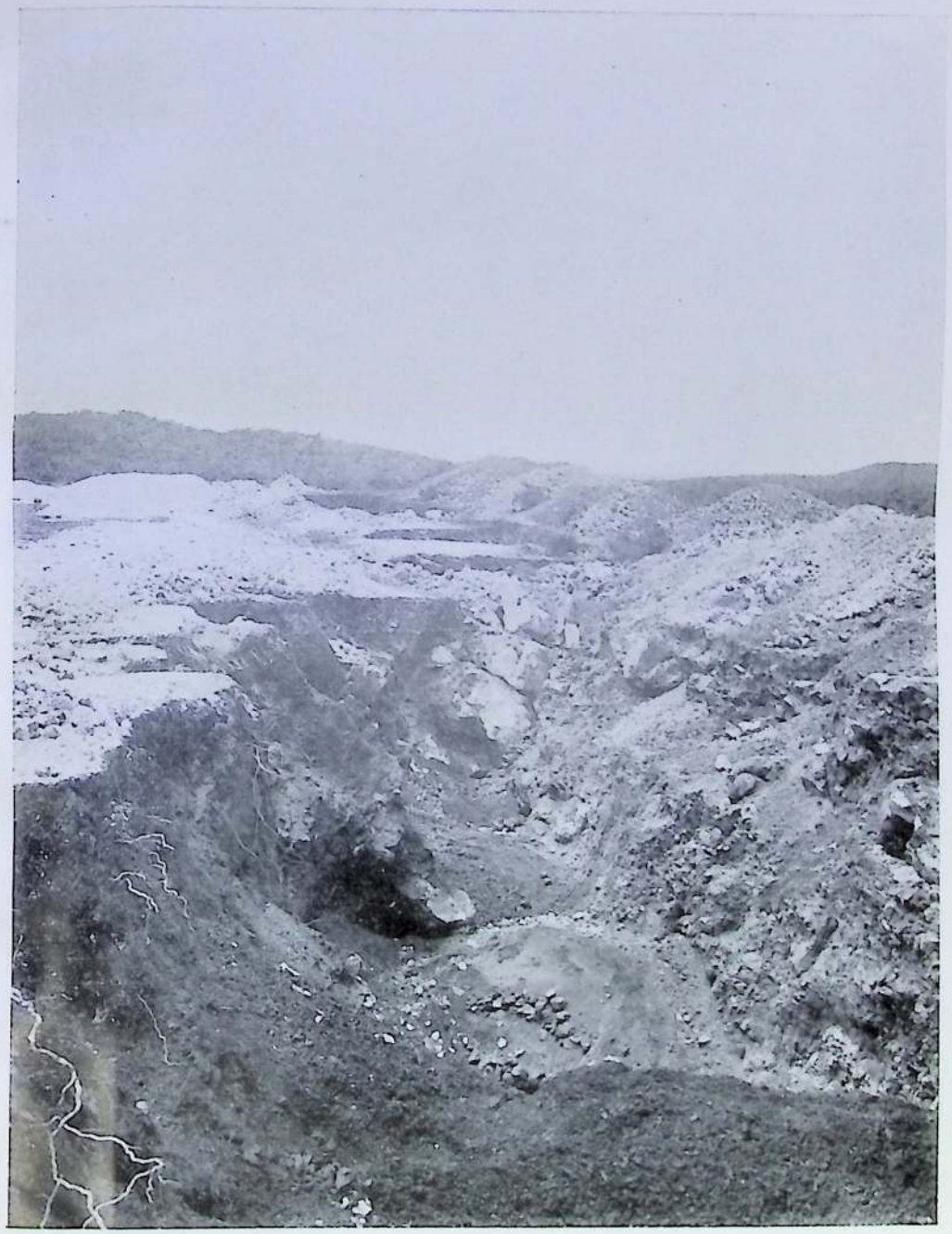
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MGIPC—M—VIII-4-18-11-8-33—750.



C. S. Fox, Photo. *G. S. I., Calcutta.*

BARYTES DEPOSIT No. 13, OCCURRING IN BASALT 2⅛ MILES S. BY W. OF GONDIPALLE, PULIVENDLA TALUK, CUDDAPAH DISTRICT.

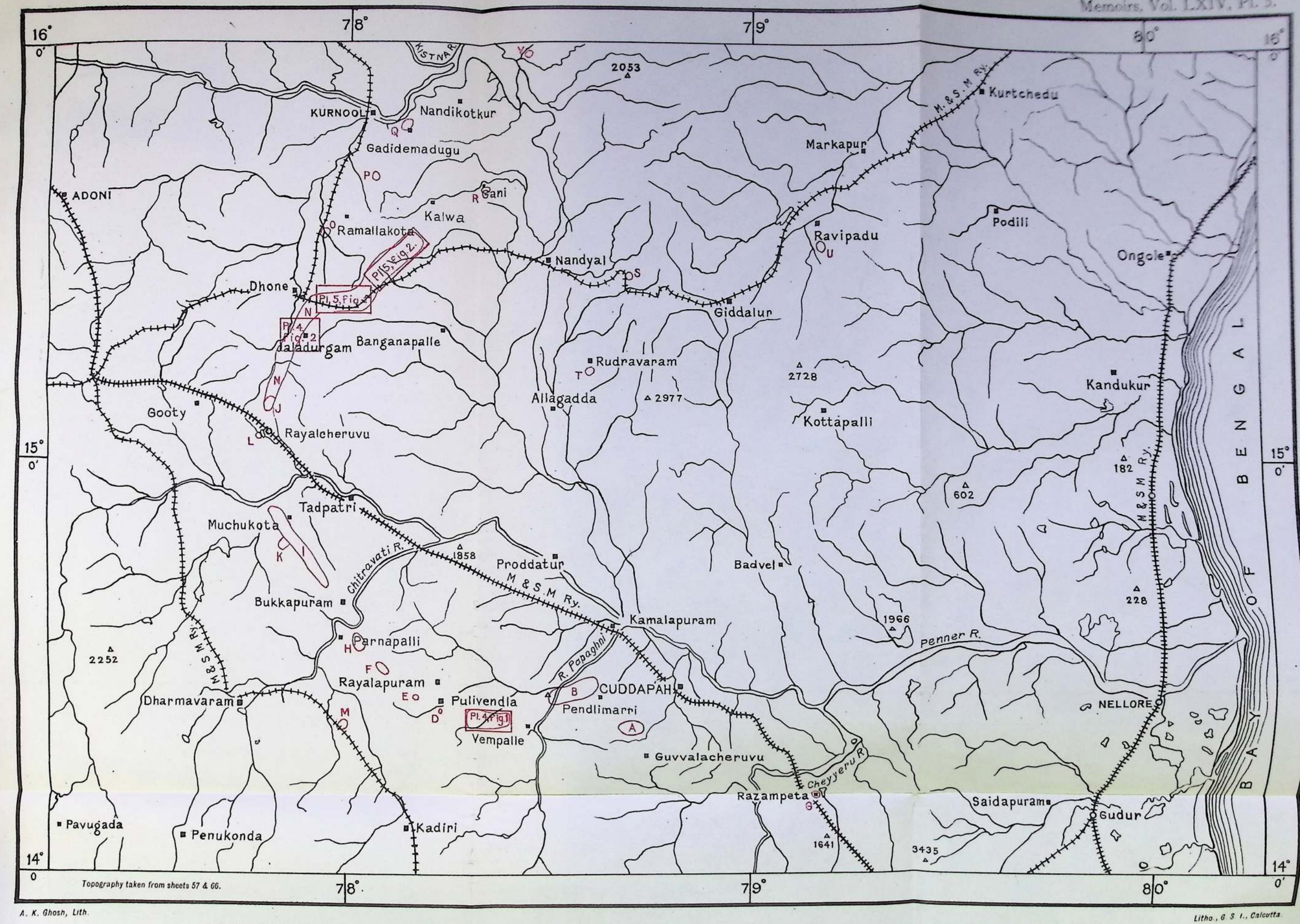
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BARYTES DEPOSIT No. 13, OCCURRING IN BASALT 2¼ MILES S. BY W. OF GONDIPALLE, PULIVENDLA TALUK, CUDDAPAH DISTRICT.

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Litho., G. S. I., Calcutta.

MAP SHOWING THE DISTRIBUTION OF BARYTES DEPOSITS IN THE CEDED DISTRICTS OF MADRAS AND THE POSITIONS OF THE MAPS FORMING PLATES 4 AND 5.

By A. L. COULSON, GEOLOGICAL SURVEY OF INDIA.

Scale, 1 inch = 16 miles.

The deposits have been described in the text under the following numbers—

A	Deposits	1-4	E	Deposit	30	I	Deposits	35-42	M	Deposit	48	Q	Deposits	126-129	U	Deposit	134
B	,,	5-11	F	,,	31	J	,,	43-44	N	Deposits	49-122	R	,,	130-131	V	,,	135
C	,,	12-28	G	,,	32	K	,,	45-46	O	Deposit	123	S	Deposit	132			
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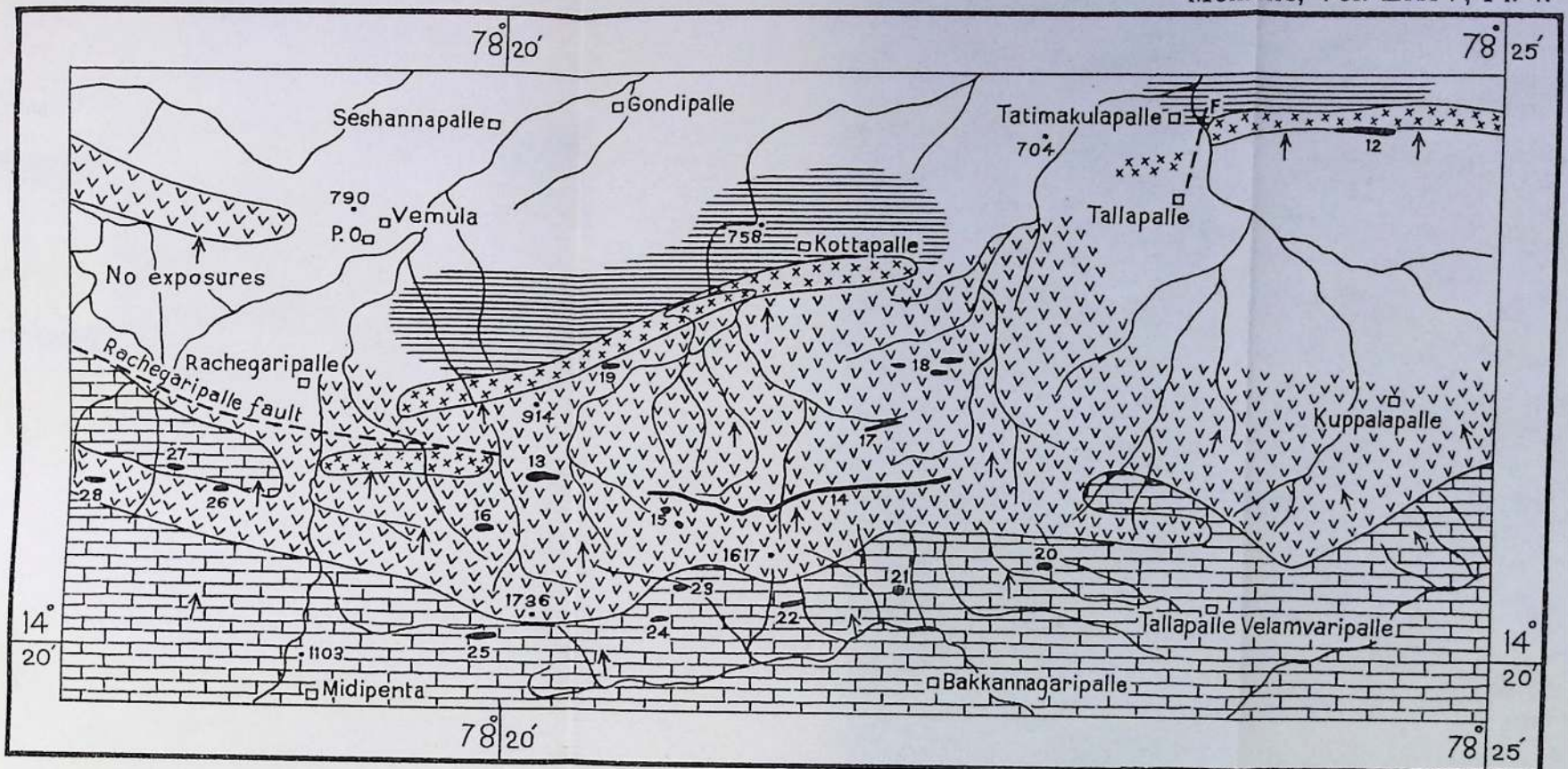


Fig. 1. Geological sketch map of part of sheet 57 J/7, showing the distribution of the barytes deposits (Nos. 12-28) in the vicinity of Kottapalle, Pulivendla taluk, Cuddapah district.

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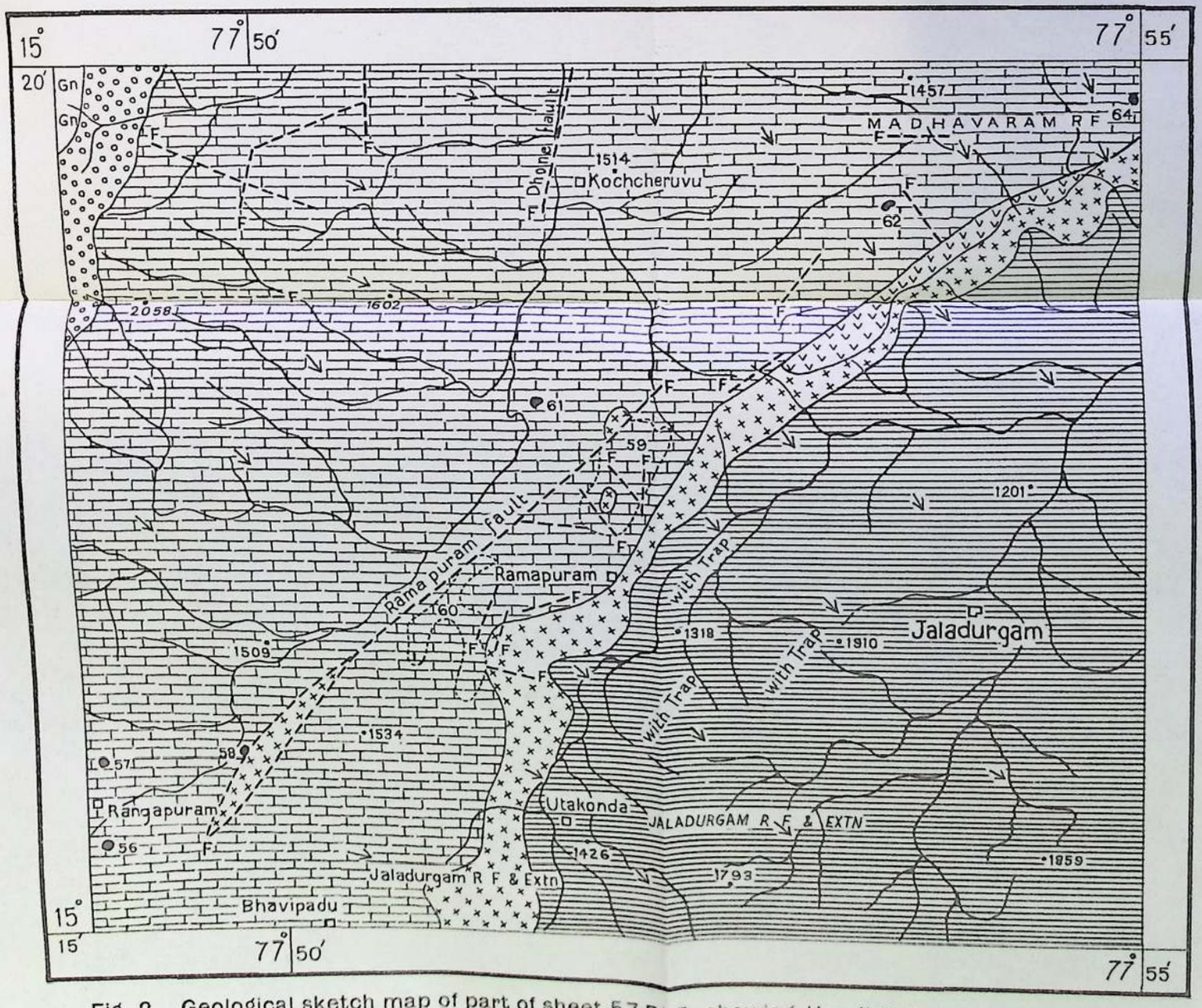


Fig. 2. Geological sketch map of part of sheet 57 E/15, showing the distribution of the barytes deposits (Nos. 56-62 and 64) in the vicinity of Ramapuram, Dhone taluk, Kurnool district.

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- Not mapped or Alluvium
- CHEYAIR SERIES
  - Tadpatri shales
  - Pulivendla quartzites
- PAPAGHNI SERIES
  - Vaimpalli limestones
  - Gulcheru quartzites

Unconformity.

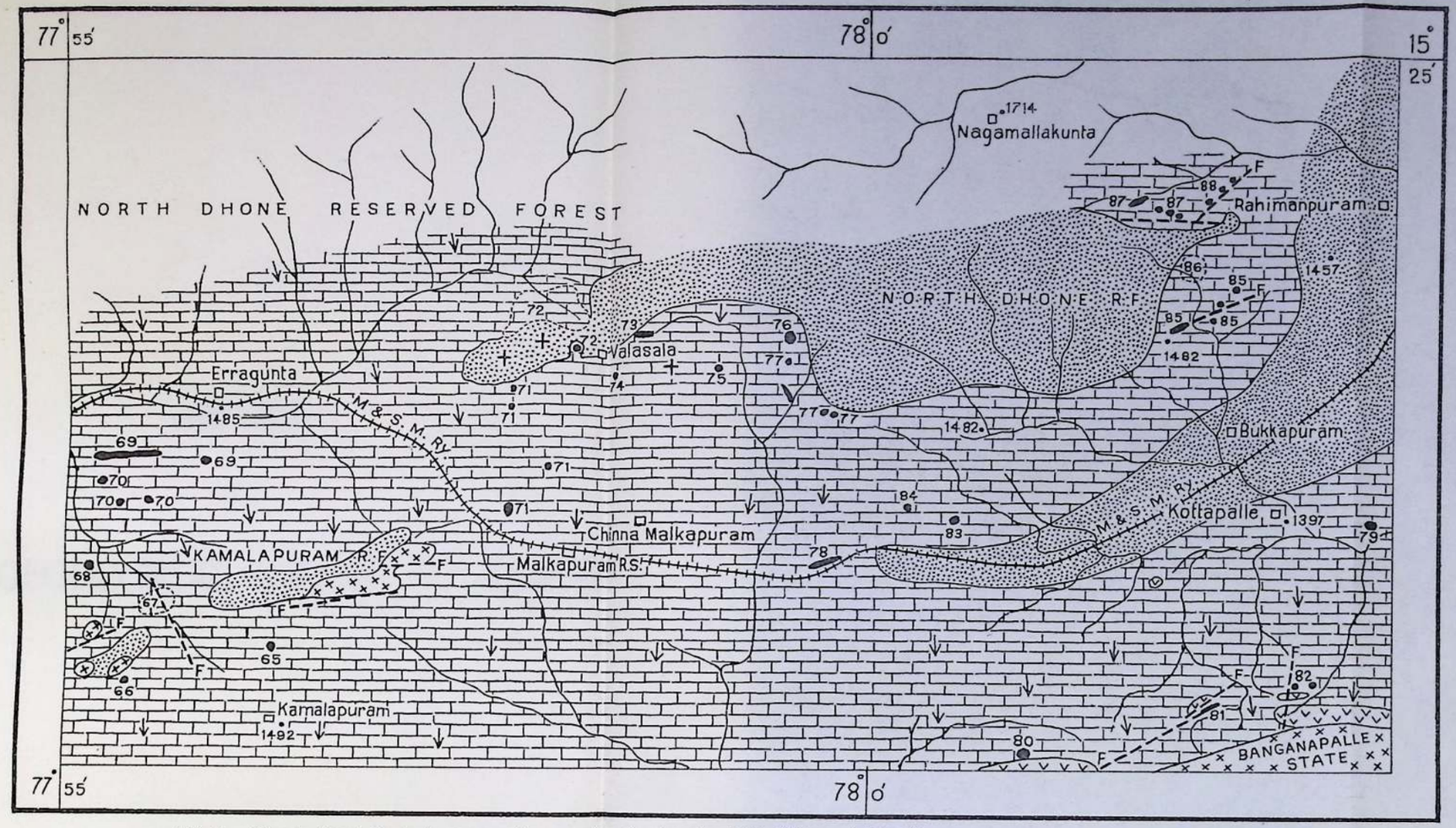
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- Intrusive trap sills
- Barytes deposits — 14
- Areas with abundant barytes — 59
- Faults — F

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Scale, 1 inch = 1 mile.

The numbers of the deposits are those in the text.

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INDEX.

- Not mapped
- KURNOOL SERIES
  - Jammalamadugu limestones
  - Banganapalli sandstones

Unconformity.

- CHEYAIR SERIES
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  - Pulivendla quartzites
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Scale, 1 inch = 1 mile.

The numbers of the deposits are those in the text.

Fig. 1. Geological sketch map of parts of sheets 57 E/15 and 57 I/3, showing the distribution of the barytes deposits (Nos. 65-88) in the vicinity of Valasala, Dhone taluk, Kurnool district.

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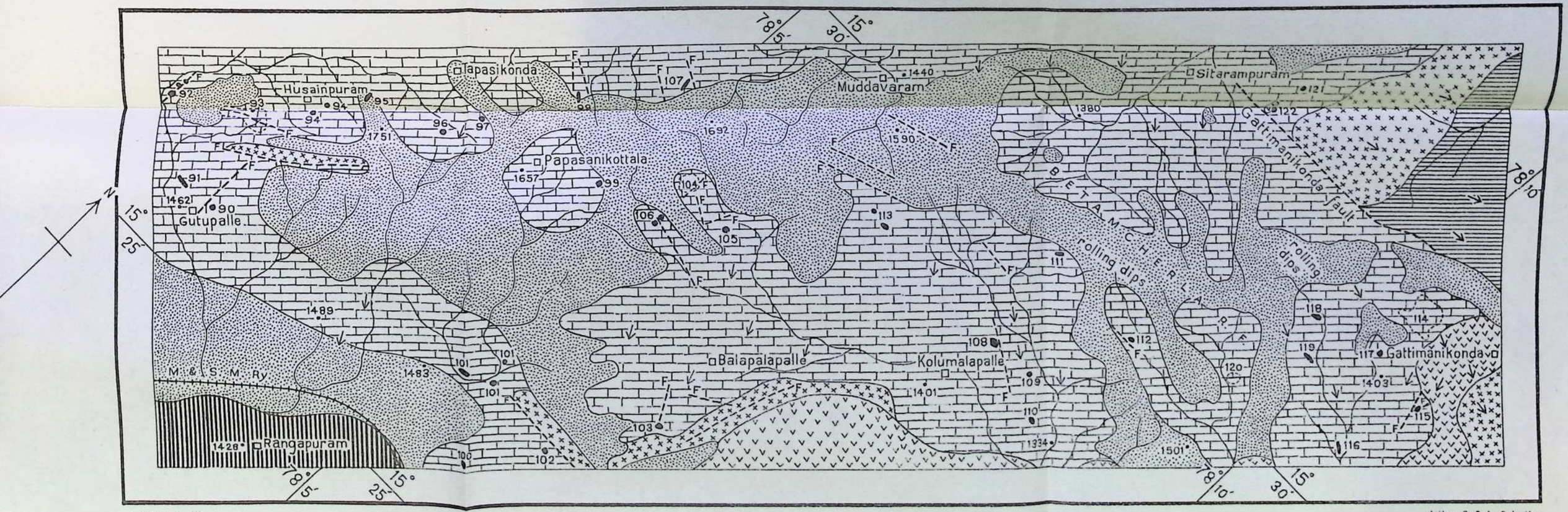


Fig. 2. Geological sketch map of parts of sheets 57 I/2 and 57 I/3, showing the distribution of the barytes deposits (Nos. 90-122) in and near the Betamcherla reserved forest, Dhone taluk, Kurnool district.

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VOLUME LXIV, PART 2.

ASBESTOS IN THE CEDED DISTRICTS OF THE MADRAS PRESIDENCY: WITH NOTES ON ITS OCCURRENCE IN OTHER PARTS OF INDIA. BY A. L. COULSON, D.Sc., (MELB.), D.I.C., F.G.S., *Assistant Superintendent, Geological Survey of India.* (With Plates 6 to 10.)

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CALCUTTA: SOLD AT THE CENTRAL BOOK DEPÔT, 8, HASTINGS STREET, AND AT THE OFFICE OF THE GEOLOGICAL SURVEY OF INDIA, 27, CHOWRINGHEE ROAD.

DELHI: SOLD AT THE OFFICE OF THE MANAGER OF PUBLICATIONS.

1934.

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FIG. 3.—Geological sketch map (parts of sheets 57 E/15 and I/3) of parts of the Dhone taluk of the Kurnool district and of Banganapalle State, showing the position of the asbestos occurrence in the vicinity of Malkapuram. Scale, 1 inch =1 mile.

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ASBESTOS IN THE CEDED DISTRICTS OF THE MADRAS PRESIDENCY: WITH NOTES ON ITS OCCURRENCE IN OTHER PARTS OF INDIA.

BY A. L. COULSON, D.Sc., (MELB.), D.I.C., F.G.S., *Assistant Superintendent, Geological Survey of India.* (With Plates 6 to 10.)

CHAPTER I.

INTRODUCTION.

General.

This memoir is complementary to that by the same author, entitled 'Barytes in the Ceded Districts of the Madras Presidency: with notes on its occurrence in other parts of India', which forms Part 1 of this Volume (LXIV) of the *Memoirs of the Geological Survey of India*. It has been found impossible to avoid a certain amount of repetition; but to reduce this to a minimum, numerous cross-references have been given. With the aid of these, the interested reader will be able easily to gain such additional information concerning any particular area which he may require. It is realised that, generally speaking, he who is interested in asbestos has but little interest in barytes, and *vice versâ*. No one wishes to purchase a memoir containing much matter irrelevant as far as he is concerned. Accordingly it has been the aim of the author to make each part of Volume LXIV independent of the other as far as possible, and in this he has been assisted by Nature inasmuch as those areas rich in barytes were found to contain no asbestos. However, it must always be remembered that both the barytes and

Memoir complementary to memoir on barytes.

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asbestos deposits are very intimately connected with the Vaimpalli shales and limestones of the Papaghni series of the Cuddapah system, and with the intrusive doleritic and basaltic sills associated with those rocks.

This paper is concerned primarily with the Cuddapah, Anantapur and Kurnool districts, which are three of the four Ceded or Deccan districts of Madras, Bellary district being the fourth. Except for four taluks[1] of the Kurnool district, these four districts were ceded in 1800 to the Hon'ble the East India Company by His Exalted Highness the Nizam of Hyderabad. It will be seen that no asbestos has been found to occur in the Anantapur district, which, generally speaking, lies between the Cuddapah and Kurnool districts. As the rocks with which we are intimately concerned, *viz.*, the Vaimpalli limestones and their associated igneous sills, were followed along their strike from Cuddapah through the Anantapur district to Kurnool in the north, a description of the Anantapur outcrops has been given in Chapter III. It will be seen therein that the existence of asbestos in the Anantapur district, although improbable, is certainly not impossible.

The Ceded or Deccan districts.

The Cuddapah, Anantapur and Kurnool districts lie between Hyderabad on the north, being bounded by the Kistna river and its tributary the Tungabhadra, and Mysore State and the Chittoor district to the south. They also lie between Mysore State and Bellary district to the west and the Guntur and Nellore districts to the east.

The author's investigation of the asbestos deposits of the Ceded districts of the Madras Presidency was undertaken under the orders of the Director, Geological Survey of India, at the request of the Government of Madras, in consequence of recommendations made by his colleague, Dr. C. S. Fox. This officer paid a visit to the deposits of asbestos near Brahmanapalle (57 J/3[2]; 14° 25′ 30″ : 78° 12′) in the Pulivendla taluk of the Cuddapah district in connection with the mining laws in so far as they affected leases for the mining of asbestos. His report has not been published, except for a brief mention in the General Report of the

Deputation.

Dr. C. S. Fox.

[1] Taluk is an administrative subdivision. In other parts of India, it is frequently called a tahsil.

[2] Numbers such as 57 J/3 refer to the modern one-inch map sheets of the Madras Topographical Survey.

Geological Survey of India for 1930. The present author, however, has had access to Dr. Fox's notes and it will be found that due acknowledgment has been made where they have been used.

The following quotation regarding the occurrence of asbestos contains Dr. Fox's recommendations referred to above:—

> 'It is to be remembered that I have only seen about nine miles of the outcrop and this is obscure in several places and dislocated in one. There is a curious regularity in the association of the dolerite sill at the base of one particular dolomitic limestone. How far to the north-west of Lingala or south-east of Brahmanapalle this horizon may be traced is not yet known. The Vaimpalli stage, with its limestones and associated igneous intrusions, extends from south of Cuddapah town to the Tungabhadra river beyond Kurnool. The distance on the curve of the outcrop is not far short of 100 miles. In this belt of rocks, search may be profitably devoted to any zone in which intrusive dolerites are seen to underlie siliceous dolomitic limestone.'

The author's field work was conducted from December, 1931, to the end of March, 1932. He was accompanied by Mr. P. N. Mukerjee, Extra Assistant Superintendent, in the Anantapur and Kurnool districts from the middle of January to the end of his field work. One-inch sheets of the Madras Topographical Survey were utilised. All lie in sheet 57 and within degree (quarter-inch) sheets 57 E, 57 F, 57 I, and 57 J. The numbers of the one-inch sheets are given in parenthesis after each village and before the latitude and longitude.

Field work.

List of Geological Formations.

Very frequent reference will be made in this memoir to King's classical description of the rocks of the Cuddapah system and of the Kurnool series.[1] The following is the classification of these rocks adopted by him, the spelling of the various names being in accordance with Sir Thomas Holland's memoir on 'Indian Geological Terminology',[2] or the 'Manual of the Geology of India'.

King's classification.

VINDHYAN SYSTEM	KURNOOL SERIES	Kundair stage	Nandyal shales. Koilkuntla limestone.
		Paniam stage	Pinnacled Quartzites. Plateau Quartzites.
		Jammalamadugu stage	Auk shales. Narji limestones.
		Banganapalli stage	Sandstones and grits.

[1] *Mem. Geol. Surv. Ind.*, VIII, Pt. 1, (1872).

[2] *Op. cit.*, LI, Pt. 1, (1926).

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Large unconformity.

CUDDAPAH SYSTEM.	KISTNA SERIES .	Srisailam quartzites. Kolamnala slates. Irlakonda quartzites.

Unconformity.

NALLAMALAI SERIES	Cumbum slates. Bairenkonda quartzites.

Unconformity.

CHEYAIR SERIES .	Pullampet shales=Tadpatri shales. Nagari quartzites=Pulivendla quartzites.
PAPAGHNI SERIES .	Vaimpalli limestones and shales. Gulcheru quartzites.

Great unconformity.

ARCHAEAN	CRYSTALLINES.

It will be noted that no unconformity is given between the Papaghnis and the Cheyairs. This point has been discussed in detail in the author's barytes memoir [1] and reasons have been given for believing in the non-existence of this unconformity, said to be present by King.

Intrusive sills.

Intrusive sills of basic igneous rocks are associated with the Vaimpalli limestones and shales of the Papaghni series, and with the Pulivendla quartzites and Tadpatri shales of the Cheyair series. Reference should be made to pages 106-108 of the author's barytes paper [2] where the age of these sills is discussed and it is concluded that the sills in the Papaghnis and the Cheyairs were intruded in late or post-Cheyair, or Nallamalai, or immediately post-Nallamalai times. It is improbable that they were all intruded at one and the same time.

Stratigraphical Notes.

Vaimpallis.

Very frequent reference will be found in the text to the Vaimpalli limestones and shales, as these rocks have great importance from the point of view of the occurrence of asbestos. Before proceeding to the detailed description of the contacts between these limestones and the intrusive basaltic or doleritic sills, the following general account of the Vaimpallis may not be out of place.

[1] *Mem. Geol. Surv. Ind.*, LXIV, Pt. 1, pp. 6, 83, (1933).
[2] *Op. cit.*, p. 108.

The Vaimpallis rest perfectly conformably upon the Gulcherus, which constitute the basal stage of the Papaghni series and which rest unconformably upon the Crystallines.

Lower members.

Very commonly these basal members of the Vaimpallis are red ferruginous shales, several hundreds of feet thick (the total thickness of the Vaimpallis is over 3,000 feet). They are well exposed in the hills to the north-west of Parnapalle (57 F/14; 14° 34′ : 77° 58′) in the valley of the Chitravati river where that river cuts through the uptilted Cuddapahs. Indeed an excellent section through the Vaimpallis may be viewed along the road from Parnapalle to Velidandla (57 J/2). Another excellent exposure of the lowest members of the Vaimpallis is in the valley of the Penner river, further to the north, in the hills to the north-west of Chinna Yeckaluru (57 F/13; 14° 55′ : 77° 48′).

Upper members.

The upper Vaimpallis are more calcareous and comprise ferruginous, flaggy, siliceous, dolomitic, magnesian and normal limestones. Reference may be made to the analyses listed in Tables I and II, on pages 157 and 187, respectively. King has referred [1] to the chalcedonic bands of different colours found parallel to the bedding planes of the Vaimpalli limestones. The limestones themselves are generally very fine-grained, compact, and pale grey in colour, weathering to a light buff colour. The change of colour on weathering is very noticeable. Usually the beds of limestone have no great thickness and they are separated by thin shales or shaly limestone. In certain places, however, as in the Brahmanapalle region described later (pages 160-161), the limestones are sufficiently massive to form a stable roof very useful from the mining point of view.

Denudation of the Vaimpallis.

Special mention must be made here of the very characteristic way in which the Vaimpallis weather. The sketch given as Fig. 26 on page 167 of King's memoir illustrates the nature of the contoured hills formed by these rocks. The large hill $2\frac{3}{4}$ miles south of Tabjula (57 F/13; 14° 54′ 30″ : 77° 49′ 30″) is an almost perfect 'text-book' illustration of contouring of the surface by uniformly eastward-dipping beds. As King states,

[1] *Op. cit.*, p. 161. *See* also A. L. Coulson, *Mem. Geol. Surv. Ind.*, LXIV, Pt. 1, p. 115, (1933).

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'The beds are dipping at so low an angle—as a general rule, from 5° to 10°—that they often crop out all around a hill or series of hills, giving the country a most picturesque look, with its ringed and sinuously parallel-lined ridges. This peculiar feature is seen at intervals very well displayed, more particularly in the (Parnapalle) 'area, and again to the north of the Penn-air' (Penner river).

It is with those exposures of the upper members of the Vaimpallis, into which there are large sills of igneous material intruded, that we are particularly concerned. The nature of these sills will be gathered from the descriptions of the specimens collected and from the analyses listed in Table VIII on pages 224-225. Certain are of very large size; but it may be said safely that from the point of view of the occurrence of asbestos at their contacts with magnesian limestones, within limits, the smaller sills have a more productive effect than the larger.

Sills basaltic and doleritic in nature.

Possibilities of Asbestos being found associated with the Sills intrusive into the Cheyairs.

It may be asked whether or not asbestos has been, or is likely to be, found associated with the basic igneous rocks which have been intruded on a gigantic scale into the Pulivendla quartzites, or, more possibly, the Tadpatri shales, both of which stages are combined to form the Cheyair series. In the author's opinion, the answer is in the negative and in amplification of this view, the following notes may be seen.

Occurrence of asbestos in the Cheyairs unlikely.

In his unpublished report on the occurrence of asbestos in the Ceded districts of Madras, Dr. C. S. Fox states:—

Dr. Fox's notes.

'The Rajupalem occurrence indicates that chrysotile may also be found in strata of the Cheyair series at some horizons perhaps similar to those of Brahmanapalle in the Vempalle stage, *i.e.*, the zone of contact between dolerite sills and overlying dolomitic beds, limestones, or perhaps calcareous shales.'

But Dr. Fox had incorrectly taken the Rajupalem on sheet 57 J/10 (78° 33′ : 14° 33′) as the Rajupalem in question[1]; whereas it is situated on sheet 57 J/11 (14° 26′ : 78° 31′). As will in the description of the asbestos occurrences at Rajupalem, the deposits here

[1] He did not visit it.

are of the normal type, being at the junction of Vaimpalli limestones with intrusive doleritic sills.

Cheyair limestones.

The limestones found as bands in the Cheyairs have been described by King as follows[1]:—

'The lowest beds' (of the Tadpatris) 'for the longest part of the outcrop, that is, from its first appearance in the Poolavaindla hills west of Cuddapah up to the neighbourhood of Ryalcheroo north of the Penn-air river, are essentially slaty and calcareous shales of pale, purple, and grey colours. The beds are more calcareous as they are followed upwards in the series, until the bands of limestone are reached. These bands of limestones are interesting, as they show, perhaps more than any others in the series, evident signs of alteration, probably brought about by the outpouring of the great flow which overlies them. They are generally grey-colored and finely crystalline, in thick beds, and are laminated and segregated in a peculiar way, with seams of amorphous silicious matter between the segregations. The laminae are contorted, undulating or sinuous, which is not the case with the beds themselves: and these waving laminae are always strongest towards the upper surface of the beds, and in the upper beds. The annexed figures' (Fig. 29 in King's memoir) 'are from one of the beds near the village of Soorapully in the valley inside of the great Jootoor flow of trap some eight miles south of the Penn-air; and the same band of limestones shows all the way to the south with very much the same style of segregation.'

Many examples of these limestones were noted by the author. The upper surface usually consists of a number of circular depressions, on the circumferences of which the more resistant chalcedonic material rises above the general level of the more easily weathered calcareous matter.

Where these bands of limestone are metamorphosed by dolerite sills, a brittle, coarse, entirely worthless, asbestiform, shaly material is sometimes seen. Thus an occurrence of this kind was noted by the author 1½ miles north of Aravedu (57 J/2; 14° 38′ 30″ : 78° 0′) in the Tadpatri taluk of the Anantapur district, where a large trap sill overlies and metamorphoses a siliceous limestone which shows the characters described above by King.

As the general characteristics of these Cheyair limestones differ remarkably from the Vaimpalli limestones, and, also, as they do not seem to be of a nature suitable for the production of asbestos, it is thought that asbestos in workable quantity and of sufficient quality will not be found at the contacts between the Cheyair limestones and the traps intruded into this stage.

Cheyair limestones differ from Papaghni limestones.

[1] *Mem. Geol. Surv. Ind.*, VIII, Pt. 1, pp. 189-190, (1872).

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Occurrence of asbestos in olivine-dolerite.

In his interesting unpublished report, Dr. C. S. Fox states:—

'I found a small development of chrysotile in the olivine-dolerite which is exposed on the south side of the trap ridge west of Pulivendla Inspection Bungalow (78° 13′ : 14° 25′ 30″). The ridge appears to consist of a composite sill (three separate sills) of dolerite, the middle one, a dark, coarse, scoriaceous-weathering rock being rich in olivine, while the layers above and below it are dolerites without olivine. It is not surprising to find asbestiform serpentine in such an olivine-dolerite (? peridotite). This locality is on the Pullampet or Tadpatri stage (shales and thin limestones) of the Cheyair series. The only other known occurrence of olivine-bearing trap is that of Juturu or Jootoor (7° 55′ : 14° 56′ 30″) which was described by P. Lake forty years ago. It is practically on the same horizon as the dolerite of the Pulivendla ridge and is probably intimately related, but these olivine-bearing outcrops have not been actually traced from the one locality to the other.

Although it is possible that small deposits of chrysotile may be found in segregations along this belt of olivine-dolerite where serpentinisation has occurred, it is doubtful if there are any of considerable economic value—unless there is an association of dolomitic limestone somewhere along the outcrop.'

These observations of Dr. Fox have great interest and deserve amplification. The author collected specimens of the sill which bear out Dr. Fox's remarks. Thus the uppermost part of the sill (21780) [1] is perhaps best described as a quartz-dolerite. It is very similar to a specimen of what is undoubtedly the same sill (43·872[2], 21775) collected near the 38th mile-post on the Cuddapah-Pulivendla road, $1\frac{1}{4}$ miles W. N. W. of Vemula (57 J/7; 14° 22′ : 78° 19′ 30″).

The central portion of the sill is very basic (43·875, 21779) and contains abundant augite, olivine, ? hypersthene, serpentine, a little felspar, iron-ore and brown mica. It is a picrite. It also has its counterpart in a similar specimen (21776) collected near Vemula.

The lowest portion of the compound sill is intermediate in basicity between the uppermost and central parts, being best described as a dolerite.

The author noticed no veins of asbestos and agrees with Dr. Fox that the occurrence of these in workable quantity is highly improbable.

[1] Numbers such as 21780 refer to the registered number of the thin section in the collections of the Geological Survey of India.
[2] Numbers such as 43·872 refer to the registered number of the rock specimen in the collections of the Geological Survey of India.

Conclusions.

From what has been written, it will have been gathered that the possibilities of finding asbestos of sufficient quality and in sufficient quantity associated with rocks of the Cheyair series, or the intrusive basic sills found associated with these rocks, are very remote. Accordingly, in the descriptive accounts which form Chapters II, III and IV, there has been no attempt to describe trap-limestone contacts other than those of the Vaimpallis and their associated basic sills.

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CHAPTER II.

ASBESTOS IN THE CUDDAPAH DISTRICT.

Historical.

King.

It is interesting to record that King remarked on the alteration of the Vaimpalli limestones at their contacts with trap[1] :—

'In the Paupugnee valley, the limestones and slates or slaty shales in immediate contact with the traps are altered in a marked manner. They are stringed with white and pink seams, patches, and knots of a rock of serpentinous or magnesian constitution easily weathered into a white powder. Occasionally these seams are of pale green colour, and are then a calcareous serpentine. The lamination of the beds in contact is undulatory and wavy: and the more massive and silicious limestones, not in such close contact with the traps, are much segregated in what appear on the edges of the beds to be corrugations. On the surfaces of the beds, however, it is seen that these corrugations are merely sections of rude columnar segregations.'

These notes presumably refer to the occurrence of serpentine near Rajupalem in the Kamalapuram taluk (*see* pages 173-176), but it will be seen that King failed to find any asbestos there, nor does he make any mention elsewhere of the occurrence of either serpentine or asbestos in the Brahmanapalle-Lopatanutula area (*see* pages 155-168).

Indeed, the existence in the Cuddapah district of asbestos in workable quantity and of sufficiently good quality has only very recently been known. According to information received by the author when at Pulivendla, asbestos was first discovered in 1924 accidentally in a well at Lingala (57 J/3; 14° 30′ : 78° 7′) by a cultivator. He is said to have shown it to M. R. Ry. B. Chinna Malla Reddi of Kondapuram, who took it to Madras. This gentleman sent specimens to the Wembley Exhibition [2] and is said to have been awarded a bronze medal. The Mysore Development Syndicate Co., Ltd., are stated to have taken over his concession and to have done the

B. Chinna Malla Reddi.

[1] *Op. cit.*, p. 164 and Fig. 24.
[2] *See* Catalogue of the India Section of the British Empire Exhibition, p. 107, (1924).

preliminary proving of the deposits in the Pulivendla taluk in 1924.

However that might be, a sample of asbestos, stated to have been obtained from 'near Tadpatri taluk in Anantapur district', was sent to the Geological Survey of India in 1924 by M. R. Ry. V. S. Chinnasami, Superintendent and Chemist, Government Glue Factory, Washermanpet, Madras. It is believed that this asbestos was really obtained from the adjoining Pulivendla taluk of the Cuddapah district, and not from the Tadpatri taluk of the Anantapur district.

V. S. Chinnasami.

The first recorded production of asbestos from the Cuddapah district was in 1924[1], when 13·5 tons of a total value of Rs. 5,400 (£ 388) were excavated, presumably by the Mysore Development Syndicate Co., Ltd. In April, 1928, the Director of Industries, Madras, forwarded for examination to the Geological Survey of India two samples of dressed asbestos from Rajupalem village of the Kamalapuram taluk of the Cuddapah district. A reference to this has been made in the 'Quinquennial Review of the Mineral Production of India for the years 1924 to 1928'[2]. As will be seen, exploratory work in connection with Rajupalem asbestos has been carried out by the Mysore Development Syndicate Co., Ltd., and, also, at the time of the author's visit in 1932, by Sheik Suleiman Shakoo Sett, who held block No. 317 of Rajupalem under prospecting license.

Mysore Development Syndicate Co., Ltd.

The Pulivendla asbestos was worked at a loss by the Mysore Development Syndicate Co., Ltd., until 1928, when the Mysore Asbestos Mines, Ltd., now of 24, Rampart Row, Bombay, took over certain holdings of the Syndicate. When at Pulivendla, the author was informed that the Mysore Asbestos Mines, Ltd., held blocks Nos. 430, 439, 440, 441, 457 and 458 of Ippatla under mining lease; Nos. 309, 312, 314, 321, 332, 333, 334 and 335 of Chinnakudala under mining lease; Nos. 142, 143, 171, 178, 193, 194 and 226 of Brahmanapalle under mining lease; Nos. 1, 11 and 12 of Gunakanapalle under prospecting license; and No. 1 of Ramanutiapalle under prospecting license. It was not known whether block No. 491 of Lingala, held under mining lease by the Mysore Development

Mysore Asbestos Mines, Ltd.

[1] *Rec. Geol. Surv. Ind.*, LVIII, p. 272, (1926).
[2] *Op. cit.*, LXIV, p. 323, (1930).

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Syndicate Co., Ltd., had been taken over by the Mysore Asbestos Mines, Ltd.

In November, 1929, the Indian Trade Commissioner, London, wrote to the Director-General of Commercial Intelligence and Statistics, Calcutta, stating that recently several consignments of chrysotile asbestos of the very first quality had appeared in London, and he requested information as to its locality. The Geological Survey of India was able to ascertain that the asbestos in question had been shipped by the Mysore Asbestos Mines, Ltd., and that it had been extracted from their Brahmanapalle mines. In May, 1930, Mr. G. H. Tipper, Mineral Adviser to the Trade Commissioner, drew the attention of this Department to this asbestos.

As noted before, the author's colleague, Dr. C. S. Fox, paid a brief visit in October, 1930, to certain of the asbestos deposits in the Pulivendla taluk with reference to an enquiry under Rule 47 of the Mining Rules. A reference to Dr. Fox's visit was made in the General Report of the Geological Survey of India for the year 1930.[1]

Dr. C. S. Fox.

Reference to the author's work on the Pulivendla asbestos deposits was made in the 'General Report for 1931'[2].

A. L. Coulson.

The author is unaware of any other publications dealing with the asbestos deposits of the Cuddapah district.

Subdivision.

For descriptive purposes, the asbestos deposits in the Cuddapah district may be considered under two heads:—

Pulivendla taluk.
Kamalapuram taluk.

The latter deposits would be described first in any account of the structure of the rocks commencing in the Cuddapah district and tracing their outcrops successively through the Anantapur and Kurnool districts. However, the deposits in the Pulivendla taluk of the Cuddapah district are so much more important economically, and have been worked to such larger extent, that it is convenient to commence with their description, rather than with that of the deposits in the Kamalapuram taluk.

[1] *Rec. Geol. Surv. Ind.*, LXV, p. 34, (1932).
[2] *Op. cit.*, p. 23, (1933).

Notes will be given later as to the possibilities of finding asbestos in the Cuddapah taluk of the Cuddapah district.

Asbestos in the Pulivendla Taluk.

1. Brahmanapalle-Lopatanutula Asbestos Area.

A geological sketch map of the Brahmanapalle-Lopatanutula area forms Plate 10, fig. 1, of this report. The greater part of this map is found on one-inch topographical sheet 57 J/3. It will be noted that the general succession here is of north-easterly dipping Vaimpalli limestones and shales, with interbedded doleritic and basaltic sills in the higher members, and, also, between these rocks and the conformable overlying Pulivendla quartzites. The Pulivendla quartzites are succeeded conformably by the Tadpatri shales, with which are associated other basic sills.

Geological map.

It will be seen, however, that the structure is not very simple inasmuch as in the vicinity of Chinnakudala and Ramanutiapalle, rather a large dislocation has broken the continuity of strata. Moreover, a somewhat similar, but smaller, dislocation, with a thrust in the reverse direction, has taken place near Ippatla. Again, between Lingala and Lopatanutula, there is a fault which has been described elsewhere by the author as the Lingala fault. This occurs practically at the junction of one-inch sheets 57 J/3 and 57 J/2.

Faults.

Attention has also been drawn elsewhere to the fact that while Pulivendla quartzites crop out in force in the hills near Lingala and again near Rachegaripalle (57 J/7; 14° 21′ : 78° 19′), there are no definite exposures of these quartzites in between these villages, except near Ramanutiapalle. The outcrops are largely masked by alluvium and it is quite possible that Pulivendla quartzites could be traced in this area if diligent search be made. An indication, however, has been given on the map forming fig. 1 of Plate 10, of the existence of a large fault striking approximately N. W.–S. E., more or less parallel to the general strike of the country.

The important asbestos area in the Pulivendla taluk may be considered as extending roughly from one mile south of Brahmana-

palle, N. N. W. for a distance of some 9½ miles to near Lopatanutula village. This is the area that has been prospected. Between Lopatanutula and the Velidandla and Parnapalle road, near the Tadpatri taluk of the Anantapur district, there is another area, the possibility of the existence in which of asbestos cannot be overlooked. However, this Brahmanapalle-Lopatanutula area will first be described in some detail, following the asbestos horizon roughly north-west along the strike of the rocks.

Asbestos area in the Pulivendla taluk.

Before proceeding to a description of these areas, it will be advantageous to give the following general idea of the sequence of formations found immediately above and below the asbestos horizon in the Brahmanapalle-Lopatanutula area.

Stratigraphical position of the asbestos zone.

The metamorphosing agent responsible for the formation of the asbestos is a dolerite sill, which occurs as the lowermost of the basic igneous sills that have been intruded into the upper members of the Vaimpallis limestones and shales of the Papaghni series, and into the Pulivendla quartzites and Tadpatri shales of the Cheyair series, of the Cuddapah system of rocks. Below this sill, there is, in this Brahmanapalle-Lopatanutula area, a large thickness of Vaimpalli limestones and shales, overlying the Gulcheru quartzites, which are singularly free from intrusive igneous rocks.

This lowermost sill is a rather coarse-grained dolerite which weathers spheroidally. The analysis by P. C. Roy and Mahadeo Ram of a specimen (41·953) of this sill, collected by Dr. C. S. Fox from Brahmanapalle, is given in Table VIII on pages 224 and 225. It varies in thickness, but appears to be never more than 30 to 40 feet thick and never comparable in size with the large sill occurring immediately below the Pulivendlas. The general dip of the sill and of the underlying and overlying Vaimpallis is about 10° to 20° to the north-east. As far as the author is aware, there is no asbestos developed at the base of the sill at its contact with the underlying rocks.[1] It is only at its contact with the overlying Vaimpallis that asbestos has been formed.

The asbestos zone is rarely more than three feet thick and is made up of numerous cross-fibred chrysotile veins of asbestos, varying from a minute size to about three inches thick, anastomos-

[1] As will be seen on pages 175 and 197, respectively, this is not true of the sills at Rajupalem in the Kamalapuram taluk of the Cuddapah district, and at Joharapuram in the Kurnool taluk of the Kurnool district.

ing through the serpentinous magnesian limestone (*see* Plate 7 and Plate 8, fig. 1).

Above the serpentinous rock containing the asbestos is a magnesian limestone, the general character of which may be gathered from the analyses of specimens 43·873 and 43·879 given below in Table I.

Analyses of the magnesian limestone overlying the dolerite sill.

TABLE I.—*Analyses of Vaimpalli Limestones from the Pulivendla taluk, Cuddapah district.*

Specimen	43·873	43·879	43·878	43·876
Slide	21777	..	21783	..
	Per cent.	Per cent.	Per cent.	Per cent.
SiO_2	5·24	3·14	5·84	37·10
Fe_2O_3, Al_2O_3	2·10	1·46	1·85	4·20
CaO	45·06	45·61	49·25	19·38
MgO	6·44	8·09	3·53	12·46
CO_2	38·26	40·49	38·23	25·80
BaO	0·75	0·07	0·15	*nil*
H_2O	2·50	0·91	1·00	0·56
TOTALS	100·39	99·77	99·85	99·54
Specific gravities	2·72	2·72	2·72	2·76

43·873 'Lowest' magnesian limestone from three-quarters of a mile south of Ippatla (57 J/3; 14° 26′ : 78° 10′ 30″).
43·879 'Lowest' magnesian limestone from 1½ miles south of Karnapapayapalle (57 J/2; 14° 32′ : 78° 4′ 30″).
43·878 'Middle' purplish, slightly magnesian limestone from 1¼ miles south-east of Lopatanutula (57 J/3; 14° 30′ : 78° 6′).
43·876 'Uppermost' dolomitic and siliceous limestone from one mile west (a little north) of Ippatla.

This magnesian limestone is fairly massive, but it is sometimes more finely bedded. It varies in thickness from 15 to 20 to 30

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feet, and irregular, thin veins of asbestos were sometimes noted nine or ten feet above the main asbestos zone.

Red shales and middle limestone.

The magnesian limestone is succeeded by a series of red shales which have a maximum thickness of about 30 feet, but their usual thickness is about 30 feet. They form a useful benchmark. However, they vary in nature for quite frequently, as will be seen, they are split into two parts by thin bands of purplish, slightly magnesian limestone, which sometimes are somewhat massive in appearance. The composition of this limestone may be gathered from the analysis of specimen 43·878 given in Table I.

Siliceous and dolomitic limestone.

The red shales, with or without their central band of purplish limestone, are succeeded perfectly conformably by a siliceous and dolomitic limestone, the composition of which may be gathered from the analysis of specimen 43·876 given in Table I.

Upper large doleritc sill.

This siliceous limestone is succeeded occasionally by another, thin series of red shales, *e.g.*, in the Brahmanapalle area. More commonly, however, it is overlain by a large doleritic sill, somewhat fine-grained as a rule, which has been intruded between it and the Pulivendla quartzites. This large sill is generally strongly epidotic and no asbestos was noted at its contact with the siliceous limestone.

Tabular summary of general succession.

The foregoing summary of the general succession may be set forth in tabular form as under, in descending order :—

Pulivendla quartzites . .	....
Vaimpalli limestones and associated basic sills.	Upper doleritic sill. (Red shales, sometimes present). Siliceous and dolomitic limestone. Red shales, quite frequently split into two parts by a band of purplish magnesian limestones. Magnesian limestone, with infrequent and worthless stringers of *asbestos*. Serpentinised rock with *asbestos*. Lower dolerite sill. Remainder of Vaimpalli limestones (very large thickness).
Gulcheru quartzites . .	....
Crystallines	....

A diagrammatic sketch section, showing the part of this general succession with which we are intimately concerned, forms Fig. 1 below.

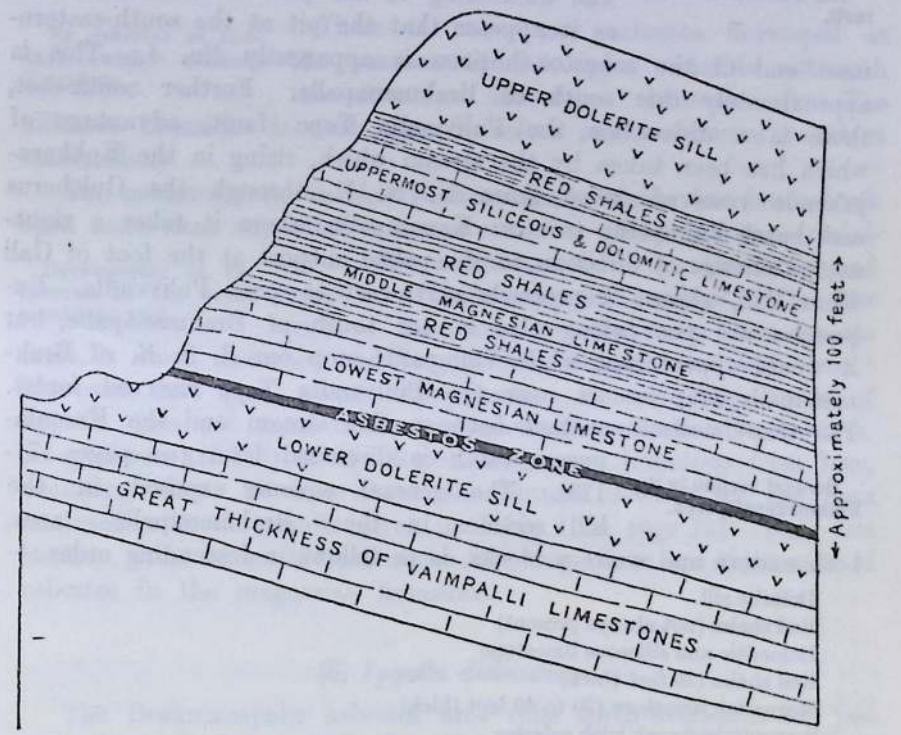


FIG. 1.—Diagrammatic sketch section showing the general succession in the Brahmanapalle-Lopatanutula area.

Subdivision of the Brahmanapalle-Lopatanutula area.

For descriptive purposes the Brahmanapalle-Lopatanutula asbestos area may be subdivided as follows :—

(*a*) Brahmanapalle area.
(*b*) Ippatla dislocation.
(*c*) Ippatla-Chinnakudala area.
(*d*) Chinnakudala-Ramanutiapalle dislocation.
(*e*) Ramanutiapalle-Lopatanutula area.
(*f*) Lingala-Lopatanutula dislocation.

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(*a*) *Brahmanapalle area.*

The Mysore Asbestos Mines, Ltd., consider the Brahmanapalle area as being composed of an eastern block, with pits Nos. 1 to 6, and a western block with about four pits. The numbering of the pits is rather uncertain as it appears that the pit at the south-eastern-most end of the asbestos horizon is apparently No. 4. This is approximately due south of Brahmanapalle. Further south-east, there is a dislocation, the Pulivendla Tope fault, advantage of which has been taken by the stream which, rising in the Kokkarajukonda reserved forest, flows N. N. E. through the Gulcherus and basal Vaimpallis to near Kanampalle, where it takes a right-angled change of direction to the police outpost at the foot of Gali Mora Hill, whence it proceeds north-east to pass Pulivendla. Exposures are poor along this stream south of Brahmanapalle, but it would appear that while Vaimpallis crop out S. S. E. of Brahmanapalle, trap occurs near the Pulivendla Tope reserved forest. The trap-limestone contact between this stream and the Kamalapuram taluk is discussed later (*see* pages 171-173). The general sequence exposed in the hill sections in the Brahmanapalle area, both eastern and western blocks, is as follows in descending order :—

The Pulivendla Tope fault.

General section in the Brahmanapalle area.

Dolerite sill
Red shales (not always present)
Dolomitic and siliceous limestone
Red shales (30 feet thick)
Magnesian limestone (20 to 40 feet thick)
Serpentinised rock with *asbestos*
Dolerite sill

The bottom sill is a fine-grained dolerite, a specimen (41·953, 20947) of which has been analysed by Mr. P. C. Roy and Mahadeo Ram in the Laboratory of the Geological Survey of India with the results given on pages 224-225. The thin section shows abundant augite, ophitically penetrated by laths of felspar, together with a fair amount of dark glass and some iron-ore. Certain specimens (41·952, 20946) are almost completely serpentinised.

Bottom sill.

Specimens of serpentinised rock carrying asbestos (N 542 and 543; N 544; N 545; N 546) were collected from the Brahmanapalle East pits Nos. 1, 2 and 3. The asbestos from these pits varies in nature and certain pits give better specimens than others.

Asbestos.

The red shales which occur between the upper doleritic sill and the siliceous limestone are not constant and are sometimes wanting. As one proceeds towards Ippatla, these red shales become less important and die out.

Red shales.

There is never any asbestos developed at the contact of the upper doleritic sill with the siliceous limestone beneath it. The siliceous limestone is dark grey in colour and sometimes weathers conchoidally.

No asbestos at contact with siliceous limestone.

The asbestos zone in this Brahmanapalle region has been developed more than any other occurrence in this district, more especially in the neighbourhood (south-west and west) of Brahmanapalle village. The last part of this zone, *i.e.*, that near the Ippatla fault, is much disturbed and barytes has been recorded from here.[1] However, that part about three-quarters to one mile south of Ippatla does not seem to have received the attention it deserves. A specimen (43·873) of the lowest magnesian limestone from here, occurring about 20 feet above the bottom dolerite sill, has been analysed with the results given in Table I on page 157. Near this locality, even 20 to 30 feet above the trap, there are thin veins of asbestos in the magnesian limestone.

Development of the asbestos in the Brahmanapalle area.

(*b*) *Ippatla dislocation.*

The Brahmanapalle asbestos area runs north-westwards for just over two miles, when it is cut off by a fault, which trends slightly north of east to slightly south of west, passing about half a mile south of Ippatla. The asbestos zone appears to have been block-faulted eastwards for a distance of slightly less than half a mile. Just south of Ippatla, there is a second (east and west) fault, and north of this, the asbestos zone continues along the course it held previously to the dislocation. The southern of the two faults responsible for the Ippatla dislocation has a downthrow to the south; the northern has an equal downthrow to the north. Assuming a dip of 10°, the approximate downthrow of either fault can be calculated as about 280 feet.

The Ippatla fault.

[1] *Mem. Geol. Surv. Ind.*, LXIV, Pt. 1, p. 25, (1933).

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In the little hill immediately south of Ippatla village, the sequence in descending order is as follows :—

Sequence at Ippatla.

Red shales
Magnesian limestone
Dolerite sill

The sill is a fine-grained dolerite (43·874, 21778), approaching a basalt in texture. It contains abundant laths of plagioclase felspar, with augite, serpentine and magnetite. This little block-faulted area south of Ippatla is worthy of attention. However, its nature precludes any great lateral extent of the asbestos zone.

(c) *Ippatla-Chinnakudala area.*

The Ippatla-Chinnakudala area lies along the continuation of the strike of the Brahmanapalle area. The most southerly portion is highly disturbed, the faulting no doubt being related to the northern of the two Ippatla faults. In descending order, the following occur in the hill-section west of Ippatla :—

Southern portion disturbed.

Dolerite sill
Shaly siliceous limestones, merging into red shales above at times
Dolerite
FAULT
Magnesian limestones

There is no asbestos in this region. The lower sill is not constant in its position and soon dies out to the north-west. The upper dolomitic and siliceous limestone (43·876) has been analysed with the results given in Table I on page 157.

The lower trap sill reappears a short distance further to the north-west, being at first thin, but increasing in size as it is followed along the strike. In the serpentinised limestone above this sill, one soon meets asbestos (N 548) veins up to half an inch in thickness (Plate 7).

Several pits have been dug into the hillside about 1½ miles W. N. W. of Ippatla. The serpentinised rock in which the asbestos occurs is mostly apple-green in colour, but the contact zone with the trap sill is very decomposed and the pits have not gone far enough to see whether, when the undecomposed contact is reached, the lower margin is dark green in colour and contains more asbestos. Water percolation along the asbestos zone has

been responsible for the decomposition. A typical cross-section of the hillside is given below as Fig. 2 :

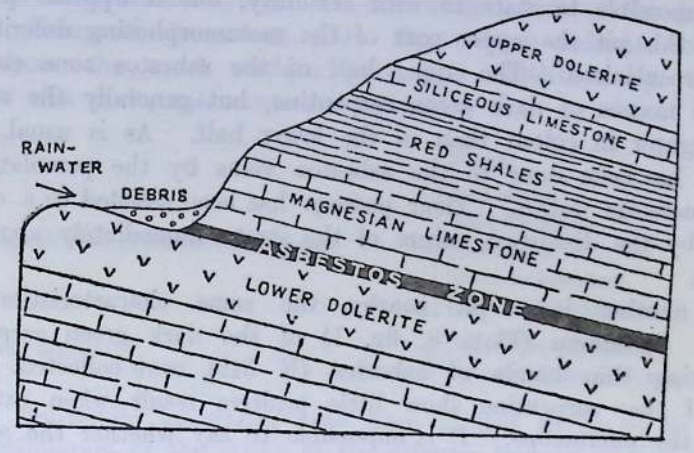


FIG. 2.—Diagrammatic section showing the percolation of water along asbestos zone in the Ippatla-Chinnakudala area.

The lowest sill here (43·877, 21782) is a dolerite, coarser-grained than its counterpart in the Brahmanapalle area to the south-east. The felspar laths which ophitically penetrate the augite have been sericitised. The rock contains a fair quantity of magnetite, with serpentine and chlorite.

Succession near Chinnakudala.

Further north-west along the strike, *i.e.*, towards Chinnakudala, the sections are usually as follows in descending order :—

Dolerite sill
Thin magnesian limestone
Red shales
Thin magnesian limestone } 40 feet
Red shales
Magnesian limestone, 25-30 feet
Serpentinised limestone with *asbestos*
Dolerite sill

Asbestos pits.

The upper dolerite sill is very inconstant in position here. It occurs immediately overlying either one of the three beds listed as beneath it in the above general succession. In one large pit about three-quarters of a mile south of Chinnakudala, the zone containing asbestos is at

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least five feet thick. In the lower half of this, at least thirteen veins of asbestos, which join and separate, were counted. This lower part of the serpentinised rock is very dark green in colour. It is impossible to state so with certainty, but it appears possible that in this pit the upper part of the metamorphosing dolerite has been serpentinised. The upper half of the asbestos zone contains sporadic masses of dark green serpentine, but generally the rock is much lighter in colour than in the lower half. As is usual, much damage has been done to the asbestos veins by the percolation of recent meteoric waters. Their passage has been assisted to a certain extent by the disturbed nature of the strata immediately above the contact.

In another large pit nearby, the same characteristics were noted. Specimens (Plate 8, fig. 1) of the dark green serpentine, containing thin bands of asbestos (N 549), were collected. Sections of the serpentine show little positive result when examined under the microscope. It is impossible to say whether the serpentine is due to the alteration of the magnesian limestone, or to complete alteration of the uppermost part of the intrusive dolerite sill. Thin laminae of silica occur in cross-joints through the serpentine.

Certain seams of asbestos in this part of the Ippatla-Chinnakudala area are more than one inch in thickness.

(*d*) *Chinnakudala-Ramanutiapalle dislocation.*

In opposite direction to Ippatla dislocation.

This dislocation is of the same nature as that at Ippatla described previously (pages 161-162), but it is in the opposite direction, and is rather more complicated.

The Ippatla-Chinnakudala asbestos zone continues in the low ground to the W. S. W. of the latter village, but is soon obliterated by alluvium. There is again an apparent large expense of red shales here at the immediate end of the ridge, the course of which we have been tracing, the increased width of outcrop of these shales being due to the flattening of the dip, combined with flattening of contours.

It seems necessary to postulate the existence of an east to west fault running practically through Chinnakudala, roughly parallel with the general course here of the Gunakanapalle stream. This fault curves round in

Horseshoe fault.

a north-westerly direction between Gunakanapalle and Ramanutiapalle, and then trends approximately due west through Ramanutiapalle. The mass of strata enclosed by this horseshoe-shaped fault has been faulted down. On the western side of the fault are normal Vaimpalli limestones. On the eastern side, in *ascending* order from the most western part (the north-westerly trending part) of this fault, one meets successively :—

		Fault
Papaghni series (Vaimpalli limestones)	.	Red shales Thin limestone Red shales Siliceous limestone Highly epidotised trap
Cheyair series	.	Pulivendla quartzites Tadpatri shales with trap

The Pulivendla quartzites have been faulted so as to lie along the continuation of the strike of the asbestos-bearing portion of the Ippatla-Chinnakudala area. The red shales found under the trap and siliceous limestone are undoubtedly the same as those found underlying the same trap W. S. W. of Chinnakudala, their wide outcrop having been already noted. The maximum downthrow of this fault cannot be much less than 460 feet.

(*e*) *Ramanutiapalle-Lopatanutula area.*

Sequence near Ramanutiapalle.

A quarter of a mile north of the village of Ramanutiapalle, the following is the sequence in descending order :—

	Feet.
Upper large dolerite sill, with epidote	..
Siliceous dolomitic limestone	..
Red shales	30
Thin-bedded magnesian limestone	10
Red shales	30
Magnesian limestone with serpentine and bands of *asbestos*	20-30
Asbestos zone	..
Lower dolerite sill	..

The lower dolerite sill increases in size towards the north-west, but thins out again. Just north-west of the hill one mile north-

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west of Ramanutiapalle, this sill bifurcates, but the southern arm persists only for a short distance. The relations of the sill here are definitely intrusive.

Sketch section.

A sketch section of the hill three-quarters of a mile north-west of Ramanutiapalle forms Fig. 3 below. Pits have been sunk here for asbestos, without as much success as attended those at the foot of the hill station 1,170 feet, $1\frac{3}{4}$ miles north-west of Ramanutiapalle, where very

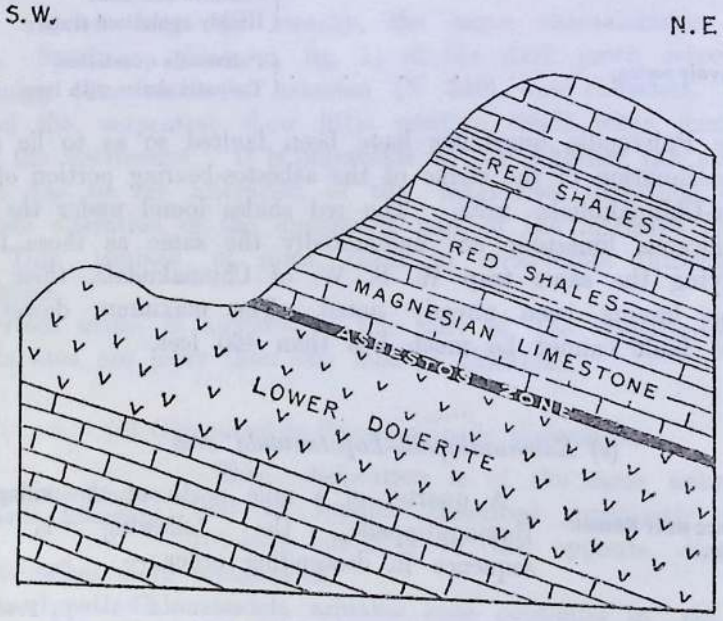


FIG. 3.—Section through the hill three-quarters of a mile north-west of Ramanutiapalle.

similar conditions are found. Further north-west from here, the lower dolerite sill increases in size and its dip flattens. The uppermost limestone, that immediately below the upper dolerite, is blackish in colour and contains many siliceous bands; it forms the scarp of the hill. Pulivendla quartzites cap the large epidotic dolerite sill which forms the hill to the east of 1,170 feet.

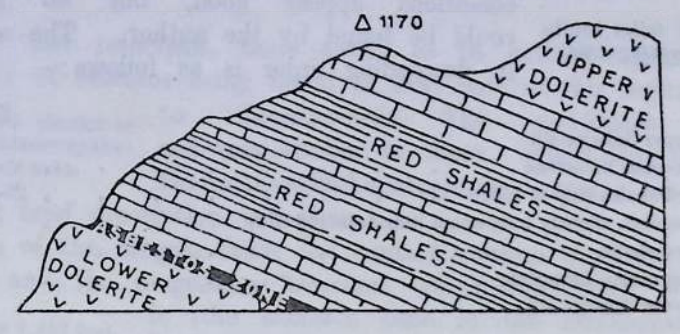


FIG. 4.—Section through the hill $1\frac{3}{4}$ miles north-west of Ramanutiapalle.

Asbestos.

The pits sunk at the foot of the hill station 1,170 feet are generally referred to as Lingala pits (Plate 6). The asbestos in these is very sporadic and though much good fibre has been extracted, its erratic distribution is a serious drawback. It would seem that the asbestos is far more abundant near the entrances of the pits than further into the hill, but this is just chance distribution as stated later (*see* page 234).[1] The dark green serpentinised zone contains veins of asbestos up to half an inch in thickness, and larger veins occur sometimes in the serpentinised limestone.

Occasional development of veins of asbestos in the siliceous limestone.

Tracing the asbestos zone in the valley north-westwards from the hill 1,170 feet, one finds that it is frequently lost in the alluvium and soil after crossing the Peddakudala stream between this hill and the next (that one which is $1\frac{1}{4}$ miles south-east of Lopatanutula). It is, however, interesting to note that between the Peddakudala stream and this hill $1\frac{1}{4}$ miles south-east of Lopatanutula, a few small veins of asbestos are occasionally developed in the lower part of the upper siliceous limestone, just above its contact with a small trap intrusion. The occurrence has no economic importance, but shows that even the upper siliceous limestone can, on occasion, have asbestos developed in it. A few shallow pits have been dug here, but no asbestos need be expected.

[1] *See* also Dr. Fox's remarks on page 220.

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A possible spot for asbestos, as yet not prospected, is the saddle at the foot of this hill 1¼ miles south-east of Lopatanutula. The conditions appear good, but no asbestos could be found by the author. The sequence in descending order is as follows:—

Hill 1¼ miles south-east of Lopatanutula.

	Feet.
Upper dolerite sill	
Siliceous limestone	30
Red shales (top of hill)	25-30
Purplish, slightly magnesian limestone (43·878)	10
Red shales	15
Magnesian limestone	15
Lower dolerite sill	

The middle limestone, an analysis of which has been given in Table I on page 157, is worked for drinking-troughs for animals. The red shales above this form the top of the hill and the upper siliceous limestone and dolerite sill are found further to the east. Further along the strike, however, where the dips have flattened, the upper siliceous limestone is also worked for troughs.

The remaining portion of the possible asbestos zone between this hill and Lopatanutula is not promising; but in the hill immediately north-west of the village, there are faint traces of thin veins of asbestos, not of any economic value.

Area near Lopatanutula.

(*f*) *The Lingala-Lopatanutula dislocation.*

The normal asbestos zone, *i.e.*, the contact between the lower dolerite and the lowest magnesian limestone, is cut off near Lopatanutula by the Lingala fault[1], which trends W. N. W.–E. S. E. between these two villages. The course of the fault is mostly masked as it is occupied by the cultivated ground of these villages; but the repetition of the Pulivendla quartzites ridge near Lingala is very striking.

Lingala fault.

2. Tract to the north-west of Lopatanutula.

It must be clearly understood that no asbestos has so far been found in the tract now to be described, and that the description

[1] *Mem. Geol. Surv. Ind.*, LXIV, Pt. 1, pp. 17-18, (1933).

is inserted in order to indicate to those interested the possibilities (or otherwise) of the tract in question.

No asbestos yet found.

From first principles, there seems to be nothing against the possibility of asbestos being found in that part of this region near to Lopatanutula. The conditions here are very similar to those appertaining in the Brahmanapalle-Lopatanutula area, as the following brief description will show.

Conditions similar to the Brahmanapalle-Lopatanutula area.

North of the Lingala fault, the contact between the lower dolerite sill and the magnesian limestone which immediately overlies it (the asbestos zone in the Brahmanapalle-Lopatanutula area), is at first lost in the cultivated ground. Thus hill station 1,267 feet, which is about half a mile north-east of Lopatanutula, is capped by the upper dolerite sill and the bulk of the hill is formed of the red shales which immediately underlie this.

Hill station 1,267 feet.

Better exposures are given in the hill three-quarters of a mile N. N. W. of Lopatanutula, where the sequence in descending order is as follows:—

Hill three-quarters of a mile N. N. W. of Lopatanutula.

Upper dolerite
Limestone
Red shales
Magnesian limestone

Still further to the north-west, the lower dolerite sill is found and the contact between this and the overlying limestone gradually ascends from the low ground as the hill 1½ miles south of Karnapapayapalle is reached. An analysis of this lowest magnesian limestone (43·879) has already been given in Table I on page 157. It will be seen that there is very little difference in composition between this magnesian limestone here, where no asbestos is found, and the lowest magnesian limestone (43·873) in the Brahmanapalle-Lopatanutula asbestos region. Comparison of the underlying dolerite sill (21·784) from 1½ miles south of Karnapapayapalle with the Brahmanapalle dolerite (41·953, 20947; 43·874, 21778; 43·877, 21782) shows that there is but little difference between them. The Karnapapayapalle specimen contains abundant magnetite and somewhat less augite.

Hill 1½ miles south of Karnapapayapalle.

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The contact continues to rise as it is followed north-west. The relations in the hill 1¼ miles S. S. W. of Karnapapayapalle are given in Fig. 5.

Hill 1¼ miles S. S. W. of Karnapapayapalle.

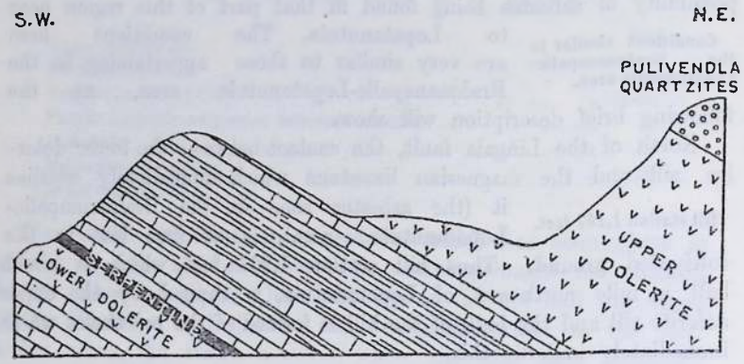


FIG. 5.—Diagrammatic section of the hill 1¼ miles S. S. W. of Karnapapayapalle.

Here there have been the formation in the contact region of lenticles and masses of apple-green serpentinised limestone (43·916, 21785). Still further to the north-west, the upper shales, which form the summit of the hill 1¼ miles S. S. W. of Karnapapayapalle, have been replaced by dolerite, and there is trap both above and below the lowest limestone; but once again, as far as could be seen, the chief product of contact metamorphism is apple-green siliceous serpentine.

The position of the contact between the lowest trap and the lowest limestone can only be guessed on account of the cultivated ground existing between this hill S. S. W. of Karnapapayapalle and the border with the Tadpatri taluk of the Anantapur district. Several cross-dislocations have taken place in the strata to the south of Velidandla (57 J/2; 14° 34′: 78° 3′), as *e.g.*, near the temple 1½ miles south of that village. The thin lower shales, the middle limestone, and most of the upper shales, are cut out by the dolerite sill mentioned above; but along the Velidandla-Tatireddipalle path, the upper limestone and part of the upper red shales may be seen a quarter of a mile S. S. W. of the temple.

Near border with Tadpatri taluk.

No useful purpose would seem to be gained by prospecting the contact in this region.

3. ASBESTOS IN OTHER PARTS OF THE PULIVENDLA TALUK.

Having described the asbestos deposits of the Brahmanapalle-Lopatanutula area and discussed the possibility of finding asbestos in the region to the north-west of that area, it behoves us to trace the contact between the lower dolerite and the Vaimpalli limestones along the strike of these rocks to where they enter the Kamalapuram taluk. It may be mentioned here, however, that no asbestos was noted in this region, with the exception of one occurrence immediately adjoining the Kamalapuram taluk and 1½ miles N. N. W. of Vempalle post office. This is mentioned on page 173.

The contact from Brahmanapalle to the Kamalapuram taluk.

It will be recalled that the Brahmanapalle-Lopatanutula area is dislocated at its south-eastern end by what has been termed the Pulivendla Tope fault. South-east of this fault, to the south of Venkatapuram (57 J/3; 14° 24′: 78° 13′), a big spread of Vaimpalli limestones and shales, chiefly the former, forms the contoured hills rising to the peaks 1,392, 1,300 and 1,210 feet. These Vaimpallis have a general north-easterly to N. N. E. dip, and they are underlain by the Gulcherus forming the north-eastern slopes of the Dorigallu and the Gorivikanama reserved forests.

South-east of the Pulivendla Tope fault.

The upper members of the Vaimpallis have been intruded by dolerite sills, which become increasingly important as one passes south-eastwards to the barytes area of Kottapalle.[1] Alluvium greatly masks the outcrops of these trap sills where they junction against the overlying rocks, but it seems certain that faulting has taken place along what has been described elsewhere as the Pulivendla fault. The overlying Pulivendla quartzites in places have been faulted out and the traps are in juxtaposition with either the Tadpatri shales or the trap sills which have been intruded into the Tadpatris. To the south of Vemula (57 J/7; 14° 22′: 78° 19′ 30″), the Pulivendla quartzites are found in force and they can be traced thence to the Kamalapuram outcrops described on pages 173 to 177.

Intrusive dolerite sills.

We are particularly concerned with such contacts that can be observed between the trap sills and the limestones. It will be remembered that it was at the *upper* contact of the *lower* dolerite sill that asbestos was formed in the Brahmanapalle-Lopatanutula

Reddish limestones or shales generally in contact with trap.

[1] *See Mem. Geol. Surv. Ind.*, LXIV, Pt. 1, pp. 18-22, (1933).

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area. In this remaining part of the Pulivendla taluk, however, it is only in few places that a small, constant, *lower* sill, comparable with that in the area just mentioned, is found. One of these localities is near Venkatapuram and Elamvaripalle (57 J/3; 14° 23′ 30″: 78° 14′), but no trace of asbestos was found as reddish limestones are generally in contact with the trap. Several small traps were noted in hill 1,210 feet to the south. In the hills to the south of Velpula (57 J/7; 14° 22′: 78° 16′ 30″), there is a lower trap, overlain by Vaimpallis, which in their turn are covered by the upper dolerite sill. The Vaimpallis which occur immediately below the lower trap are very ferruginous, red, sandy shales with somewhat circular concretions, similar to those noted at Tatimakulapalle (57 J/11; 14° 27′ 30″: 78° 31′ 30″) in the Kamalapuram taluk (*see* page 177); the shales alternate with limestones. No serpentinisation was noted. Two or more horizons of trap appear to exist to the west of Velpula, but the main lower one, the junction of which has been discussed above, appears to die out more or less at the junction of sheets 57 J/3 and J/7, just west of the Kadiri road.

Lower contact of dolerite easily traced.

The junction of the large sill of dolerite immediately underlying the Pulivendlas with the Vaimpalli limestones and shales, which it has intruded, is very plain and is easily traced from Velpula to Tallapalle Velamvaripalle (57 J/7; 14° 20′: 78° 24′ 30″).[1] However, the sill culminates in the peaks of 1,736 and 1,617 feet and it dips generally northwards at about 15°. Immediately beneath the trap, one usually finds red ferruginous shales with interbedded limestones, and in no case was the author successful in finding the least trace of asbestos along this contact.

Small trap intrusions.

The occurrence of small trap intrusions was noted in the lower ground at the foot of and to the south of the scarped trap hills; this was mentioned in the author's description of the barytes deposits of this region.[2] Almost invariably, however, the contacts of these isolated and probably discontinuous occurrences south of the main sill, with the Vaimpalli limestones and shales, are very indefinite and usually masked by alluvium. Though diligent search was also made with these contacts, no asbestos was noted. It is thought, however,

[1] *See* the geological map forming fig. 1 of Plate 4 in *Mem. Geol. Surv. Ind.*, LXIV, Pt. 1, (1933).
[2] *Loc. cit.*, p. 22.

that the possibilities of obtaining asbestos here are better than in the case of the lower contact of the big dolerite sill; but it is not anticipated that asbestos in workable quantity will be found.

Ridge north-east of Tallapalle Velamvaripalle.

The possibilities for asbestos in the ridge running north-eastwards from the village of Tallapalle were examined. This ridge, which culminates in the peak of 1,204 feet, is formed of dolerite which dips north-westwards at an angle of about 15°, the general strike of the strata having changed to a north-easterly direction, which is maintained until the Papaghni river is crossed. The Vaimpallis underlying the dolerite are mostly shaly types, the junction of which with the trap being general masked by abundant debris. No asbestos was noted. Between this ridge and the main Kottapalle ridge to the west, there is a small patch of Vaimpalli shales, about one mile north-west of Tallapalle Velamvaripalle, which is crossed by the path from this village to Tallapalle. No asbestos could be seen in this region.

Asbestos near Vempalle.

Reference has been made elsewhere[1] to the very faulted state of the strata in the vicinity of Vempalle, the village which has given its name to the Vaimpalli shales and limestones, and near hill station 1,088 feet. However, about 1½ miles N. N. W. of the Vempalle post office, just near the border with the Kamalapuram taluk, there is a small quarry in serpentinous limestone which is just above the contact with a small dolerite sill. The serpentinous limestone is quarried for use as rollers and as drinking-troughs for animals. A small amount of cross-fibred asbestos, less than half an inch in thickness (N 530), can be seen; but it does not appear that asbestos of sufficient quality will be found in quantity enough to be worked economically.

Asbestos in the Kamalapuram Taluk.

Asbestos at Rajupalem.

Reference has been made in the historical section of this chapter to the development of the asbestos occurring at or near Rajupalem (57 J/11; 14° 26′: 78° 31′) in the Kamalapuram taluk of the Cuddapah district. The chief development work has been done by

[1] *Mem. Geol. Surv. Ind.*, LXIV, Pt. 1, p. 17, (1933).

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Sheik Suleiman Shakoo Sett of Rajupalem village, who had a prospecting license for asbestos for Allotment No. 317 of Rajupalem at the time of the author's visit in December, 1931.[1]

Sketch map.

The quarry worked by this gentleman is in the eastern side of hill 964 feet, the quarry being some six furlongs W. S. W. of Rajupalem village. The hill in question is just within the western margin of one-inch sheet 57 J/11. A sketch map showing its position forms Fig. 6 below.

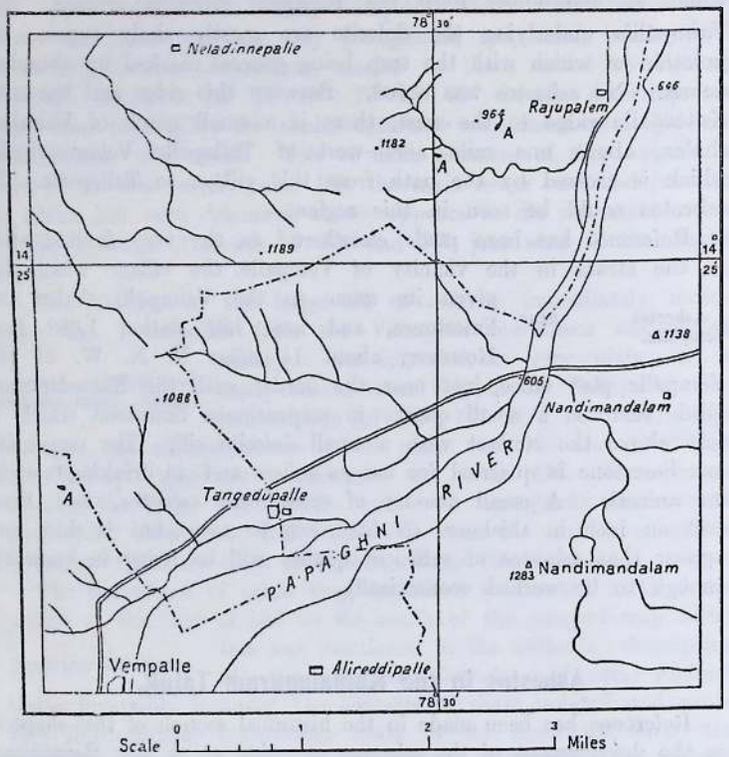


FIG. 6.—Sketch map (parts of sheets 57 J/7 and J/11) of parts of the Cuddapah, Kamalapuram and Pulivendla taluks of the Cuddapah district, showing the asbestos (A occurrences near Rajupalem. Scale, one inch = one mile.

[1] This license is not recorded in the review of the 'Mineral Production of India during 1931', *Rec. Geol. Surv. Idd.*, LXVI, p. 320, (1933).

About nine feet of serpentinised limestone had been exposed above a dolerite sill at the time of the author's visit. The veins of chrysotile asbestos in this serpentinised limestone are usually about a quarter of an inch thick. The best veins are between 1½ feet and two feet above the top of the metamorphosing trap sill. The following is a general section, given in descending order. The general dip of the series is at about 20° to 30° towards the north-west.

Section at hill 964 feet.

Upper dolerite sill	
Apple-green serpentinised [1] and banded limestone	
Banded green serpentine	1 foot
Veins of *asbestos* in serpentine (N 520, 21761) . .	1 inch
Banded green serpentine (N 519, 21760) . . .	1 foot 3 inches
Contact rock (43-915, 21759)	9 inches
Altered dolerite sill (43-868, 21758)	

The lower dolerite is moderately fine-grained and has been largely serpentinised. It strongly resembles that at Brahmanapalle. The total thickness of limestones and serpentine between the two dolerite sills amounts to between nine and 11 feet. The asbestos is not confined to the region above the lower dolerite, but also occurs (N 523) in the serpentinised limestone at a distance of 1½ feet below the upper dolerite sill.

Occurrence of asbestos below the upper sill.

The asbestos found in Suleiman Sett's property deteriorates as one proceeds westwards. Thus a specimen (N 524, 21764) of the poorer quality asbestos to the south-west of the main quarry is of the cross-fibred type, but the fibres are bent and are somewhat brittle.

Deterioration of asbestos westwards.

A striking feature of the contact region is the prevalence of irregular masses, stringers, or nodules of magnetite (N 525) in the

[1] It is interesting to record that the apple-green serpentine is used locally for medicinal purposes. The serpentine (only pale green is used!) is broken up and leaves of a certain tree (? *nim*) are wrapped all around the broken-up material, and then a cloth around the lot. Clay is moulded round the cloth ball and some twenty or thirty of these clay balls are baked. The balls are removed after a certain period of time, when the internal contents have been reduced to powder. This powder is then ready for use and is administered internally in cases of venereal diseases as follows:—A small amount of the powder is added to a mixture of one part of milk to one of water and is then drunk, such doses being taken frequently by the patient.

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first few feet of the limestone above the trap. It is said locally that where the magnetite occurs, the asbestos is of poor quality. The existence of magnetite at the contact region near Malkapuram in the Dhone taluk of the Kurnool district will be referred to later (*see* pages 188-189).

Prevalence of magnetite.

Mention has been made elsewhere by the author [1] of the near-by occurrence of barytes. It is relevant to refer here to the occurrence in plots Nos. 314 and 317 of Rajupalem of steatitic chalk (N 526, 21765) on the western side of hill 964 feet, in the gap in the hills running north-west to Gonumakulapalle (57 J/7; 14° 27′: 78° 29′) and roughly $1\frac{3}{8}$ miles west (a little south) of Rajupalem. This material seems to have originated from the action on Vaimpalli shales and limestones of solutions, released by the overlying dolerite sill. The upper material appears to be chiefly chalk, whilst the lower steatitic material is very calcareous. Dislocation has taken place in this neighbourhood. The probable occurrence of the barytes along a fault-course has been suggested elsewhere[2]. Accordingly the asbestos contact cannot be traced continuously between the quarry on the hill 964 feet and that now to be described, which occurs further to the south-west.

Barytes and chalk.

The Mysore Development Syndicate, Ltd., and, also, the Mysore Asbestos Mines, Ltd., are said to have worked two quarries asbestos in plot No. 50-A of Rajupalem, which is a quarter of a mile east (a little south) of the summit of hill 1,182 feet. This hill is on sheet 57 J/7, but the quarries are just within the western boundary of sheet 57 J/11 and are situated $1\frac{3}{8}$ miles W. S. W. of Rajupalem (*see* Fig. 6). There is about 12 feet of serpentinous limestone between two sills of dolerite and asbestos (N 527, 21766) occurs in thin veins about 2 feet 9 inches above the top of the lower sill. The asbestos is not of good quality. It is of the cross-fibre type, but the strands are of very unequal length. The asbestos-bearing portion of the serpentinised limestone has a total thickness of about six inches. The maximum total thickness of asbestos vein observed is only about half an inch, but the usual thickness is only half this. The bands of asbestos bifurcate and rejoin.

Asbestos east of hill station 1,182 feet.

[1] *Mem. Geol. Surv. Ind.*, LXIV, Pt. 1, p. 15, (1933).
[2] *Loc. cit.*

Asbestos was also noted about six feet from the top of the lower trap (*i.e.*, about three feet below the base of the upper dolerite), but it was of even worse quality than the veins described above.

The whole series of limestones and dolerite sills dips at 45° to the north.

Both firms gave up work in the areas as the length of fibre was small and the quality was not good. Also the high dip rendered working difficult.

Possibilities of other Discoveries in the Kamalapuram Taluk.

The author followed the outcrops of the Vaimpalli limestones and the associated dolerite sills on the left side of the Papaghni river from Rajupalem past Venkatapuram (57 J/11; 14° 30′: 78° 35′) to Letapalle (57 J/10; 14° 31′: 78° 36′). King has mentioned [1] how in the vicinity of Boodyapully, which is now called Chabali (57 J/10; 14° 30′: 78° 36′), the Pulivendla quartzites overlying the Vaimpallis bend sharply round and cross the river. The author has elsewhere stated [2] that he does not agree with King that the quartzites on the right (eastern) side of the Papaghni are Pulivendlas, but considers them to be basal Kurnools, *i.e.*, the Banganapallis. Be that as it may, the possibilities of asbestos in workable quantity being found to the north-east of Rajupalem are not good, though perhaps efforts could be directed to the vicinity of Errapalle (57 J/11; 14° 28′ 30″: 78° 3′), where the Vaimpallis and dolerites are seen in juxtaposition. The Vaimpallis here, however, are mostly variegated shales with little limestone. They dip north-west into the hills at about 30° to 40°. Further to the north-east of Errapalle, the outcrops of the Vaimpallis are obscured; and at Venkatapuram, dolerites crop out down to the Papaghni river.

Possibilities not good.

A good view of the Pulivendla quartzites, which form the summits of the hills with hill stations 1,399 feet and 1,711 feet and overlie sills of dolerite, may be obtained from near the village of Tatimakulapalle (57 J/11; 14° 27′ 30″: 78° 31′ 30″). There appears to be a dislocation along the line of the pass between this village and Animala (57 J/11; 14° 28′: 78° 30′ 30″). Peculiar white concretions (43·914) were noted in red, sandy and calcareous Vaimpalli shales, three-quarters

Near Tatimakulapalle.

[1] *Mem. Geol. Surv. Ind.*, VIII, Pt. 1, p. 162, (1872).
[2] *Op. cit.*, LXIV, Pt. 1, pp. 11-12, (1933).

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of a mile N. N. E. of Tatimakulapalle. No traces of asbestos were seen, nor is it thought likely that asbestos occurs here.

Turning our attention to that part of the Kamalapuram taluk south-west of Rajupalem, it may be stated that asbestos in workable quantity is not likely to be found here also. As was seen on page 173, asbestos occurs in small amount in the adjoining Pulivendla taluk to the N. N. E. of Vempalle. Accordingly, it is possible that a small amount of asbestos may be found if the dolerite-limestone contacts in that part of the Kamalapuram taluk be prospected thoroughly. Here and to the north-west, there are occasional bands of Vaimpalli limestones and shales which are residuals between the dolerite sills. They could not be mapped on the scale of map available (one inch to the mile) as they do not have any great lateral extent before they are cut out by dolerites crossing the bedding. Usually the dips of these Vaimpallis are into the hills, *i.e.*, to the north-west; but in certain parts, as, *e.g.*, north of hill station 1,088 feet, they strike at right-angles to the general trend of the Pulivendla-quartzite-capped hills. This, however, is exceptional and would appear to be due to faulting. One of the faults probably trends north and south on the western side of the main southern spur of the hill station. Generally speaking, these residuals of Vaimpalli limestones cannot be said to show conspicuous serpentinisation. There has been the development in places of red (sard), green (chrysoprase), and common chalcedony.

South-west of Rajupalem.

Possibilities of Asbestos in the Cuddapah Taluk.

King's field maps (old Atlas of India sheets, scale, one inch to four miles) show a few sills of dolerite interbedded with the Vaimpalli limestones and shales on the eastern side of the Papaghni river, not far distant from the village of Tummaluru (57 J/11; 14° 28′: 78° 34′). Reference has been made in the author's asbestos report[1] to the occurrence of a vein of barytes in an epidiorite sill (21752; 43·866, 21753) 1½ miles north of Chimalapenta (57 J/11; 14° 26′: 78° 35′ 30″). The original augite of the rock has been uralitised and the sill is far more altered than its counterpart in the Brahmanapalle area. It is capped by, and overlies, Vaimpalli limestones, the upper

No asbestos found.

[1] *Mem. Geol. Surv. Ind.*, LXIV, Pt. 1, pp. 12-13, (1933).

members of which in turn are capped by the Banganapalli sandstones which spread away to Chabali (57 J/11; 14° 30′: 78° 36′) in the north. A diligent search was made along the contact between the upper surface of the sill and the overlying Vaimpalli limestones, which here are rather siliceous. No traces of asbestos were seen. The sill has a tachylytic chilled upper margin of about six inches thick and the limestones have been slightly metamorphosed.

Small intrusions of trap were noted east of Tummaluru[1], but in no case could asbestos be seen, nor is it thought likely that this mineral exists here, or in other parts of the Cuddapah taluk of the district of that name.

[1] *Mem. Geol. Surv. Ind.*, LXIV, Pt. 1, p. 13, (1933).

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CHAPTER III.

SERPENTINE IN THE ANANTAPUR DISTRICT.

Introduction.

The author knows of no authentic occurrence of asbestos in the Anantapur district, but a short reference to the dolerite-Vaimpalli limestone contacts in this district is of value as it may save much useless prospecting. It is interesting to record in this connection that according to information supplied by the Collector, Mr. A. Krishnappa of Cuddapah applied on the 15th October, 1930, for a prospecting license for asbestos in the Goddumarri reserved forest in the Tadpatri taluk. Further enquiry elicited the information that :—

Prospecting licenses.

'Particulars regarding the survey numbers, etc., in Goddumarri village for which a prospecting license was applied for, are not available as the application was lodged for failure to furnish these particulars.'

Accordingly this license does not appear in the list of prospecting licenses granted for areas in Anantapur during 1930, which is published in the 'Mineral Production in India for 1930'.[1]

There are two areas with possibilities of asbestos in the Anantapur district. Both of these are in the Tadpatri taluk, but they are situated near its opposite borders. The first, the Nerijamupalle area, is adjacent to the area north-west of Lopatanutula in the Pulivendla taluk of the Cuddapah district, which area has already been described in Chapter II (*see* pages 168-170). The second area, the Vengannapalle area, is adjacent to the Gooty taluk of the Anantapur district. These will be described in detail and brief notes will be given on other areas in the district where dolerite sills junction with Vaimpalli limestones.

Possible areas for asbestos.

Nerijamupalle Area.

The village of Goddumarri, to which reference has been made, is situated on the northern (left) bank of the Chitravati river on Tadpatri shales which conformably overlie the Pulivendla quartzites, the basal stage of the Cheyair series of the Cuddapah system. A

Faulted area near Pulivendla - Parnapalle road.

[1] *Rec. Geol. Surv. Ind.*, LXV, p. 383, (1932).

short distance to the west of the village, the Pulivendla quartzites, which dip north-east at a gentle angle, strike across the Chitravati river. On the southern side of the river, these quartzites show that the strata is highly faulted. Reference has been made elsewhere to the number of faults shown by these Pulivendla quartzites on either side of the Parnapalle-Pulivendla road, west of the village of Velidandla (57 J/2 ; 14° 34′ : 78° 3′).[1] No dolerite sills were noted north of this road, or in the Daditota reserved forest ; but dolerite sills occur in force to the south, between the uppermost Vaimpallis and the Pulivendla quartzites. It is thought that Mr. Krishnappa's activities were directed to this locality to the east and north-east of Nerijamupalle (57 J/2 ; 14° 32′ 30″ : 78° 1′), just without the eastern border of the Nerijamupalle reserved forest, wherein two important veins of barytes occur.[2]

Reference may conveniently be made here to the general sequence of rocks noted in the area to the north-west of Lopatanutula as given on page 169. The upper dolerite sill that was traced from north-east of Rajupalem in the Kamalapuram taluk of the Cuddapah district and through the Pulivendla taluk of that district, apparently dies out just to the south of the Pulivendla-Parnapalle road, west of Velidandla ; and the Pulivendla quartzites rest directly on Vaimpalli limestones and shales with no intervening trap sills. One cannot identify here with certainty the various bands of limestones and red shales recognized throughout the Brahmanapalle and Lopatanutula areas. The lower trap also dies out near the road, south-east of milestone 17. It, however, is apparently faulted out.

General sequence.

As in the latter part of the area to the north-west of Lopatanutula, the contact between the lower dolerite sill and the Vaimpalli limestones and shales overlying it and occurring beneath the large upper sill, is very largely masked by the cultivated ground. It was followed by the author from its entrance into the district at a point just over $1\frac{3}{4}$ miles due east of Nerijamupalle till it dies out at the road mentioned above. He was unsuccessful in finding traces of asbestos ; and while not denying the possibility of its existence, he sees no reason to believe that it will ever be found in sufficient quantity or of requisite quality to warrant economical attention.

Contact largely masked.

[1] *Mem. Geol. Surv. Ind.*, LXIV, Pt. 1, pp. 29-30, 33, (1933).
[2] *Loc. cit.*, pp. 32-33.

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Vaimpallis between the Chitravati and Penner Rivers.

There is only one occurrence of trap noted by the author between the Chitravati and Penner rivers. This is the small plug which occurs just on the forest boundary 1½ miles S. S. E. of Tabjula (57 F/13; 14° 54′: 77° 49′ 30″).[1] Thus the large stretch of Vaimpallis between these rivers, and covering parts of one-inch sheets 57 F/14 and F/13, need not be prospected further for asbestos. The absence of dolerite sills in the Vaimpallis is a striking change from their prevalence in these rocks in the Cuddapah district.

Only one occurrence of trap.

Vengannapalle Area.

Following along the strike of the Vaimpallis north of the Penner river, a dolerite sill[2] is found intrusive into these rocks a quarter of a mile E. N. E. of Cherlopalle (57 F/13; 14° 56′ 30″: 77° 48′ 30″). This same sill can be traced at intervals to the hills north of Vengannapalle (57 F/13; 14° 58′: 77° 48′), which form part of the boundary with the Gooty taluk of the Anantapur district. King[3] noted the occurrence of serpentine in the Vaimpallis here :—

Occurrence of serpentine noted by King.

'Further north again, beyond the Penn-air, some of the beds in the upper part of the series are seamed with serpentine, and there are strong traces of trap close by, which, as far as could be made out in a part of the country so obscured by cotton-soil, appears to underlie these evidently altered beds of limestone. The locality is about six miles south of Ryalcheroo, in a low hill to the east-south-east of Vengannapalle.

The strata crop out round the western side of this hill and show one or two thickbeds of pale green and white limestone, thinly interlaminated with pale green or whitish semi-translucent serpentine. There are besides thicker seams and rocks of this mineral; but specimens obtained from these are very brittle, and break into irregular semi-conchoidal and coboidal little masses which are too small to be of any use except for very small ornaments. Possibly, however, deeper quarrying might produce less friable specimens.'

He added that :—

'At present the workmen at Ryalcheroo only carve ornaments out of small blocks of the pale green (waved with white and dark grey stripes) serpentinous beds of limestone.'

[1] *Mem. Geol. Surv. Ind.*, LXIV, Pt. 1, pp. 34, 38, (1933).
[2] Just north of Chinna Yeckaluru (57 F/13; 14° 55′: 77° 48′), some pale green serpentine is developed near a fault, but no trace of trap could be seen.
[3] *Mem. Geol. Surv. Ind.*, VIII, Pt. 1, p. 165, (1872).

Also that :—

'The broader and lighter band(s) are those which are most serpentinous in their composition, and these are laminated with thin and rapidly undulating layers of calcareous matter, while the darker and more numerously laminated bands are the more calcareous.'

Between the hill a quarter of a mile E. N. E. of Cherlopalle and the hill three-quarters of a mile south-east of Vengannapalle (the same distance north, a little east, of Cherlopalle), there are no rock exposures; but there is little doubt that it is the same sill that is found in this hill. The overlying Vaimpalli limestones here dip at 15° to 20° to the east. The dolerite sill has caused the serpentinisation of the adjoining limestone sporadically for a vertical distance of some 30 feet or more. The generally pale green serpentine (N 560) occurs in bands and nodules, usually parallel to the bedding of the magnesian limestone. The thickness of the intrusive dolerite sill cannot be estimated with certainty, but it must be fairly considerable. Its upper five or six feet or so, as well as the lower part of the limestone, are very decomposed and altered, with conspicuous development of pistachio-green epidote (N 559, 21792) in both rocks. At times, also, there is a fair development of magnetite at the contact.

The author searched the contact region thoroughly, but could find no traces of asbestos, though the stratigraphical conditions are very similar to those at Brahmanapalle and Lopatanutula, except that there is a larger thickness of magnesian limestone above the sill and there are no shales. Several old pits, long since fallen into disuse, were noted; it is thought that they were the pits mentioned by King in the notes quoted before.

Stratigraphical relations similar to those at Brahmanapalle.

What is probably the same dolerite sill is found dipping under Vaimpalli magnesian limestones in the hill one mile north (a little west) of Vengannapalle on the border with the Gooty taluk. Between this and the former hill, there are abundant fragments of dolerite in the cultivated ground. The intrusive nature of the dolerite sill is very well shown in this hill, the trap breaking frequently across the bedding. This is particularly the case in the southern extremity of the hill, where the sill has serpentinised the overlying magnesian limestones to a very remarkable extent, more than in the hill previously described. At least 30 to 40 feet show pale green, serpentinised and chalcedonic rock. A specimen (43·885,

The dolerite-limestone contact is faulted at Vengannapalle.

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21797) shows the development of abundant diopside.[1] There also seems to be a dislocation along part of the contact, and at times calcite (43·917) is developed. Specimens of the dolerite (43·917, 21793; 21794) show a medium to fine-grained rock with abundant prisms of augite and laths of felspar associated with much fine magnetite. No asbestos could be seen at the contact, nor it is thought that further search will be profitable.

Faulted outlier of Pulivendla quartzites.

The summit of the hill immediately to the north is capped by Pulvendla quartzites, which appear to be a faulted outlier. The dolerite sill could not be seen at the foot of this quartzite hill. As it is traced northwards from the south-western extremity of the preceding hill, the amount of serpentinisation progressively decreases and then the sill junctions against shales which show serpentinisation to a small extent.

Serpentine in the Gooty Taluk.

Chintalacheruvu.

In the Gooty taluk, on the western and northern slopes of the hill adjoining the Pulivendla-quartzite-capped hill just mentioned, thin but persistent basaltic veins (43·886, 21798) intrude blackish siliceous limestones with little or no serpentinisation. Serpentine, however, was noted in the hill 2¼ miles E. N. E. of Chintalacheruvu (57 F/13; 15° 0′: 77° 48′); but no trap was seen here.[2]

[1] See page 227 where the development of diopside is discussed. Diopside was not observed in the dolomitic limestones and dolomites of the asbestos areas of Cuddapah and Kurnool districts, respectively.

[2] Further north, in the Tadpatri taluk, near its trijunction with the Gooty taluk of the Anantapur district and the Dhone taluk of the Kurnool district, trap sills were noted in the Vaimpallis west of Lakshumpalle [*see Mem. Geol. Surv. Ind.*, LXIV, Pt. 1, p. 39, (1933)], but the author could not see any trace of serpentinisation. Though the contact was very covered with debris, it is thought that further prospecting will not be of value.

CHAPTER IV.

ASBESTOS IN THE KURNOOL DISTRICT.

Introduction.

The sole previous reference to the occurrence of asbestos in the Kurnool district of the Madras Presidency is that to the author's work contained in the General Report of the Geological Survey of India for 1932.[1] The only occurrences found in the district are those near Malkapuram and Joharapuram. These will be described in the following brief account of the serpentine and trap occurrences found as one progressively follows the strike of the Vaimpallis from the Lakshumpalle occurrence in the Anantapur district just mentioned (footnote, page 184).

A. L. Coulson.

Asbestos in the Dhone Taluk.

In only one instance were signs of serpentinisation noted in blocks of limestone seen in the neighbourhood of the dolerite sills intrusive into the Vaimpallis east and south-east of Chandrapalle (57 E/16; 15° 13′: 77° 49′).[2] This was by a fault 1½ miles south-east of the village. These trap sills continue almost to east of Bhavipadu (57 E/16; 15° 15′: 77° 50′).

Chandrapalle.

After a short distance, the sills reappear south-east of Kochcheruvu (57 E/15; 15° 19′ 30″: 77° 52′)[3] and continue for some three miles along the strike to one mile E. S. E. of the deserted village of Pardeshbhai, where a thin trap occurs a short distance below the Pulivendla quartzites. This appears to be the easternmost outcrop of the Kochcheruvu traps.

Kochcheruvu.

The section in the big hill 2¼ miles south-east of Kochcheruvu is very interesting. The following is the sequence in descending order :—

Pulivendla quartzites	....
Vaimpalli limestones and associated traps	Upper dolerite sill, thick (43·889, 21802)
	Shales
	Thin yellowish limestone
	Ferruginous shales
	Thin basalt sill (43·888, 21801)
	Limestones

[1] *Rec. Geol. Surv. Ind.*, LXVII, p. 23, (1933).
[2] *Mem. Geol. Surv. Ind.*, LXIV, Pt. 1, pp. 50-51, (1932).
[3] *Op. cit.*, pp. 54, 56.

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The thick upper dolerite sill is intruded between the uppermost Vaimpallis and the Pulivendlas; it also injects the quartzites and the limestones. It is a fine-grained dolerite. The laths of felspar in the lower sill are smaller than those in the upper; in addition, a fair amount of glass is present.

Though diligent search was made, no traces of serpentinisation were noted; however, the hill was grass-covered at the time of the author's inspection and serpentine may have escaped notice.

A few isolated traps intrude the Vaimpallis three-quarters of a mile south-west of Kamalapuram (57 E/15; 15° 21′: 77° 56′ 30″).

Kamalapuram.

A dolerite (43·891, 21806) occurring five furlongs north of the village has slightly serpentinised the limestone above it. The dolerite is rather coarse-grained and a section shows abundant serpentine.

Occasional basalts were noted in the hills to the north of Malkapuram railway station; but they were not of any size. Certain

Chinna Malkapuram.

of the limestones near the station show green serpentine, but no asbestos was seen.

The Malkapuram (57 E/15; 15° 21′: 77° 59′) dolerite sills are very interesting and they can be traced from south of Kamalapuram

Malkapuram asbestos area.

eastwards for about $5\frac{3}{4}$ miles to $2\frac{1}{4}$ miles south-west of Kottapalle (57 I/3; 15° 22′; 78° 2′ 30″), and, after a short interruption, for some $3\frac{1}{3}$ miles to past Mudduletiswami (57 I/3; 15° 21′ 30″: 78° 5′ 30″). A sketch geological map showing this area forms fig. 3 of Plate 10.

Hill 1,574 feet, occurring $1\frac{1}{2}$ miles south-east of Kamalapuram, is capped by Pulivendla quartzites in its eastern part and to the west by red ferruginous Vaimpalli shales, which underlie the quartzites. The dolerite junctions at the top sometimes with the Pulivendlas and sometimes with the red Vaimpalli shales. It thickens to the west and then practically dies out, as in the hill $1\frac{3}{4}$ miles S. S. E. of Kamalpuram, there is but a thin sill of trap. A fault, however, separates these two hills and appears to have occurred practicaliy at the time of intrusion of the trap. At the western end of hill 1,574 feet, there is a peculiar rock (43·897, 21811) of uncertain origin containing black and dark red fragments, set in a calcareous groundmass, which may be fragments of shales or of trap, highly altered.

There is a lot of epidote and quartz at the summit of the hill $1\frac{1}{4}$ miles west by south of Malkapuram. The trap here, and on hill 1,574 feet, is a fine-grained epidotised basalt (43·896, 21810).

Remnants of Vaimpalli limestones and dolomites occur in a strip running E.–W. to the south of the village of Malkapuram.

Analyses of dolomites near Malkapuram.

The contact relations between these rocks and the enveloping trap are extremely interesting. There has been the formation of green serpentine in serpentinous dolomite (43·893, 21808) on the northern side of the hill three-quarters of a mile W. S. W. of Malkapuram. The usual rock found here (43·894) has been analysed with the results given in Table II.

TABLE II.—*Analyses of Vaimpalli Dolomites from the Dhone taluk of the Kurnool district.*

Specimen.	43·894.	43·898.	43·901.
SiO_3	1·42	2·69	48·40
Al_2O_3, Fe_2O_3	1·40	1·35	1·42
Ca O	30·78	30·92	15·37
Mg O	21·30	20·88	10·38
CO_2	44·77	43·32	22·96
Ba O	*nil.*	*nil.*	1·20
H_3O	0·31	0·80	0·19
TOTALS	99·98	99·96	99·92
Specific gravities	2·85	2·84	..

43·894. Dolomite[1], three-quarters of a mile W. S. W. of Malkapuram (57 E/15), Kurnool district (Mahadeo Ram).

43·897. Dolomite[1], a quarter of a mile south-west of Malkapuram (Mahadeo Ram).

43·901. Country rock (silicified dolomite) near barytes vein, $1\frac{3}{4}$ miles west of Rahimanpuram (57 I/3), Dhone taluk, Kurnool district (Mahadeo Ram).

[1] *See Mem. Geol. Surv. Ind.*, LXIV, Pt. 1, p. 112, (1933).

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This outcrop of Vaimpallis extends eastwards up to the northern slopes of hill station 1,835 feet, one of the peaks of the dividing range between the Dhone taluk of the Kurnool district and the Banganapalle State. Its contact with the trap is very irregular and there is no possible doubt that the trap is intrusive in its relations.

Asbestos.

A fair quantity of serpentinous rock has been formed three furlongs south-west of Malkapuram and this limestone contains irregular and very sporadic cross-fibred veins of chrysotile asbestos (N 572, N 573), never thicker than three-sixteenths of an inch, which show up best on the weathered surface of the enclosing dolomite. A small quantity of magnetite (N 574, N 575) is also associated at times with the serpentine (Plate 8, fig. 2).

Sequence at Malkapuram.

The general succession in this hill a quarter of a mile south-west of Malkapuram is as follows in descending order :—

Pulivendla quartzites	....
Vaimpalli 'limestones'[1] and associated intrusive igneous rocks	Dolerite Dolomite containing occasional thin veins of *usbestos* Dolerite Large thickness of Vaimpalli limestones and shales

The same bed of dolomite is not always in juxtaposition with the lower dolerite; also the rocks here are locally buckled and contorted. Accordingly, even if the little asbestos that exists were present in fair amount, it would not be easily worked. The more or less ideal conditions of the Pulivendla taluk, with regularly and gently dipping dolerites and limestones, is not found in the vicinity of Malkapuram.

A specimen of dolomite (43·898) from a few feet above the lower dolerite (43·899, 21812) was analysed with the results given in Table II on page 157. An analysis of the dolerite is given in Table VIII on pages 224 and 225.

Examination under the microscope of the latter rock shows it to be a quartz-dolerite[2], showing eutectic intergrowths of alkali

[1] The word 'limestones' is of course used in the general sense, including dolomites, magnesian limestones, etc.

[2] *Cf.* A. Johannsen, 'A Descriptive Petrography of the Igneous Rocks', II, 'The Quartz-Bearing Rocks', Chicago, p. 418, (1933). The term 'quartz-diabase' used in America is equivalent to the British term 'quartz-dolerite', of which type of rock the Whin Sill is a well-known example.

felspar and quartz and, also, a somewhat titaniferous augite ophitically penetrated by laths of felspar.

Sequence south-east of Malkapuram.

Further to the east, *i.e.*, to the south and south-east of Malkapuram on the slopes of hill station 1,652 feet, the dolomite or dolomitic limestone which abuts against the lower dolerite is barren of asbestos veins. The succession here is more complicated; in descending order, it is as follows :—

Pulivendla quartzites	....
Vaimpalli limestones and their associated igneous rocks	Thin dolerite Ferruginous shales Thin basalt Ferruginous shales Thin basalt Shaly dolomitic limestones with serpentine Thin basalt Dolomitic limestone containing serpentine and magnetite (30-40 feet) Large dolerite sill Large thickness of Vaimpalli limestones and shales occurring to the north of the Malkapuram stream

Of this sequence, the upper dolomitic limestones and shales are discontinuous and die out as they are traced westwards; but the lowest dolomitic limestone or dolomite is the same as that south-west of Malkapuram where it shows definite asbestos. It is not anticipated that workable asbestos will be found in this region.

Large strike-fault.

Before leaving this area, mention must be made of a large east to west strike-fault, the Pasupula fault, immediately above the Pulivendla quartzites. A valley has formed along the site of this fault between two ridges, which are capped by Pulivendlas (*see* Plate 10, fig. 3).

Tufa.

An extremely interesting deposit of a tufa, which is quite recent in age, occurs on the junction of the two one-inch sheets 57 I/3 and 57 E/15. The tufa (43·900, 21813) overlies dolerite on the northern side of the range between the Dhone taluk of the Kurnool district and the Banganapalle State. It is a cavernous rock, the cavities of which contain many stalactites and stalagmites. The Malkapuram stream which before its passage through a gap in the Pulivendla-capped ridge,

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drains a large area of Vaimpalli limestones, has a precipitous passage down to the relatively low-lying country at the foot of what has been described by King as the Pasupula terrace.[1] The consequence is that there are several waterfalls over trap and the evaporation of the spray in this hot climate leads to the continued deposition of tufa. As the position of the stream has changed, so has the place of deposition of the tufa altered. Accordingly, at the present time, tufa is found adjoining former positions of the stream which are a fair distance removed from its present position. Minor rills have assisted in the removal and redeposition of the calcareous matter.

It would appear that an exactly similar deposit of tufa occurs 1½ miles W. S. W. of the village of Malkapuram along the precipitous course of a stream which drains a spread of Vaimpalli limestones in the vicinity of Kamalapuram.

As has been stated, the large Malkapuram quartz-dolerite sill dies out to the north of hill station 1,835 feet. The ridge containing this peak and that 1,741 feet high, is capped by Pulivendla quartzites which dip to the south and S. S. E. conformably under Tadpatri shales. Vaimpalli limestones and shales usually underlie the Pulivendlas, but frequently small intrusions of dolerite were noted. There are few signs of serpentinisation and none at all of asbestos in this part. From about 1¼ miles due south of Kottapalle (57 I/3; 15° 22′: 78° 2′ 30″), however, there is a large sill of dolorite which is continuous eastwards into the Mudduletiswami sill. It is interesting to record the occurrence of a small trap intrusion in the Vaimpallis on the side of the Malkapuram-Kottapalle track, seven furlongs W. S. W. of the latter village.

Kottapalle.

The structure of the Papaghni and Cheyair rocks in the vicinity of Mudduletiswami (57 I/3; 15° 21′ 30″: 78° 5′ 30″) is rather complicated.[2] The high ridge south of Ambapuram (57 I/3; 15° 23′: 78° 5′ 30″) is capped by quartzites which, from a hasty examination, appear to be Paniams as the limestones immediately underlying them resemble the Jammalamadugus. The Banganapalli grits underlying these limestones and overlying the Vaimpallis cannot well be seen.

Mudduletiswami.

[1] *Mem. Geol. Surv. Ind.*, VIII, Pt. 1, p. 164, (1872). A. L. Coulson, *op. cit.*, LXIV, Pt. 1, p. 54, (1933).
[2] *Op., cit.*, LXIV, Pt. 1, p. 65, (1933).

Vaimpallis, which are at times covered by Banganapallis, crop out in the low ground in the vicinity of Kottala and dip under the very large Mudduletiswami sill, which, in its turn, underlies the strong Pulivendlas and forms the cliff above the temple. In other words, the Mudduletiswami sill has been intruded between the uppermost Vaimpallis and the Pulivendla quartzites. It is generally a fine-grained basalt (43·902, 21815), but it changes its nature greatly. The rock contains frequent veins of quartz and epidote. Mr. P. N. Mukerjee traced the lower contact of the sill with the Vaimpallis to hill station 1,741 feet, but he observed no signs of serpentinisation.

As has been noted elsewhere[1], the covering layer of Banganapallis and Jammalamadugus effectively masks the geology of the area to the north-east of Rangapuram. Near Hanumantharayakottala (57 I/3; 15° 26′ 30″: 78° 7′), to the south-west of Betamcherla, the first outcrop of a large basic sill is met. This sill extends in a north-easterly direction to Gattimanikonda (57 I/2; 15° 32′: 78° 11′), where its outcrop is cut off by the Gattimanikonda fault[2] and by a covering of Banganapalli sandstones.

Betamcherla.

'The whole region east of Balapalapalle is one of immense disturbance, but as is usual in these parts, the structure is partly masked by the covering of Banganapalli and Jammalamadugu rocks, especially in the vicinity of Hanumantharayakottala. The large expanse of Betamcherla trap (43·906, 21823; 43·905, 21817) beginning near this village extends up to the Gattimanikonda fault on sheet 57 I/2. This basalt (for most of it is basaltic in texture) though continuous in outcrop, is not constant in stratigraphical position. It appears to be a gigantic sill, the intrusion of which was accompanied by faulting. East of Balapalapalle, it overlies, and, also, is apparently faulted against, quartzites which have been referred to the Pulivendla stage of the Cheyair series. North of Bugganipalle, in the region at present masked by Banganapalli sandstones and grits, there must be a change in the stratigraphical relations of the trap sill because still further north, in the neighbourhood of Gattimanikonda, the basalt clearly underlies the Pulivendlas and has been intruded between them and the Vaimpallis.'

Minute traces of barium were noted in a specimen (43·906) of this sill from south-west of Gattimanikonda.[3] There are no signs of serpentinisation or of asbestos in the Vaimpallis underlying this sill, even when the junction is clearly visible, as, *e.g.*, at about three-

[1] *Mem. Geol. Surv. Ind.*, LXIV, Pt. 1, p. 45, (1933).
[2] *See Op. cit.*, pp. 69, 70, 77, and Pl. 5, fig. 2, (1933). Also *Rec. Geol. Surv. Ind.*, LXVI, pp. 442-443, *et. seq.*, and Pl. 26, (1933).
[3] *Mem. Geol. Surv. Ind.*, LXIV, Pt. 1, p. 111, (1933).

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quarters of a mile S. S. W. of Gattimanikonda. As has been stated above, the Betamcherla trap sill underlies the Pulivendlas at Gattimanikonda and to the south of this village. Further to the south, in the vicinity of Bugganipalle (57 I/3; 15° 28′: 78° 10′ 30″) and Betamcherla, the sill is covered by Banganapalli grits and sandstones and flaggy Jammalamadugu limestones, which are quarried as building stones to a large extent near the latter place.

Ramallakota-Gani 'doubly-hinged' fault.

The large dislocation to the north of Gattimanikonda, for which the pre-Kurnool Ramallakota-Gani 'doubly-hinged' fault is responsible, has had the result of shifting for some considerable distance to the west the outcrops of Vaimpallis which we have traced continuously from the Cuddapah district.

Kalava wall.

The structure here is complicated by post-Kurnool movement, which has resulted in that very peculiar feature known as the Kalava (Calwa) wall and which has been described elsewhere by the author in a separate paper.[1] This wall is the result of post-Kurnool monoclinal folding, more or less along the line of the pre-Kurnool 'doubly-hinged' Ramallakota-Gani fault. The two main faults which accompanied the formation of the wall have been termed the Gunnygull fault and the Somayajulapalle fault.

Vaimpallis in the Nandyal Taluk.

Gani.

Whilst the main outcrops of the Vaimpallis to the north of the Ramallakota-Gani fault are found in the Kurnool taluk, a small outcrop of these rocks occurs to the south-east of the village of Gani (57 I/6; 15° 40′: 78° 19′), where they are faulted against Tadpatri shales. Frequent traps occur in the Vaimpalli limestones here, all with an E. N. E.–W. S. W. trend.[2] In no case, however, was serpentinisation noted.

Asbestos in the Kurnool Taluk.

Loddipalle fault.

Returning to the main exposures north of the Ramallakota-Gani fault, the first outcrops of the Vaimpallis are found in the vicinity of Uyyalavada (57 I/2; 15° 38′: 78° 4′ 30″). There are, however, no traps associated with these rocks. The outcrops are soon masked to the

[1] *Rec. Geol. Surv. Ind.*, LXVI, pp. 438-448, Pl. 26, (1933).
[2] *Mem. Geol. Surv. Ind.*, LXIV, Pt. 1, p. 86, (1933).

north by Banganapalli grits. An interesting post-Kurnool fault, the Loddipalle fault, runs E. S. E.–W. N. W. along the southern boundary of the Loddipalle reserved forest.[1] The forest hills are capped by Paniams and the low ground to the south by Banganapallis over Vaimpallis. Jammalamadugu limestones crop out on the western and northern sides of the forest, where they are fairly thick.[2] A fault as described above must be existent on the southern side in order that the juxtaposition of Paniams and Banganapallis may be explained.

The Rudravaram sill.

A few miles to the north-west, in the vicinity of Bhiravapuram (57 I/2; 15° 41′: 78° 2′ 30″), the first outcrop of a large trap sill, the Rudravaram sill, is met.[3] This sill is practically continuous to the Tungabhadra river (*see* Plate 10, fig. 2), which forms the boundary between the Nizam's dominions and this Kurnool taluk of the Kurnool district. It appears to have been intruded into the Vaimpallis lower down in the stratigraphical scale than has been the case in the exposures of these rocks that we have traced continuously from the Cuddapah district. It will be remembered that the large dolerite and basaltic sills have been found to be intruded usually into limestones and shales at the top of the Vaimpalli stage, immediately below or not far removed from the Pulivendla quartzites.

The Narnuru sill.

In these Kurnool taluk exposures, there is, however, another and probably distinct coarse dolerite sill, found in force to the south-west of the important village of Narnuru (57 I/2; 15° 43′: 78° 5′), which occurs higher up the stratigraphical sequence. Definite Vaimpallis crop out in the cultivated land between these two sills, though much of the geology is masked by exposures of Banganapalli sandstones and grits which dip under the Jammalamadugu limestones to the E. S. E. at a very gentle angle. Reference may be made here to the geological sketch map which forms fig. 2 of Plate 10. This exposure of Narnuru trap may have formed an island in the Banganapalli sea, as it is overlain directly by rocks most resembling the Jammalamadugu limestones. There is a good section just on the western boundary of the grounds of the rest house at Narnuru, where shaly sandstones and thin limestones, mostly of an arenaceous facies, can be seen lying on the eroded surface of a coarse trap. It is

[1] *Mem. Geol. Surv. Ind.*, LXIV, Pt. 1, p. 82, footnote No. 1, (1933).
[2] These rocks are quarried for building stones near Loddipalle.
[3] Rudravaram is a small village on sheet 57 I/1 (15° 45′ 30″: 78° 5′).

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thought that these beds are Jammalamadugus, though it is possible that they are merely calcareous Banganapallis.

The Narnuru trap is not found elsewhere, and it is the lower, or Rudravaram, sill with which we are here concerned.

Formation of serpentine by the Rudravaram trap.

At Chinnavami Konda, which attains a height of 1,327 feet east of Bhiravapuram, and also at the hill half a mile north of the village, the Rudravaram trap is overlain by Banganapallis. There is no sign of metamorphism of the Banganapallis, which here are very ferruginous grits and sandstones having a gentle E. S. E. dip under the Jammalamadugus and Paniams of the Loddipalle reserved forest. The contact between the dolerite and the Vaimpallis can be seen in the valley north of Bhiravapuram, but better still in the hills to the E. S. E., east and E. N. E. of Vabalapuram (57 I/2; 15° 42′: 78° 2′), where the conditions are somewhat similar to those at Brahmanapalle in the Pulivendla taluk of the Cuddapah district. There is, however, the very important difference that the dolerite we are now discussing makes contact with a dark, siliceous limestone, very similar to the upper siliceous limestone in the Brahmanapalle-Lopatanutula area. This limestone is of no great thickness, usually about five to six feet, but very variable. It is overlain by light grey limestones, similar to the magnesian limestones at Brahmanapalle in which the asbestos of that neighbourhood was found. There has been the formation in the light grey limestone of varying amounts of apple-green serpentine, sometimes with reddish serpentine (43·908). Though the contact was followed very closely and innumerable specimens were broken, not a single minute trace of asbestos was seen by the author. Had the trap been intruded just above the dark grey limestone, so that the light grey magnesian limestones were in contact with it, the chances of the occurrence of asbestos would probably have been more favourable.

The intruding rock (43·909, 21827; 43·910, 21828) is a coarse-grained dolerite with varying amounts of quartz. The augite is titaniferous. Serpentine and magnetite are common. The rock is coarser in grain than the Brahmanapalle sills.

Tadankapalle and Vamasamudram.

The contact east of Tadankapalle and Vamasamudram, and further to the N. N. E., across the Kurnool-Chittoor road, is largely masked by debris from the Banganapallis and Vaimpallis of the ridge to the east. There appears to have been much faulting in the

Vaimpallis here. Reference may be made to the notes regarding breccias formed of Vaimpalli fragments which have been published elsewhere.[1] The Banganapalli rocks were undoubtedly continuous far further to the west than they are at present found. They apparently cap the Gulcheru quartzites (which form the basal stage of the Papaghni series) in the big hill, 1,554 feet, in the Yaparlapadu reserved forest on sheet 57 E/14, north-east of Ulindakonda. However, the covering of these rocks presumably has been eroded from the Gulcherus, which form the Tadankapalle-Vamasamadram-Chinnatandrapadu-Pasupula range.

The width of outcrop of the Rudravaram dolerite sill increases in the vicinity of the Kurnool-Chittoor road, where it crops out over a mile wide across the strike. This may partly be due to increased thickness of the sill, but a contributing cause is the shallower dip here possessed by the coarse dolerite sill. On sheet 57 I/1, the width of outcrop narrows as Rudravaram is approached, and the sill appears to die out, or to be faulted out, east of the *jagir* village of Nutanapalle (57 I/1; 15° 46′ 30″: 78° 5′). Just south-west of Rudravaram, the contact of the sill with the overlying Vaimpallis is plainly visible, and there is a good development of apple-green serpentine. Though the limestones immediately above the dolerite here are of the light-grey magnesian type, there is no trace of asbestos. However, this region is very crushed and the Vaimpalli strata is greatly buckled. The general dip is E. S. E. The Vaimpallis are capped by Banganapalli sandstones and breccias in the low hills east and north-east of Rudravaram, which extend to the Gadidemadugu reserved forest.[2]

Rudravaram.

The author has referred elsewhere[3] to the large east and west Siddireddipalle (57 I/1; 15° 47′: 78° 5′) fault, the existence of which is considered necessary in order to explain the dislocations of the strata near this village and Nutanapalle.

Siddireddipalle fault.

‘Abundant fault-breccias occur to the south of mile 6 on the Kurnool-Nandikotkur road, trending W.N.W.–E.S.E. About seven furlongs north-west of Gadidemadugu, there is an important N.E.–S.W. fault. Whilst in the Gadidemadugu reserved forest, the general trend of one fault is the same, but that of another is N.W.–S.E.

[1] *Mem. Geol. Surv. Ind.*, LXIV, Pt. 1, pp. 82-83, (1933).
[2] *Op. cit.*, p. 84, (1933).
[3] *Loc. cit.*

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The exposures of the Vaimpallis and their associated traps to the north of the Siddireddipalle fault are interesting as it is in these rocks to the east of Joharapuram (57 I/1; 15° 49′: 78° 4′) that the second occurrence of asbestos in the Kurnool district was noted.[1] Exposures are poor near Nandanapalle in the valley of the north-flowing tributary of the Tungabhadra river.[2] Further towards Kurnool, along the Nandikotkur-Kurnool road[3], near the village of Kottavengupalle, dolerite crops out in force to the west of the village of Vengupalle, but in the vicinity of the village, Jammalamadugu limestones are strongly developed and appear to overlie the trap without intervening Banganapalli sandstones. The occurrence here, and also at Kurnool town itself, of these Jammalamadugu limestones indicates that there is either a post-Kurnool dislocation between the outcrops of these rocks at Gadidemadugu, where they dip to the E. S. E. at a gentle angle, and the outcrops just mentioned, or else these Jammalamadugus have been gently folded. The ancient schistose rocks cropping out in the vicinity of the Hindri river between Joharapuram and Kurnool are possibly the equivalents of the Dharwars. They consist of hornfels, micaceous schists with quartz-reefs, reddish granite, and traps. Reference may be made here to the ancient (? Dharwar) schistose series, intruded by felspar-porphyries and dolerites of varying ages, which crops out in the Kadiri taluk of the Anantapur district[4], just to the west of the basal rocks (Gulcherus) of the Cuddapah system.

Joharapuram asbestos.

The Cuddapah rocks have a shallow easterly dip east of Joharapuram. The exposures are poor at the village, but a short distance to the east, the Gulcherus are met. These are not very thick and have largely been removed for building purposes. They are overlain by Vaimpalli limestones, which are succeeded in a short distance by a large dolerite sill, which dips eastwards gently and crops out for about a mile along its direction of dip. It is very unfortunate that the junction between the dolerite sill and the Vaimpallis which underlie it should be in a region that is more or less covered with

[1] The other occurrence of asbestos is at Malkapuram in the Dhone taluk of the Kurnool district (*see* p. 54). Reference to the author's discovery of asbestos east of Joharapuram was made in the General Report of the Geological Survey of India for 1932 [*Rec. Geol. Surv. Ind.*, LXVII, p. 23, (1933).]

[2] The Kurnool-Cuddapah canal is bridged across this stream about half a mile N. by W. of Nandanapalle. The structure is interesting from an engineering standpoint.

[3] The mileposts on this road are not as given in the latest (1923) one-inch maps.

[4] *Mem. Geol. Surv. Ind.*, LXIV, Pt. 1, p. 30, footnote No. 2, (1933).

rice-fields, which receive abundant water from the Kurnool-Cuddapah canal. However, about seven furlongs east of Joharapuram, very occasional thin veins of asbestos (N 600) were noted in serpentinised limestone (43·912, 21831), which occurs just below the base of the trap which, locally, is very serpentinised. Further away from the contact, the trap (43·911, 21929) is a coarse-grained dolerite with titaniferous augite. It possibly formerly contained olivine, which since has been altered to serpentine and other products. Distinct, but minute, traces of barium were noted in this rock.[1]

The lower contact of the trap and the Vaimpallis meets the Tungabhadra river between Gondiparlu and Doddipadu, and probably curves round more or less following the course of the river here as far as Puduru (57 I/1; 15° 51′: 78° 8′ 30″). The chances of good asbestos in this region are not considered favourable. In this connection it may be remarked that the Collector of the Raichur district of Hyderabad stated that neither barytes nor asbestos had so far (March, 1932) been discovered in the vicinity of Alampur (57 I/1; 15° 52′ 30″: 78° 8′).

Tungabhadra river.

The contact of the dolerite with the Vaimpalli limestones which *overlie* it (we have so far considered the contact of the dolerite with the limestones which *underlie* it) is also unfavourable. It crosses the Kurnool-Cuddapah canal by the 22nd milepost on that canal, and then runs across the marshy ground towards Kottavengupalle, where it is covered by Jammalamadugu limestones and surface soil in the cultivated fields. Green serpentine has been formed in the magnesian limestones here and the resultant serpentinous limestone has been used locally as a building stone. No traces of asbestos were seen, however. This upper contact of the dolerite probably follows the course of the Tungabhadra towards Puduru.

Upper contact of dolerite.

[1] *Mem. Geol. Surv. Ind.*, LXIV, Pt. 1, p. 112, (1933).

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CHAPTER V.

ASBESTOS IN OTHER PARTS OF INDIA.

Afghanistan.

Although it does not form part of India, it is desirable to include here this brief account of the occurrence of asbestos in Afghanistan.

Khost valley. According to B. H. Powell[1], asbestos (*sang reshadar*) exists in flat beds or veins

'above the Khost valley,[2] and could be procured in considerable quantities. It is said to be twisted into rope by the hill people of those parts'.

In this connection, it is interesting to note that A. B. Wynne[3] states in a footnote that

'I have seen specimens of asbestos from two miles west of Segai Kangah Khost, where it is so plentiful the people are said to make it into ropes; the locality is stated to be two long days' journey from Thal into Afghanistan'.

A specimen of asbestos (J 263) from the Khost district was received by the Geological Survey of India in 1899 from Lieut. G. L. Carter, Commandant, Kurram Militia, Parachinar.

Jalalabad. According to E. Balfour[4], asbestos is found at Jalalabad (38 J/7; 34° 26′ : 70° 28′).

Kandahar. C. L. Griesbach[5] states that three miles north of Kandahar (34 E/10; 31° 37′ : 65° 42′ 30″), near its contact with a Cretaceous limestone, a basalt

'is altered into a semi-crystalline rock; it also changes into a serpentinous rock very soft and calcareous, with veins and lumps of light green or yellowish colour which the natives of Kandahar use for the manufacture of the more inferior kind of beads for rosaries'.

Kabul. A sample of chrysotile asbestos from Kabul territory, sent in 1912 to the Geological Survey of India for examination, gave the following results on analysis

	Per cent.
SiO_2	40·00
Fe_2O_3, Al_2O_3	7·69
MgO	34·44
H_2O	15·38
TOTAL	97·51

[1] 'Hand-Book of the Economic Products of the Punjab', I, 'Economic Raw Produce', p. 46, Roorkee, (1868).
[2] The Khost valley is on sheets 38 G and K.
[3] *Rec. Geol. Surv. Ind.*, XII, p. 111, (1879).
[4] 'Cyclopaedia of India', I, p. 179, (1885).
[5] *Mem. Geol. Surv. Ind.*, XVIII, Pt. 1, p. 52, (1881).

Baluchistan.

Quetta-Pishin district. A network of minute ? chrysotile veinlets was noted in dark serpentine (24·555) collected by Dr. L. L. Fermor from Khanozai (34 N/6; 30° 37° : 67° 19′ 30″) in the Quetta-Pishin district of Baluchistan.

Zhob district. Chrysotile asbestos with chromite and serpentine (J 453 and J 484) was collected in 1902 by E. Vredenburg from Tuarai, Upper Zhob.

A sample of asbestos from the Zhob district, sent to the Imperial Institute, London, in 1903 for examination, was valued at about £2-10-0 per ton, f. o. b. Thames.

In 1926, Dr. G. de P. Cotter collected asbestos (M 800) from five miles N. N. W. of Hindubagh (34 N/9; 30° 49′ 30″ : 67° 44′ 30″) in the Zhob district.

Bihar and Orissa.

Bonai State. In 1926, Mr. H. C. Jones collected weathered specimens (N 155) of asbestos from Rangra (73 F/4; 22° 2′ 30″, 85° 9′ 30″), Bonai State. He states[1] that there is not enough to be of economic value.

Mayurbhanj State. P. N. Bose records[2] that near 'Rangom Hill' (Rangan Pahar; 1,999 feet; 73 J/3; 22° 25′ 30⁰ : 86° 13′) in the Bamanghati subdivision of Mayurbhanj State, on the road from Beter Amda (Bhitaramda; 73 J/7; 22° 25′ : 86° 20′) to Dublabeda (Dublabera; 73 J/3; 22° 26′ : 86° 11′ 30″), quartz-veins containing opal, actinolite, asbestos and chalcopyrite were seen in decomposed epidioritic rocks. Samples were described by E. Vredenburg as being

'principally opal in which are imbedded well-shaped prisms of a transparent dark-green actinolite passing along the borders of the specimens into fibrous asbestos'.

Monghyr district. R. S. Sherwill[3] mentions the occurrence of thin veins of asbestos in slates on the Goria Koh *ghat* (? Ghorakhor Hill; 1,315 feet; 72 K/12; 25° 12′ 30″ : 86° 31′). Sherwill also states[4] that massive asbestos is reported to have been found near the summit of Pirpahar Hill (334 feet; 72 K/11; 25° 22′ 30″ : 86° 31′), three miles to the east of Monghyr.

Samples of asbestos, brought in 1912 by Mr. K. M. Pandin to the Geological Survey of India, and said to have been collected from

[1] *Mem. Geol. Surv. Ind.*, LXIII, Pt. 2, (*in the Press*).
[2] *Rec. Geol. Surv. Ind.*, XXXI, Pt. 3, p. 172, (1904).
[3] *Journ. As. Soc. Beng.*, XXI, p. 197, (1852).
[4] *Op. cit.*, p. 204.

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Ranchi district.

near Itcheel (? Itki; 73 E/3; 23° 21′: 85° 8′), were of indifferent quality.

Singhbhum district: Seraikela State.

Mention is made in the 'Quinquennial Review of Mineral Production of India for 1909 to 1913'[1] of the occurrence of asbestos in the Seraikela State, Singhbhum. The asbestos is stated to be of the chrysotile variety, obtainable in long columnar masses suffering from the defect of brittleness.

Dr. L. L. Fermor[2] mentions the occurrence of asbestos in Seraikela State in the neighbourhood of Bara Bana (73 F/14; 22° 38′: 85° 55′ 30″) and Surangposi. He states that the mode of occurrence is unknown

'but the region indicated is mapped as granite traversed by epidiorite dykes; there may be also strips of Dharwar schists within the granite. The asbestos may then occur either in such Dharwar schists or as an alteration product of the epidiorite dykes. In the Kolhan to the west of Chaibassa true chrysotile-asbestos has been found in the chromite quarries opened out on the partially serpentinized peridotite hills. The quality of this chrysotile-asbestos is good, but the quantity revealed by the operations for chromite is insignificant. It may, however, be of interest to remark that in Canada the asbestos and chromite, although associated with the same serpentine masses, are not developed at the same points, but are extracted from separate quarries; it might therefore be worth while to prospect the Kolhan serpentines for asbestos at those points where chromite has not been discovered.'

In 1912, the Rajah of Seraikela presented a specimen of asbestos (K 823) from Seraikela to the India Museum.

In 1923, Messrs. Ambler and Co., Calcutta, presented asbestos from Bara Bana (L 996 and 997).

According to Dr. J. A. Dunn[3], asbestos occurs in a number of places in Seraikela State, but only the asbestos at Bara Bana is a workable proposition.

'Here large dolerite dykes cut a serpentinised basic (or ultrabasic) rock which occurs as inclusions in the granite. Close to the serpentine the dolerites themselves show a distinct alteration to tremolite. The main deposit of asbestos occurs in the serpentine, bounded on the east and west by two large north-south dykes. The larger pieces of asbestos are confined to those parts of the serpentine which show considerable shearing, the asbestos occurring in the shear planes with the fibres arranged parallel to the planes, and generally horizontally. The "logs" of asbestos are frequently up to 14 feet in length and 12 inches in diameter. Such large pieces invariably abut at either end against well marked joint planes. Unfortunately the asbestos is rather too brittle for successful spinning but it is quite a good material for lagging, etc. The mineral is mined according to the requirements of the market

[1] *Rec. Geol. Surv. Ind.*, XLVI, p. 236, (1915).
[2] *Op. cit.*, LIII, p. 252, (1921).
[3] *Mem. Geol. Surv. Ind.*, LIV, pp. 157-158, (1929).

The origin of the deposit is doubtful, it may have resulted from the alteration of one of the ultrabasic rocks of the area, or of a part of the Dalma series of epidiorites—specimens of the mineral do occur in the main outcrop of the Dalma flows. From its position in the area, however, it is difficult to understand how it could be a portion of the Dalma epidiorites, as the granite in this part of Singbhum has only stopped the lower beds of the Iron ore series.

In the harder serpentine and tremolite-rock the asbestos veins are quite short and the fibres, orientated perpendicular to the vein walls, rarely exceed a few inches in length.'

Details as to the production of asbestos from Seraikela State for the years 1921 to 1932 are given in Table III below:—

TABLE III.—*Production of Asbestos from Seraikela State.*

Year.	Quantity.	Value.	
	Tons.	Rs.	£
1921	11·5	1,100	73
1922	..	..	..
1923	..	..	..
1924	92	11,550	831
1925	..	..	..
1926	40	5,000	373
1927	40	5,800	432
1928	148	20,460	1,527
1929	80	10,600	746
1930	..	..	..
1931	..	..	..
1932	90	9,000	677
TOTALS	501·5	62,910	4,659

Messrs. Poddar Mining Syndicate, Wardha, Central Provinces, were the agents of the company which worked the deposit of asbestos in Seraikela State. There was no recorded production from 1929 to 1931, but production was again commenced in 1932 when the deposit was worked by the State.

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In 1911, Mr. B. P. Mundell presented to the Geological Survey of India a specimen of asbestos (K 724) from Bhalidih (? Bhelaidih 73 J/8; 22° 33′: 86° 14′), near Kalimati, Singhbhum district.

Singhbhum district: Dhalbhum.

Dr. J. A. Dunn[1] records small deposits of tremolitic asbestos in an altered basic igneous rock at Manpur (73 J/6; 22° 36′: 86° 16′) and Digarsai (73 J/2; 22° 35′: 86° 14′) in Dhalbhum. The asbestos is a short-fibred, rather brittle material. None of the occurrences is of economic value. A specimen from near Manpur, collected by Dr. A. K. Dey, is registered as N 187.

Singhbhum district: Kolhan Estate.

Mr. H. C. Jones[2] records worthless thin veins of asbestos in ultrabasic rocks at Tonto (73F/11; 22° 23′: 85° 37′) and Nurda (22° 20′: 85° 44′).

Bombay.

Belgaum district.

Asbestos is said to occur in the Gokak taluk (47 L/16) of Belgaum district.[3]

Idar State.

Sir Henry Hayden[4] recorded the discovery by Middlemiss of amphibole asbestos to the south-east of Dev Mori (46 E/6; 23° 39′: 73° 28′). According to Middlemiss[5]:—

'The asbestos, 26/402 (12420), was found originally on the south side of the little divide, 800 yards south of the hill path from Dev Mori to Kundol.' (Kunol; 46 E/6). 'Other deposits were found in some shallow pits sunk across the wider part of the ellipse of outcrop. It appears to occur sparingly and irregularly among the steatite, but it has not yet been properly exposed by any prospecting operations. Examined in the Geological Survey Laboratory by the late Mr. H. S. Bion, it gave the following analysis:

	Per cent.
Ign (H_2O)	1·529
SiO_2	55·54
Fe_2O_3, Al_2O_3	8·35
CaO	12·15
MgO	21·27
Loss	1·17
TOTAL	100·00

[1] *Rec. Geol. Surv. Ind.*, LXIII, p. 29, (1930).
[2] *Mem. Geol. Surv. Ind.*, LXIII, Pt. 2, (*in the Press*).
[3] *See* G. Watt, 'Dictionary of the Economic Products of India', I, p. 338, (1889).
[4] *Rec. Geol. Surv. Ind.*, XLII, Pt. 2, p. 73, (1912).
[5] *Mem. Geol. Surv. Ind.*, XLIV, Pt. 1, p. 100, (1921).

The iron and alumina have not been separated and a little manganese is present.

The asbestos is remarkably pure, soft and of silky and long staple, without any hard residual fibres. By simply macerating it in water with a slight movement, and afterwards drying, the beautifully soft silky tresses are obtained together with a certain amount of fine down. In the matter of tensile strength it of course cannot compare with serpentine asbestos, but this quality is not imperative in many of the modern uses to which asbestos is now put.'

Burma.

Amongst several minerals forwarded by Major H. Burney from Ava and examined by J. Prinsep[1], was asbestos 'from the crevice of a rock among the hills of Tsa-gain; fine silky white Amianthus, crystallized on siliceous delomite'. Tsa-gain is Sagaing (84 O/13; 21° 52′ 30″: 95° 59′).

Sagaing district.

Central India.

Asbestos (J 620) from near Sejawara (46 J/6; 22° 38′: 74° 19′), Bhopawar Agency, was presented in 1902 by Balkrishna C. Joshi, Collector's Vernacular Office, Godhra.

Alirajpur State.

A specimen of white asbestos (K 310) from Kajlidongri (Kajlidong; 45 J/5; 22° 57′: 74° 28′), Jhabua State, was presented to the Indian Museum in 1909 by H. J. Winch, Esq.

Jhabua State.

Two samples of soft friable asbestos of very short staple and inferior colour were submitted for examination to the Imperial Institute from Jobat State[2] in the Bhopawar Agency of Central India. It was reported that the asbestos was of the very lowest possible quality, and would not even pay the cost of freight to a possible market. It was added that it was just possible that a local use might be found for the material as a fire-proofing for packing[3], etc.

Jobat State.

Central Provinces.

In 1906, a specimen of asbestos with talc and black manganiferous films (J 868) from Tumkhera Khund (64 C/3; 21° 24′ 30″: 80° 13′) was presented to the Indian Museum by R. K. Chhullary, Esq. An output of 18 tons

Bhandara district.

[1] *Jour. As. Soc. Beng.*, I, p. 14, (1832).
[2] Jobat State lies almost wholly on sheets 46 J/7 and 11. It is south-east of Idar State (*see* p. 202).
[3] W. R. Dunstan, *Techn. Rept. and Sc. Papers, Imp. Inst.*, p. 42, (1903).

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of crude asbestos for 1908 was reported from the deposit here[1]. Details of the occurrence are lacking, but the production since 1908 will be seen in Table IV below:—

TABLE IV.—*Production of Asbestos from the Bhandara district.*

Year.	Quantity.	Value.	
	Tons.	Rs.	£
1908	18·0	..	..
1909	..	..	..
1910	3·0	90	6
1911	..	..	..
1912	..	..	..
1913	..	..	..
1914	..	..	..
1915	..	..	..
1916	..	..	..
1917	7·0	540	36
1918	13·0	1,108	74
1919	9·0	1,396	121
1920	..	..	..
1921	..	..	..
1922	14·0	1,400	93
1923	..	..	..
1924	19·8	1,876	135
TOTALS	83·8	6,410	465

There has been no recorded production from 1925 onwards.

[1] *Rec. Geol. Surv. Ind.*, XXXIX, p. 217, (1919). Dr. L. L. Fermor [*op. cit.*, L, p. 275, (1919), has mentioned this occurrence, but he gives no details.

According to Mr. H. Crookshank[1], chrysotile occurs in thin veins in limestone near Bachai (55 N/5; 22° 52′: 79° 19′) in the Narsinghpur district. Mr. Crookshank noted similar limestones in many places along the southern side of the Narbada and states:—

Narsinghpur district.

'Although the material which I picked up was of no value whatever, it is possible that workable chrysotile occurs elsewhere in these limestones, but has so far been overlooked.'

A specimen of asbestos, forwarded in 1908 to the Geological Survey of India by Rao Bahadur Pundit Damodar Rao Shrikande, Damoh, was stated to have been found in the hills around Saugor (55 I/13; 23° 51′: 78° 46′). It was added that asbestos occurs at Sanoda (55 I/13; 23° 53′: 78° 55′) village, near Ludhora railway station, Saugor district.

Saugor district.

Jammu and Kashmir.

Thin veins and stringers of asbestos were found by Mr. D. N. Wadia[2] to occur in association with some epidote veins traversing Panjal trap in the north-western corner of the Shamsh Abari (43 F/15; 34° 22′: 73° 56′) mountain mass in the Karnah tahsil of Kashmir.

Karnah tahsil.

It was from this same Karnah tahsil that samples of impure asbestos were sent in 1910 to the Geological Survey of India by the Conservator of Forests, Jammu and Kashmir State. The colour was bad and the fibres short and brittle.

Madras.

(*Other than the Ceded districts*).

In the 'Manual of the Coimbatore District in the Presidency of Madras'[3], Nicholson states that asbestos had recently been found near Perundurai (58 E/11; 11° 16′ 30″: 77° 36′).

Coimbatore district.

Amphibole asbestos of poor quality, obtained from a locality 'six furlongs from the Coimbatore-Mettupalaiyam line', was forwarded by the Director of Industries, Madras, in 1922. This locality, however, is very vague, as a glance at sheet 58 A will show.

[1] *Mem. Geol. Surv., Ind.*, LXVI, Pt. 2, (*In the Press*).
[2] *Rec. Geol. Surv. Ind.*, LXII, p. 30, (1930).
[3] P. 24, (1887).

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In 1931, Mr. A. H. Gaston forwarded to the Geological Survey of India a specimen of anthophyllite asbestos from Cherangode village (? Cherankod; 58 A/6; 11° 33′: 76° 20′) in the Nilgiri district.

Nilgiri district.

According to E. Balfour[1], asbestos is found abundantly in the Salem district. Probably much of that taken as asbestos is not that mineral.[2] It must also be remembered that the boundaries of the old Salem district include much that is now part of the North Arcot district.

Salem district.

Asbestos of the slip-fibre type was found by the late Mr. M. Vinayak Rao[3] at the southern extremity of the magnesite deposit in the Chettichavadi jagir of the Salem district.

Mysore State.

The localities where asbestos has been found in Mysore State have been summarised in the 'Review of Mineral Production of Mysore for 1915-1929' by A. M. Sen, published as *Bulletin* No. 11 *of the Mysore Geological Department*. They are as follows:—

Summary.

'Amphibole Asbestos.

Chitaldrug District.—
(1) N. E. of Mayikonda village; fibres are hard and stained brown.
(2) Near Budihal—Ganjigere (Hosdurga taluk).
(3) Near Kudnirkatte Sukalhatti, about a mile east of Holalkere.

Kadur District.—
(1) In a coffee estate near Mudosi, Mudgere taluk.
(2) Near milestone 4/16 on the Belur—Mudgere Road.

Hassan District.—
(1) Near Kabbur, (2) Idegondanhalli, (3) Sunnakal Hosur near Yennehole-ranganbetta, (4) Tattikere and Hiritalal and(5) Bettadasatenhalli,—all in the Hole-Narasipur taluk.

Bangalore District.—
(1) Avalhalli, (2) Bidadi.

Mysore District.—
(1) Near Nagamangala, (2) 2 miles S. W. of Mandya, (3) Ne r Konur—about 12 miles S. E. of Nanjangud, (4) 3 furlongs S. W. of Aichanhalli, Krishnarajapete taluk and (5) near Terakanambi, Gundlupet taluk.

Tumkur District.—
A small exposure, about 6 furlongs W. of Mavattur, Tumkur taluk.

[1] 'Cyclopaedia of India', p. 179, (1885).
[2] V. Ball, 'Economic Geology', p. 519, (1881).
[3] *Rec. Geol. Surv. Ind.*, LXIII, p. 29, (1930).

Serpentine Asbestos.

Hassan District.—
(1) E. and E. N. E. of Yenneholeranganbetta (3165) near Hole-Narasipur.
(2) Near Idegondanhalli.

Mysore District.—
(1) Near Mavinhalli (2) Gopalpur.

Shimoga District.—
Near Shinganmane.'

The most comprehensive account of the asbestos deposits of Mysore is the paper entitled 'Brief Notes on Asbestos with an account of some of its occurrences in the Mysore State', by B. Rama Rao, published in *Records of the Mysore Geological Department*, XXII, Part 2, pages 58 to 99, (1925). Further reference will be made to this paper, but it suffers from the disadvantage of not describing all the deposits, and in not giving full references to the relevant literature regarding the discovery of the individual deposits. Accordingly, it has been thought desirable to include in this memoir such brief descriptions of the individual deposits as it has been possible to gather from the available literature.

V. S. Sambasiva Iyer[1] has recorded veins of

Bangalore district.

'pure white asbestos of good length of fibre, flexible and easily separable by the fingers'

within a few feet of the surface of lands of Avalhalli (57 H/9; 12° 56′ 30″: 77° 33′), a couple of miles to the west of Bangalore Fort. The veins traverse a talcose tremolitic rock.

A. Primrose[2] had previously heard of the occurrence of asbestos in the Jangam *hobli* of Anekal (57 H/10; 12° 42′ 30″: 76° 42′) taluk, but could not obtain any further information concerning it.

Amphibole asbestos is recorded from Bidadi (57 H/5; 12° 48′: 77° 23′)[3] in the Channapatna taluk.

The production of asbestos from the Bangalore district of Mysore is given below in Table V.[4]

[1] *Rec. Mysore Geol. Dept.*, IV, p. 158, (1903).
[2] *Op. cit.*, III, p. 215-216, (1903).
[3] B. Rama Rao, *Op. cit.*, XXII, Pt. 2, p. 73, (1925).
[4] *Rec. Geol. Surv. Ind.*, LIII, p. 195, (1921); *op. cit.*, LIV, p. 157, (1923).

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TABLE V.—*Production of Asbestos from the Bangalore district of Mysore.*

Year.	Quantity.	Value.	
	Tons.	Rs.	£
1920	107	4,280	428
1921	67	2,680	179

There has been no recorded production of asbestos from the Bangalore district since 1921.

Chitaldroog district.

According to L. Rice [1],

'asbestoid is found in the pot-stone near Talya, and ligniform asbestus among the Mayakonda hills'.

Mayakonda (14° 17′ : 76° 5′) is on sheet 57 B/3. In this connection it is interesting to note that V. S. Sambasiva Iyer records[2] asbestos in a

'highly weathered talcose actinolite tremolite rock of the gneissic series, in the north-east part of the village and amidst houses'

of Mayakonda.

This same author states[3] that

'A fine silky and pure variety of asbestos occurs on the vertical sides of two cuttings just close to a basic serpentinous dyke near the south waste-weir of tank, Gangigere,' (Ganjigere ; 57 C/6 ; 13° 44′ : 76° 23′) 'Hoshdurga Sub-Taluk. The exposures noticed are too small to enable one to form an opinion about its probable mode of occurrence and of quantity. But the close proximity of the serpentinous dyke is in favour of its quality.'

A. M. Sen[4] noted two veins of asbestos at the north end of the small hill near Sukhalhatti, just south of Kudinirkatte (57 B/4 ; 14° 2′ : 76° 12′), about one mile east of Holalkere. One of them is 80 feet long and about two inches wide.

According to B. N. Venkataramaiya[5], asbestos of inferior quality occurs on the western slope of the hill two furlongs west of the village

[1] 'Mysore and Coorg', II, p. 452, Bangalore, (1876).
[2] *Rec. Mysore Geol. Dept.*, V, Pt. 2, p. 57, (1904).
[3] V. S. Sambasiva Iyer, *op. cit.*, II, p. 115, (1901).
[4] *Op. cit.*, XXVI, p. 16, (1927).
[5] *Op. cit.*, X, pp. 88-89, (1910).

Hassan district.

of Yedegondanahalli (57 D/6 ; 12° 39′ : 76° 19′)[1], in veins in actinolite-schists. The material is mixed up with calcite and other impurities.

Venkataramaiya also notes the occurrence of veins of asbestos in a 'caught-up patch of actinolite-schist' about-one mile south-east of Kabbur (57 D/6 ; 12° 41′ : 76° 18′ 30″) on the western slope of hill station 3,008 feet.[2] The asbestos is

'white, coarse and stiffly fibrous ; and the bundles of fibres are cut up by the joints found in the mother-rock'.

Sambasiva Iyer also records[3] soft white asbestos from a cutting to the north-west of the 2-3/29th furlong stone on the Hole Narasipur-Yedatore road, and about half a mile to the north of the village of Yedegondanahalli. He states that

'the place of the occurrence forms the junction with the gneiss of a long patch of dunite forming the low ridge to the west of the road at this point. Asbestos of similar quality is also found on the west margin of the southern extension of the ultra basic rock mentioned above, and about a furlong to the west of the village of Idegondanhalli. It is this line of hills that is evidently referred to as an inexhaustible supply of asbestos by Messrs. Lavelle and Marsh in their reports published as appendices to the auriferous tracts in Mysore by Mr. R. B. Foote.'

According to Venkataramaiya[4], the licensee, Mr. Venkataramana Iyer of Hunsur, explored the country round about for asbestos and Venkataramaiya concludes that a

'fairly large quantity seems to exist in this area, notwithstanding the erratic nature of its occurrence'.

Venkataramaiya also notes the occurrence of asbestos

'in veins or small stringers in the caught-up patches of actinolite schist'

on the north-eastern spur of hill station 3,165 feet. He states the hill is composed chiefly of dunite and is called Yennecholerangan Betta.[5] The patches are comparatively few in number, and are small and irregularly distributed.

Two old asbestos pits were noted by Venkataramaiya about two furlongs off the above-mentioned spur, and south of the ruined village of Sunnakal Hosur. He also mentions that Mr. J. Burr had taken out a prospecting license over an area of two square miles

[1] Yedegondanahalli is in the Hassan district, but it is very near the border with the Mysore district of Mysore. The spelling given is the modern spelling.
[2] Presumably the hill shown on the topographical sheet as 3,000 feet.
[3] *Rec. Mysore Geol. Dept.*, V, Pt. 2, p. 59, (1904).
[4] *Op. cit.*, X, pp. 88-89, (1910).
[5] Actually 3,161 feet ; 57 D/5 ; 12 47′ : 76° 16′.

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north of the road in the bend of the river Hemavati, presumably near Ulivala (57 D/5; 12° 50′ 30″ : 76° 20′), but he had not noted any real asbestos here.

These localities are very near those mentioned by V. S. Sambasiva Iyer, who records asbestos in two places on the eastern slope of hill station 3,165 feet (? 3,161 feet; 57 D/5; 12° 47′ : 76° 16′), about three miles east of Hole Narasipur, and also at two places to the east of the ridge. He states the country-rock here is a complex mixture of ultrabasic rocks, amphibolite and dunite. He anticipates a fairly large quantity of asbestos may be available.

P. Sampat Iyengar[1] gives the four following localities for the occurrence of asbestos in the Hassan district:—

(1) Near Bettad Satanhalli (57 D/1; 12° 50′ : 76° 14′), north and N. N. W of Hole Narsipur.

(2) In the low ground immediately west of hill station 2,948 (? 2,945 feet; 57 D/5), 2½ miles north-east of Hole Narsipur.

(3) On the rising ground three-quarters of a mile W. S. W. of Haritalal, Hole Narsipur taluk.

(4) At the commencement of the *nala* close to hill station 3,008 (? 3,000 feet; 57 D/6; 12° 40′ : 76° 18′ 30″), just about a mile south-east of the village of Kabbur.

The second locality is not far distant from the Yenneholerangan Betta locality mentioned previously. The last is the same as that mentioned by Venkataramaiya.

Sampat Iyengar states[2] that

'In all the areas the mineral asbestos is formed by the alteration of the tremolite actinolite schist in close proximity to the amphibole peridotite intrusions. The alteration of the former by meteoric waters along schistose planes generally results in the formation of tough wood-like fibrous masses resembling mountainwood, if along the transverse fissures and joints, the asbestos formed is usually soft and white.'

The interested reader is referred to the description of the Hassan deposits given by B. Rama Rao on pages 74 to 89 of his paper referred to previously (page 207). It will be seen that both amphibole and chrysotile asbestos occur in the district.

The first recorded production of asbestos from the Hassan district is that of 412 cwts. in 1906.[3] In 1913, a small amount of work was

[1] *Rec. Mysore Geol. Dept.*, XVIII, Pt. 2, pp. 89-91, (1919).
[2] *Loc cit.*, p. 90.
[3] *Rec. Geol. Surv. Ind.*, XXXIX, p. 217, (1910).

carried out[1], and from 1916 to 1923, a small production has been recorded according to the figures given in Table VI below. These figures have been taken from statistics in the office of the Geological Survey of India. Even allowing for the small production from Bangalore district, they differ for some years from those given in a table in the 'Review of the Mineral Production of Mysore for 1915 to 1929'.[2]

TABLE VI.—*Production of Asbestos from the Hassan district of Mysore State.*

Year.	Quantity.	Value.	
	Tons.	Rs.	£
1906	20·6	..	..
1914	5·0	344	23
1916	5·0	330	22
1917	141·0	4,000	267
1918	344·0	13,360	891
1919	379·0	15,160	1,318
1920	1,711·0	68,440	6,844
1921	237·0	9,480	632
1922	228·0	9,120	608
1923	247·0	9,880	659
1929	150·0	3,000	224
TOTALS	3,467·6	1,33,114	11,488

There has been no production of asbestos in the Hassan district recorded to the Geological Survey of India after 1929.

Kadur district.

R. B. Foote[3] collected specimens of red and brown tinted asbestos in haematite-quartzite on the south side of the Bababudan Ghat road, below the pass. Sambasiva Iyer[4] found only a few stringers of asbestos in this locality.

[1] *Rec. Geol. Surv. Ind.*, XLVI, p. 236, (1915).
[2] *Bull. Mysore Geol. Dept.*, 11, p. 113, (1931).
[3] *Mem. Mysore Geol. Dept.*, I, p. 46, (1900).
[4] *Rec. Mysore Geol. Dept.*, V, Pt. 2, p. 58, (1904).

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Sambasiva Iyer, however, also records about 20 small veins of asbestos near the '4/16 furlong stone' on the Belur-Mudgere road[1], running in several directions through a country-rock composed of

'parallel and alternating schist bands of dark hornblende, tremolite and actinolite, all occurring in gneiss'.

R. B. Bruce Foote[2] mentions a show of asbestos

'in a coffee estate between Karnbail' (? Karbyle; 48 O/12; 13° 8′ 30″: 75° 43′ 30″) 'and Mudasosi,' (48 O/12; 13° 8′ 30″: 75° 43′) 'about five miles east of Mudgere. The stone is of good fibre as to length and softness but was so much discoloured by the red soil under which it occurs very greatly obscured that its value could not be estimated on the spot.'

Sambasiva Iyer[3] states that this deposit occurs in a talcose tremolitic and actinolitic amphibolite in the midst of Coffee Garden No. 26, near Mudasosi, Mudgere taluk.

A. Primrose[4] notes that asbestos occurs in several places in the Mandya taluk of the Mysore district. He himself noted coarse

Mysore district.

reddish asbestos about two to three miles south-west of Mandya (57 D/14; 12° 31′ 30″: 76° 54′). He found the mineral sold in every bazaar, being used as a medicine, being reduced to powder, mixed with water or milk, and so drunk. He adds that it probably owes its medicinal properties to its containing some proportion of magnesia and iron.

E. W. Wetherell[5] states that

'An impure short fibre, but a very soft variety of the above' (asbestos) 'was met in small patches, chiefly in the neighbourhood of Nagamgala.' (Nagamangala; 57 D/13; 12° 49′: 76° 45′ 30″). 'It is clearly derived from the schist as every possible gradation from crumpled schist to pure asbestos may be met with. There are indications of workings in most of the patches and the material is used by the natives for medicinal purposes. There is no great abundance and the material would be useless for commercial purposes.'

A. Primrose[6] states that he discovered

'a form of coarse asbestos running in a talcose rock and occurring in irregular patches S. W. to the village of Kuganpur.' (Position not found). 'On the 11th December' (? 1895) 'I visited ground near the village of Pusran, where pale asbestos was reported to occur and found it at the south end of the village of Tarikere,' (? 57 D/13

[1] There are two roads from Belur (48 0/16; 13° 10′: 75 52′) to Mudgere (48 O/12; 13° 8′: 75 38′ 30), but on the northern of these alone is a milepost 16 shown. This is near the village of Chikkameduru (48 O/16; 13 10′ 30°: 75 49′).
[2] *Mem. Mysore Geol. Dept.*, I, pp. 46-47, (1900).
[3] *Rec. Mysore Geol. Dept.*, V, Pt. 2, p. 58, (1904).
[4] *Op. cit.*, III, pp. 215-216, (1903).
[5] *Op. cit.*, III, p. 101, (1903).
[6] *Op. cit.*, I, p. 22, (1900).

12° 45′ 30″: 76° 58′) '1½ miles east of Pusran; but the asbestos was very poor and was not *in situ*.'

Other occurrences of amphibole asbestos in the Mysore district of Mysore are:—

(*a*) Near Konur (? Konanuru; 57 D/16; 12° 1′: 76° 50′), about 12 miles south-east of Nanjangud.[1]

(*b*) Three furlongs south-east of Aichanhalli (? Dodda Yachenahalli; 57 D/6; 12° 36′: 76° 25′), Krishnarajapete taluk.

(*c*) Near Terakanambi (58 A/13; 11° 49′: 76° 47′ 30″), Gundalpet taluk.[2]

B. Rama Rao[3] noted the occurrence about 1½ miles W. S. W. of Mavinhalli (? Mavinahalli; 57 D/12; 12° 12′ 30″: 76° 32′) of a greenish brown silky-lustred chrysotile, as irregular

'lenticular veins in a brownish weathering dark grey talcose serpentine rock (probably altered dunite or pyroxenite) close to its contact with a basic hornblende granulite dyke. The few veins noticeable, seldom exceed ½ to ¾ of an inch in width, and they are broken up by irregular lines of parting either parallel, diagonal or one intersecting the other breaking the length of the fibres into very small proportions. In all these cases the fibres are arranged crosswise to the cracks.'

He gives analyses of the vein material and the wall rock. His conclusions were that

'the asbestiform veins in this area have resulted from the alteration *in situ* of small veins of probably pyroxenite and that the asbestoform veins had developed prior to the alteration of the rock mass into serpentine, talc and other hydrous magnesian silicates. In all these veins of chrysotile it is only the cross-fibre type which has been noticed, and neither slip-fibre nor mass-fibre types have been found till now. The asbestos fibres of these veins show a decidedly higher double refraction than the serpentine of the rocks.'

Another occurrence of serpentine asbestos is said to be at Gopalpur (? Gopalapura; 57 D/12; 12° 14′ 30″: 76° 32′ 30″) in the Mysore district.[4]

Shimoga district.

Chrysotile asbestos is recorded from near Shinganman in the Shimoga district.[5]

Tumkur district.

A small exposure of amphibole asbestos is recorded from about six furlongs west of Mavattur (57 G/7; 13° 27′: 77° 20′), Tumkur taluk.[6]

[1] *Bull. Dept. Mines Geol. Mysore*, 7, p. 135, (1916).
[2] *Bull. Mysore Geol. Dept.*, 11, p. 112, (1931).
[3] *Rec. Mysore Geol. Dept.*, XXII, Pt. 2, pp. 90-91, (1925).
[4] *Ibid.*, p. 73, (1925).
[5] B. Rama Rao, *Rec. Mysore Geol. Dept.*, XXII, Pt. 2, p. 73, (1925). This village could not be traced.
[6] B. Rama Rao, *loc. cit.* Mavattur is at the trijunction of the Tumkur and Maddagiri taluks of the Tumkur district, and the Dodballapur taluk of the Bangalore district.

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North-West Frontier Province.

Bannu. According to B. H. Powell[1], a fibrous silky mineral, believed to be asbestos, is found in the Bannu district.

Chitral. 'During the survey of the Shishi Kuh,' (38 M/14; 35° 45′: 71° 52′ 30″) 'the valley forming the geological continuation of the southern portion of the Chitral valley below Drosh, Mr. Tipper found large masses of basic igneous rocks in many places converted into serpentine. A white asbestiform mineral has been formed in veins and cracks in the serpentine. In spite of a very thorough search no deposit of any size was discovered. Such as does occur is harsh, brittle and of poor quality.'[2]

'Poor asbestos in narrow veins was found by Mr. Tipper in the basic rocks in the stream running west from the glaciers above the camping ground of Deh Shal on the road from the Shah Janali Pass' (or Rich pass; 14,100 feet; 36° 47′: 72° 52′) 'in Chitral'.[3]

Kurram. In 1926, Dr. G de P. Cotter collected asbestos (M 799) from 1¼ miles north-west of Kharlachi post, west of Parachinar (38 K/1; 33° 54′: 70° 6′), Kurram Agency.

A specimen of asbestos (D 11) from this agency had previously been received in 1874 from Capt. N. Cavagnari.

Persia.

Though not strictly relevant, and, like Afghanistan, not forming part of India, opportunity is taken to record here the occurrence of

Bashkard district. asbestos near a locality Jaghdan (26° 22′: 57° 45′) in the Bashkard district, about 80 miles distant from the telegraph station at Jask. A specimen was sent by the Director, Persian Gulf Telegraphs, Indo-European Telegraph Department, to the Geological Survey of India in 1904.

G. H. Tipper[4] states that asbestos has been known from Gujur, 30 miles north-west of Ravar, Eastern Persia, for many years. Speci-

Eastern Persia. mens shown to him were very brittle and of short fibre. He adds that asbestos of poor quality occurs in thin veins in the crushed serpentine rocks south of Kahnu.

[1] 'Hand-Book of the Economic Products of the Punjab', I, 'Economic Raw Produce', p. 58, Roorkee, (1868).
[2] *Rec. Geol. Surv. Ind.*, LV, p. 14, (1924).
[3] *Op. cit.*, LVI, p. 22, (1926).
[4] *Op. cit.*, LIII, p. 74, (1921).

Punjab.

R. W. Palmer[1] observed chrysotile asbestos in association with a dolerite dyke on the Shali ridge (53 E/8; 31° 11′ 30″: 77° 17′) north

Simla Hill States. of Simla[2], the fibres reaching one or 1½ inches in length. The deposit was not fully opened up, but there seemed to be no evidence of any extensive development.

Rajputana.

Asbestos from Ajmer-Merwara (J 399-402) was presented in 1901 to the Indian Museum by the Extra Assistant Conservator of Forests,

Ajmer-Merwara. Ajmer-Merwara. A specimen (J 530) from Ramgarh (? 45 J/7; 26° 16′ 30″: 74° 17′) was presented in 1902 by the Reporter on Economic Products.

Samples of asbestos from Ramgarh, Niemrikhera, Naikailan, Kuruntia and Kotra (? 45 J/4; 26° 1′ 30″: 74° 13′) were reported on unfavourably by the Imperial Institute, London.

A specimen of asbestos (L 946) from near Sendra (45 J/4; 26° 5′: 74° 11′ 30″), Ajmer-Merwara, was received by the Geological Survey of India in 1923.

Dr. A. M. Heron[3] reported that a band of serpentine in crystalline limestone has been worked for asbestos in a large open-cut one mile north-east of Kanwlai (Kaolai; 45 J/10; 26° 36′: 74° 35′) in the Ajmer subdivision near the Jodhpur frontier, N.N.W. of the city of Ajmer.

'The asbestos is in veins ramifying through the serpentine, the largest being about ¼ inch wide. Evidently the small proportion of asbestos present, in proportion to the country-rock, and its shortness of fibre, have precluded successful exploitation.'

The production of asbestos from Ajmer-Merwara is given below in Table VII:—

TABLE VII.—*Production of Asbestos in Ajmer-Merwara.*

Year.	Quantity.	Value.	
	Tons.	Rs.	£
1927	5·7	1,150	86
1931	6·0	70	5

[1] *Rec. Geol. Surv. Ind.*, LIII, p. 12, (1921).
[2] Shali peak, 9,406 feet, is nine miles north-east of Simla railway station.
[3] *Rec. Geol. Surv. Ind.*, LVIII, p. 23, (1926).

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The production of 1931 was made by Messrs. Shiam Lal Pragnarain of Ajmer.

Banswara State. Short and long fibre asbestos (I 353-354) from Banswara (46 I/6; 23° 22′ 30″ : 74° 27′) was presented in 1891 to the Indian Museum by Raghonath Rao Yadow Bhagwat, Secretary, Council of Regency, Gwalior State.

Bundi State. Tremolite and asbestos with quartz (M 596) were collected in 1925 by Mr. B. C. Gupta from trap north-west of Khenia (45 O/7; 25° 20′ : 75° 22′ 30″).

Jodhpur State. In 1905, B. N. Saha, Esq., presented a specimen of chrysotile asbestos (J 711) from Khera Limri, Haripur, Jodhpur State.

Amphibole asbestos from Barimadho in the Sojat (45 G/9) *hakumat* of Jodhpur was forwarded to the Geological Survey of India in 1920.

Mewar. Asbestos (J 376) from Mewar was presented to the Indian Museum in 1901 by the Reporter on Economic Products.

Mewar : Dungarpur. Specimens of asbestos (K 923-928) were collected from near Dewar (46 E/9; 23° 55′ : 73° 40′) in Dungarpur State. According to Dr. P. K. Ghosh[1], it is not economic quality.

Sikkim.

In 1916, a specimen of asbestos with calcite from near Tong (78 A/10; 27° 33′ : 88° 39′), north of Gangtok, Sikkim, at an elevation of 5,000 feet and not far from mile 30 on the Lachung road, was sent to the Geological Survey of India by C. H. Dracott, Esq., State Engineer, Sikkim.

United Provinces.

Garhwal district. E. T. Atkinson[2] records the discovery of asbestos in the

'hill to the north, and at a short distance from Ukhimath' (53 N/N. W.; 30° 31′ 30″ : 79° 6″) 'in Garhwal. It is said to be of very good quality. The people use it medicinally for dressing wounds and burns, and as a wick for oil lamps, but it may yet be turned to a profitable account as a packing for steam-joints and the like.'

[1] *Rec. Geol. Surv. Ind.*, LXVI, pp. 455, 458, 460 and Pl. 28, (1933).
[2] 'Notes on the Economic Mineralogy of the Hill Districts of the N. W. Provinces of India', Allahabad, pp. 34-35, (1877).

Ukhimath is in the Kaliphat Malla *patti* of the Nagpur pargana of the Garhwal district of the Kumaun division.

A specimen of asbestos from near Parkandi (53 N/1; 30° 29′ : 79° 6′), Kaliphat, Garhwal district, is registered as G 505.

F. J. Stephens[1] states :—

'Asbestos is known to occur in three localities in the N. W. Provinces of India, *viz.*, Pithagora in Kumaun, on Badhangurh Mountain, and near Joshimath in Garhwal. At Pithagora[2] an impure serpentine, when traversed by a greenish translucent jade, is found to contain innumerable little veins of greenish and white asbestos, rarely more than ¼ in. in width.

Badhangurh[3] Mountain rises to a height of 9,500 feet in the dividing range between Kumaun and Garhwal. Hornblende rock, forming part of the mountain, is traversed by parallel veins of white, silky asbestos sometimes 6 in. wide.

The third locality[4] is about 70 miles from the town of Ranikhet in Kumaun and close to the Mana and Niti passes into Thibet. Veins of asbestos sometimes 4 or 5 in. in width, and masses of asbestos sometimes more than 6 ft. in width, occur in rock of a serpentinous nature.'

Dr. J. Coggin Brown collected asbestos (K 1,000) from Pithoragarh in 1906.

[1] 'Note on the Occurrence of Asbestos in the North-West Provinces of India', *Trans. Inst. Min. Met.*, XII, p. 192, (1902).
[2] Pithoragarh; 62 C/N. W.; 29° 35′ : 80° 12′ 30″).
[3] Given by T. H. D. La Touche in his 'Bibliography', I B., p. 17, (1918), as 30° 1′ : 79 35′, but it is not given on sheet 53 N/S. E.
[4] Joshimath; 6,107 feet; 53 N/N. E.; 30° 33′ : 79° 34′ 30 . Joshimath is in the Nagpur pargana of Garhwal district in the Kumaun division.

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CHAPTER VI.

THE MODE OF ORIGIN OF ASBESTOS, WITH PARTICULAR REFERENCE TO THE DEPOSITS IN THE CEDED DISTRICTS.

Introduction.

Having described in detail the occurrences of asbestos in the districts of Cuddapah and Kurnool and traced through Anantapur the outcrops of the Vaimpalli limestones and their associated basic sills, and having summarised the occurrences of asbestos in other parts of India, we are now in a position to discuss the mode of origin of the occurrences in the Ceded districts and to draw a parallel between them and deposits in other countries of the world.

Dr. C. S. Fox recognized the similarity of the Cuddapah deposits to those east of Carolina in the Transvaal, South Africa. Hall[1] gives the following succession in feet across the chrysotile horizon on Goedverwacht farm[2]:—

Similarity of the Cuddapah to the Transvaal deposits.

		Feet.
Pretoria series	1. Rooihoogte quartzite with about six inches of a cherty conglomerate at the top	8
Dolomite series	2. Shales and slates	..
	3. Thin basic sill	..
	4. Shales and slates	..
	5. Basic sill	20
	6. Dolomite, interleaved with chert and black slate; altered and carrying cross-fibre veins of chrysotile near the base	40-60
	7. Basic sill, its base not exposed, but its width is not less than	25
	8. Main dolomite series	..

The succession given above and the diagrammatic section given by Hall[3] may be compared with the typical succession in the Brahmanapalle-Lopatanutula area as given previously on page 158. It is also interesting to give in full Hall's summary of the principal features of the chrysotile deposits in altered dolomite[4]:—

Principal features of the Transvaal deposits.

'(*a*) The fibre invariably lies in serpentinized dolomite and is restricted to the fibre contact (or to within a few feet of the contact) between this altered dolomite and an intrusive sheet or sill of doleritic affinities, and persists along the strike—with intermittent non-payable zones—more or less as far as the sill or sills continue.

[1] A. L. Hall, 'Asbestos in the Union of South Africa', *Mem. Geol. Surv. South Africa*, No. 12, pp. 145-156, (1930).
[2] *Op. cit.*, p. 151.
[3] *Op cit.*, p. 152.
[4] *Op. cit.*, pp. 155-156.

(*b*) The deposits are of the usual cross fibre type and are disposed with the dip of the sill (and country formation). In the workings so far made, the asbestos seams are at the upper contact of the sills.

(*c*) The principal developments up to the present, are those in the Dolomitic Series east of Carolina, but other occurrences of the same nature are to be expected (and have actually been found) in other areas where the Dolomitic Series is found, and intruded by basic sills. (Chapter VII).

(*d*) The fibre is of very superior quality, but as a rule distinctly longer at or near the surface, the number and thickness decreasing somewhat rapidly in the direction of dip, though the alteration of the dolomite itself persists.'

It is also worth noting that[1]:—

'The earliest attempts to recover chrysotile within the Union are associated with this type of deposit, and although mining activities have been carried on at intervals since 1905—and at several localities—they have not so far furnished any substantial and continuous contribution to the output of chrysotile, comparable to that which has been and is being supplied from the more common occurrences of this fibre in serpentine, derived from basic rocks. Though the yield, therefore, has been intermittent and never an important factor in the market, the geology of these occurrences is of great interest in forming a close parallel to the deposits of the Grand Canon of Azizona, described by L. F. Noble.' [2]

The following remarks of Hall [3] are of interest with reference to the chrysotile occurring at the upper contact of the dolerite sill with the dolomitic limestone which it has altered :—

Position of the asbestos.

'East of Carolina, the Dolomite Series is defined above by the Rooihoogte quartzite (base of Pretoria Series) and below by the Black Reef quartzites, and within these limits the dolomite shows a series of from five to seven intrusive dolerite sills, having a variable thickness up to some 30 feet. The chrysotile has been found close to the *upper* contact of several of these sills, the relative positions of which are shown on Fig. 21, which also indicates the particular intrusion belonging to each of the principal developments. Invariably the dolomite within a few feet of the contact referred to has become serpentinized, and it is in this altered calcareous rock that one meets interbedded cross-fibre seams, of chrysotile, always disposed in conformity with the dip (and with the inclination of the contact plane). It is obvious that another development of fibre should lie at the *lower* contact of the sills, since the serpentinization (though not necessarily the fibre itself) is due to the metamorphic influence of the igneous sheet—a result depending just as much on the lower as on the upper contact. Since prospecting is actually confined only to the latter, it is quite possible that additional horizons—not yet proved—may be located *below* the sills close to their base.'

According to Dr. C. S. Fox, the plates attached to his report on the Brahmanapalle asbestos occurrences

Dr. C. S.

[1] Hall, *op. cit.*, pp. 145.
[2] 'Contributions to the Geology of the Grand Canyon, Arizona', *Amer. Journ. Sci.*, XXIX, pp. 520-522, (1910).
[3] *Op. cit.*, p. 146.

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'illustrate examples of cross-fibre veins of chrysotile in the siliceous dolomitic limestone; in serpentinised limestone; and in partially serpentinised tachylite respectively. The development of chrysotile is irregular but evidently marked where the tachylitic material is thick. The chrysotile zone is seldom greater than three feet thick—most of which is in the limestone. The veins are generally thin—less than half an inch wide—and in each exposure it was seen that the zone was very poor in chrysotile in several places. These rich patches and poor patches will make mining somewhat uncertain and the uncertainly must become greater with the question of behaviour in depth. The belief that serpentinisation has resulted from the percolation of meteoric waters requires careful investigation, as, if this is true, the deposits may prove to be unattractive in depth. From my personal scrutiny, I was of the opinion that the serpentinisation was due to the virginal water freed from the cooling igneous material. This water would react on the limestone without evidence of any weathering phenomena and serpentinisation would be effected both in the dolomitic material above and the trappean material below the contact of the two rocks while still hot. This absence of weathering or oxidation is what we in fact find. The evidence of serpentinisation seems to me in support of relatively deepseated phenomena. If this is true, the uncertainty as regards the prospects in depth, *i.e.*, to the dip along the base of the limestone, is similar to that along the outcrop and not worse.'

Genesis of Carolina asbestos.

Hall's remarks on the genesis of the Carolina deposits of the Transvaal are particularly apposite and, accordingly, are reproduced below in full [1]:—

'In the Carolina type of deposit—the seams' (of asbestos) 'are exclusively distributed (and disposed) with reference to an intrusive basic sill, which is directly overlain by altered (serpentinized) dolomite. The asbestos never lies in the sill itself, but is confined to a zone of altered dolomite up to some three or sometimes five feet above the margin of the sill; further away from the latter, where the dolomite is not altered, there is no fibre, while the seams are disposed with the bedding planes of the dolomite, becoming more numerous and more definite in proportion to the more pronounced alteration of the country rock. These features would seem to point conclusively to a metamorphic origin of the chrysotile due to a basic intrusion. It is very improbable, however, that the asbestos is a direct product of contact metamorphism. The first effect of the emplacement of the sill was the formation of metamorphic minerals, *e.g.*, olivine—characteristic of carbonate rocks; for this change the necessary magnesia and silica exist in the dolomite. In this rock silica is not distributed throughout—like in a peridotite as silicates—but only along certain layers, generally trending with the bedding, so that the distribution of the fibre in interbedded seams readily follows. The second step is the change of the metamorphic magnesian silicates into serpentine which requires the addition of water and is accompanied by an increase of volume; the source of the water may have been magmatic or meteoric, probably the former as suggested by the tendency of the serpentine to persist in the direction of the dip after the asbestos has more or less wholly given out. The conclusion, that the effect of the basic

[1] *Op. cit.*, pp. 242-244.

sill is limited to the formation of olivine, etc., and its subsequent serpentinization, but does not cover the formation of the chrysotile, is based on the following line of thought:—The intrusion of the sill and its metamorphic effects are in the nature of the case deep-seated, so that contact minerals should persist for as far as the sill does, and the same should hold good for the asbestos, if this be also regarded as directly due to the intrusion, *i.e.*, the successive changes (emplacement of sill—production of metamorphic olivine—its serpentinization *and* formation of fibre) should be independent of the present surface. As a matter of repeated observation, there is a very marked tendency for the asbestos to die out comparatively rapidly, as the fibre channel is followed in the direction of dip, though serpentinized dolomite is maintained. This conclusive result applies in variable extent to all the Carolina deposits as well as to the similar minor occurrences referred to in Chapter VII. The formation of this type of chrysotile occurrence is therefore not believed to be the direct, but only indirect, result of the emplacement of a basic sill and its consequent metamorphism.

The genetic problem of the chrysotile type of deposit in dolomite is probably (1) analogous to that of the serpentine of Mountville, described by Merrill[1], where a massive dolomite with siliceous layers contains veins and nodules or partly fibrous serpentine, derived from diopside with considerable increase of volume, and (2) to that described by *Noble* and *Diller* from the Grand Canon, Arizona.[2]

In the Algonkian succession of Asbestos Canon is a sill of diabase with crystalline limestone above and below; these carry bands and nodules of serpentine with chrysotile veins, specially over a horizon from 3 to 15 feet under the sill, but only where the strata have been invaded by the intrusion; these minerals are not found where the sill lies between shales, neither do they occur in the igneous rock itself. It is pointed out that the serpentine is of contact metamorphic origin, connected with the invasion of the limestone by the diabase. Diller regards the serpentine surrounding the veins as derived from some mineral in the limestone and not from the diabase. The fact that these Algonkian rocks are magnesian and in places siliceous, in form of chert bands and nodules, and that the general trend agrees with the direction of bedding, are further analogies with the Carolina Fibre Belt.'

Supposed origin of the Carolina asbestos in the zone of weathering.

Hall then proceeds to discuss the origin of chrysotile asbestos in the zone of weathering, noting that in South Africa, the most important chrysotile occurrences are found in areas of very high precipitation, whilst those occurrences in regions of moderate or low precipitation show only a minor or poor display of fibre. He adds that if the chrysotile deposits described by him in his Chapters III, IV

[1] 'On the Serpentine of Mountville, New Jersey', *Proc. U. S. Nat. Mus.*, II, pp. 105-111, (1888).

[2] L. F. Noble, 'Contribution to the Geology of the Grand Canyon, Arizona. The Geology of the Shimuno Area', *Amer. Journ. Sci.*, XXIX, pp. 520-521, (1910).
J. S. Diller, 'The Types, Mode of Occurrence, and Important Deposits of Asbestos in the United States', *Bull. U. S. Geol. Surv.*, No. 470, pp. 516-519, (1910).

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and VII are arranged in a descending order of importance, the order will agree fairly closely with that of decreasing precipitation. The change from serpentine to asbestos is usually accompanied by increase in specific gravity and increase in water contents, according to Hall. He concludes by stating:—

'The nature of these changes, the special prominence of the fibre display in areas of high precipitation the markedly reduced display in fibre deposits situated in regions of moderate or low rainfall, and lastly the general experience of a lack of economic persistence in depth (more marked in areas of low than of high precipitation) when taken together, suggest features more or less characteristic of the zone of weathering, as if the formation of chrysotile were somehow connected with the present surface. Where a transformation involves an increase in volume, it is reasonable to suppose that the increasing weight of superincumbent material must sooner or later set a limit to fibre formation. Hence the formation of chrysotile would not be continued indefinitely in depth, but be more prominent nearer the surface as is actually observable. Hydration requires water and in the zone of weathering, it is much more likely to have been of meteoric than of magmatic origin. Such a process should lead to an irregular distribution of the seams, and this can be observed in several instances. Where, in other cases, an occurrence of fibre has more the characters of a lode, there is the possibility that a definite structural element, *c.g.*, contact between two different formations, may represent more or less effective water parting, with the result that conditions of fibre formation might be more favourable along such planes than elsewhere. The views here developed imply that the origin of chrysotile is not necessarily always a deep-seated phenomenon, but perhaps one of comparatively recent date, in the sense that the derivation of magnesite from ultrabasic rocks is also not a deep-seated change, with the natural difference that the latter case is one of carbonation under relatively dry conditions.

——————— It is realized that the above views, in which the possibility is discussed of the Law of Association being genetically involved with changes characteristic of the Zone of Weathering, will probably appear novel and startling to those who look upon the origin of chrysotile as conditioned by acid intrusions. The writer has, however, been much impressed with the aspects of situation and lack of persistence in depth, referred to above, and has found great difficulty in reconciling these with the generally accepted mode of origin that is based on igneous and therefore deep-seated causes, requiring independence of the zone of weathering and unlimited persist nce in depth.'

The author makes no apology for quoting so extensively the views of Hall, more especially so when the deposits that we have discussed in the Ceded districts of Madras resemble so closely those of Carolina in the Transvaal. We are now in a position to see how far Hall's conclusions are applicable to those Madras deposits and to formulate our own ideas concerning the origin of these deposits.

Madras Asbestos, Dolomitic Limestones, and Dolerites.

Asbestos occurs both above and below trap, but only exceptionally below.

We have noted in our description of the Rajupalem asbestos occurrences in the Kamalapuram taluk of the Cuddapah district of Madras that in one instance, veins of chrysotile asbestos were noted in the magnesian limestone just above the lower of the two dolerite sills, and, also, just below the upper dolerite sill (*see* page 175). The occurrence in the field appears to indicate that the upper occurrence of asbestos was due to the upper dolerite and the lower occurrence to the lower dolerite, the former being below the associated dolerite and the latter being above the associated dolerite. The sole occurrence of asbestos noted in the Kurnool taluk of the Kurnool district, that at Joharapuram, was also *under* the lower contact of the metamorphosing dolerite sill. Generally speaking, however, the occurrences of asbestos in the magnesian limestones of the Vaimpalli stage are above the metamorphosing and intrusive dolerites. The author does not hold the opinion that other asbestos horizons will be found in the magnesian Vaimpalli limestones *below* the intrusive dolerites, as has been suggested by Hall might possibly be the case with the dolomites of Carolina.

Composition of the Vaimpalli limestones.

The composition of the Vaimpalli limestones which have been affected by the intruding sills is a matter of no little importance and it is unfortunate that, though he speaks of the rocks into which the Carolina sills have been intruded as dolomites, no analyses have been given by Hall. The percentage composition of dolomite (Ca Mg C_2O_6 or Ca C O_3, Mg C O_3) is as follows:—

	Per cent.
CO_2	47·9
Ca O	30·4
Mg O	21·7
TOTAL	100·0

This may be expressed alternatively as:—

Calcium carbonate, 54·35 per cent; magnesium carbonate, 45·65 per cent.

Turning to the analyses of the Vaimpalli rocks from the Pulivendla taluk of the Cuddapah district given on page 157, one notes that three of the limestones occurring above the lower dolerite are

best termed magnesian limestones; whilst the fourth, the uppermost, is a dolomitic and siliceous limestone. On the other hand, the analyses of the Vaimpalli rocks from above the dolerite sill in the Dhone taluk of the Kurnool district, which are given on page 187, indicate those rocks to be dolomites. It will be remembered that it is in the magnesian limestones of the Pulivendla taluk that the largest deposits of asbestos are found; and the dolomites of the Dhone taluk merely show occasional veins of asbestos. Provided that the metamorphosing dolerite sills are of approximately the same composition in these two areas, and that all other conditions are equal, it may perhaps be inferred that the magnesian limestones have a better predisposing influence for the formation of asbestos than the dolomites.

Composition of the basic sills.

However that may be, we are led now to consider the composition of the sills that were intruded into the Vaimpallis. The analyses of two specimens of dolerites intrusive into the Vaimpallis just below asbestos horizons have been given in Table VIII which follows. Unfortunately no analyses of the Carolina sills have been given by Hall, but the average dolerite according to Osann and an analysis of a quartz-dolerite have been given for purposes of comparison.

TABLE VIII—*Analyses of Dolerites from Madras and elsewhere.*

Number.	41·953	43·899	A	B
	Per cent.	Per cent.	Per cent.	Per cent.
SiO_2	46·63	50·04	49·50	51·04
TiO_2	1·60	1·73	1·42	2·22
Al_2O_3	12·26	13·26	14·37	13·69
Fe_2O_3	3·84	2·94	6·55	2·97
FeO	10·94	12·57	5·84	9·12
MnO	0·70	0·83	0·17	0·22
BaO	*nil*	*nil*	..	0·03
MgO	6·46	5·22	7·75	5·75

TABLE VIII—*Analyses of Dolerites from Madras and elsewhere*—contd.

Number.	41·953	43·899	A	B
	Per cent.	Per cent.	Per cent.	Per cent.
CaO	12·20	8·06	9·96	9·46
Na_2O	2·73	2·39	2·50	2·27
K_2O	0·16	0·72	0·84	1·01
H_2O+110°C.	2·81	1·96	0·66	1·48
H_2O—110° C.	0·24	0·31		0·37
P_2O_5	0·19	*trace*	0·44	0·30
TOTALS	100·76	100·03	100·00	100·36 [1]
Specific gravities	3·137	3·075	..	2·95

41·953. Dolerite collected by Dr. C. S. Fox from below the asbestos zone, Brahmanapalle asbestos mines, Pulivendla taluk, Cuddapah district, Madras (P. C. Roy and Mahadeo Ram).

43·899. Quartz-dolerite collected by A. L. Coulson and P. N. Mukerjee from below the asbestos zone, a quarter of a mile south-west of Malkapuram, Dhone taluk, Kurnool district, Madras (P. C. Roy and Mahadeo Ram).

A. Average dolerite (nine analyses) according to Osann.[2]

B. Quartz-dolerite, Whin Sill, Scordale Beck, Westmorland (Harwood).[3]

Both Madras specimens differ from the ordinary dolerite in having a slightly lesser percentage of alumina (12·26 and 13·26 against 14·37), much higher ferrous oxide (10·94 and 12·57 against 5·84), and considerably less ferric oxide (3·84 and 2·94 against 6·55). While the magnesia content of both (6·46 and 5·22) is less than that of the average dolerite (7·75), the lime content differs, being greater in one case (12·20) and less (8·06) in the other than the usual (9·96). It will be noted that the silica percentage of the quartz-dolerite from Malkapuram is higher than that of the dolerite from Brahmanapalle. With the exceptions noted above, all other constituents of the Brahmanapalle and Kurnool rocks are very comparable with those of the average dolerite.

[1] Includes 0·12 per cent. S, 0·06 V_2O_3, 0·29 CO_2 (less 0·04 O for S).
[2] R. A. Daly, 'Igneous Rocks and their Origin', New York, p. 27, (1914).
[3] A. Holmes and H. F. Harwood, 'The Age and Composition of the Whin Sill and the related Dikes of the north of England', *Min. Mag.*, XXI, p. 512, (1928).

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The material point that may be gained from a study of these analyses is that, apart from the state of oxidation of their iron content, the metamorphosing dolerites responsible, at least, for the serpentine produced in the magnesian limestones and dolomites are ordinary dolerites and the formation of the serpentine, and, as will be seen, that of the chrysotile, cannot be ascribed to any special feature in the composition of the intruding sills.

Age of the intruding sills.

Reference may be made here to the author's barytes report where the age of these sills is discussed.[1] As they were intruded into the Vaimpallis and into the Cheyairs in late or post-Cheyair, or Nallamalai, or immediately post-Nallamalai times, and as there is no definite unconformity between the Cheyairs and the Papahgnis[2], the sills are, geologically speaking, not very much older than the Vaimpalli rocks into which they have been intruded. Accordingly these intrusive sills were injected into calcareous and magnesian rocks which, at the time of the intrusion, were probably not consolidated completely. Thus the limestones would contain connate moisture[3] which would be available to assist the development of the serpentine.

Bearing this in mind, we can now turn our attention to a study of the processes resulting in the formation of the serpentine.

Formation of the Madras Serpentine.

Graham.

A few questions naturally present themselves. Was the serpentine formed directly or is it an alteration product of minerals of, *say*, the enstatite or olivine groups? Is it necessary to postulate first the formation, by metamorphism of the magnesian limestones, of magnesian silicates and the later alteration of these magnesian silicates by reactions similar to those given by Graham in his paper[4] on the Thetford asbestos for the alteration of the original silicate minerals of the peridotite? Alternatively, were lime-magnesian minerals formed and was the serpentine formed later from these?

[1] *Mem. Geol. Surv. Ind.*, LXIV, Pt. 1, pp. 106-108, (1933). Also p. 146 of this memoir.

[2] This point has been discussed fully by the author elsewhere as noted on page 146.

[3] The water content in limestone is not generally determined, but usually limestones contain an appreciable amount of water. *See* analyses given by J. F. Kemp, 'A Handbook of Rocks for use without the microscope', p. 105, London, (1911).

[4] R. P. D. Graham, 'Origin of Massive Serpentine and Chrysotile-Asbestos, Black Lake-Thetford Area, Quebec', *Econ. Geol.*, XII, pp. 154-202, (1917).

It is considered most unlikely that minerals of the enstatite or olivine (forsterite, fayalite or olivine) groups were formed. One may, therefore, consider the possibility of the formation of lime-magnesian silicates of the nature of tremolite or diopside.

Prior formation of magnesian silicate minerals unlikely.

According to Van Hise[1], dolomites are transformed to silicate rocks in his zone of anamorphism, where complex minerals are characteristically formed at the expense of simpler ones. The silicates are the ultimate products under the conditions there obtaining, the process being one of simple silicification: the silica originally present in the dolomite, or contributed to it by 'ground waters', replaces the carbon dioxide and forms the silicate. Either diopside or tremolite forms according to the following reactions, which have been numbered for ease of reference:—

Van Hise.

Dolomite — Diopside

(1) $\ldots\ldots Ca\,Mg\,(C\,O_3)_2 + 2\,Si\,O_2 = Ca\,Mg\,Si_2\,O_6 + 2\,C\,O_2$

Dolomite — Tremolite — Calcite

(2) $\ldots\ldots Ca\,Mg\,(C\,O_3)_2 + 4\,Si\,O_2 = Ca\,Mg_3\,Si_4\,O_{12} + 2\,Ca\,C\,O_3 + 4\,C\,O_2$

There is a decrease of volume of 40·11 and 25·20 per cent. respectively, provided the silica is a solid, the calcium carbonate remains as a solid when tremolite forms, and the liberated carbon dioxide escapes.

According to Van Hise[2], the change of diopside to serpentine may be represented by Equation (3) below:—

Diopside — Serpentine

(3) $\ldots\ldots 3\,Ca\,Mg\,Si_2\,O_6 + 3\,C\,O_2 + 2\,H_2O = H_4\,Mg_3\,Si_2\,O_9 + 4\,Si\,O_2 + 3\,Ca\,C\,O_3 + k$[3]

Supposing all the compounds separated as solids, the increase in volume is 56·32 per cent. If only the serpentine and quartz remain as solids, the increase in volume is 0·44 per cent.

As Van Hise states[4], serpentine is rarely produced from tremolite; and so if our serpentine in the occurrences with which we are con-

[1] C. R. Van Hise, 'A Treatise on Metamorphism', *Mon. U. S. Geol. Surv.*, p. 822, (1904).

[2] *Op. cit.*, pp. 274-275.

[3] +k means that heat is liberated; —k means that heat is absorbed by the reaction. *See* Van Hise, *op. cit.*, p. 210.

[4] *Op. cit.*, p. 286.

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cerned is derived from the alteration of calcium magnesium silicates, it is almost certain that its formation proceeded according to Equation (3) above. This involves the assumption that the change to silicates took place under the conditions of the anamorphic zone, which corresponds to the kata-zone of Grubenmann and Niggli[1], or to use the more preferable term, the hypo-zone of Dr. L. L. Fermor.[2]

The sills have not been subjected to hypo-zone metamorphic conditions.

We are not at all justified in believing this. On the contrary, we know that the serpentine in the magnesian limestones is found only very close to the metamorphosing dolerite sills; and it is a very legitimate conclusion that the serpentine is either a direct metamorphic product of that intrusion, or, alternatively, it is derived from the alteration of a direct metamorphic product of that intrusion. There is no evidence that the dolerite sills have been subjected to hypo-zone metamorphic conditions at any period of their existence, and we are led to conclude that the associated serpentine could not have been formed under hypo-zone conditions.

Direct formation of serpentine from dolomite.

Accordingly, we can now consider the possibility of the reaction of the dolomite with silica and water, with the resultant formation of serpentine and carbon dioxide, the calcium carbonate molecule of the dolomite becoming liberated as calcite as shown in the following equation:—

	Dolomite	Quartz		Serpentine	Calcite
(4)..	$Ca\,Mg\,(C\,O_3)_2$	$+\,2\,Si\,O_2$	$+\,2\,H_2\,O$	$=H_4\,Mg_3\,Si_2\,O_9$	$+3\,Ca\,C\,O_3$
					$+3\,C\,O.$

There is no apparent reason why this reaction should not be caused by the intrusion of the dolerite sills. It has already been mentioned that in addition to magmatic solutions, the connate water[3] in the magnesian limestones was also available to assist this reaction. It is thought, however, that the hydrothermal solutions accompanying the dolerites were the chief source of the water required. The limestones are far from pure and they all contain silica, probably in

[1] U. Grubenmann and P. Niggli, 'Die Gesteinsmetamorphose', I, Berlin, pp. 376-394, (1924).
[2] Letter to *Geol. Mag.*, LXIV, pp. 334-336, (1927).
[3] *See* Footnote No. 3, p. 226.

the form of small grains of quartz. Further reference will be made later to the formation of the carbon dioxide, which escaped through cracks in the serpentinised rock.

Formation of magnetite.

An equation should also be given that will account for the formation at the same time of serpentine and magnetite, which minerals, it will be remembered, were constantly found associated in the magnesian limestones close to their contacts with the intrusive dolerite sills. It will also be recollected that generally the asbestos was not developed to any extent when magnetite occurred. The iron now present in the magnetite is thought to be an original constituent of the magnesian limestones and not to have been derived from the dolerite sills. A glance at Tables I and II on pages 157 and 187 will show that the combined percentage of ferric oxide and alumina amounts to as much as 2·10 in the case of the Vaimpallis of the Pulivendla taluk, and to almost 1·40 per cent. for the Dhone taluk limestones. These limestones, however, are especially free from ferruginous matter and it is considered that the original limestones from which the magnetite and serpentine were developed, were much more ferruginous. The iron was probably present in the form of iron carbonate. Magnetite is abundantly deposited from solutions, especially those bearing iron carbonate, according to the reaction given by Van Hise[1]:—

	Siderite		Magnetite
(5).....	$3\,Fe\,C\,O_3$	$+\,O=$	$Fe_3\,O_4 + 3\,C\,O_2 + k$

Magnetite also forms extensively from siderite *in situ*. Van Hise states that these changes liberate heat and decrease the volume. Magnetite is, of course, one of the products of innumerable reactions between minerals, as a brief reference to Van Hise's treatise will show. One may mention here the development of magnetite by the hydration and oxidation of a ferruginous member of the enstatite group, or of the diopside group, etc.; but all these other methods of origin of magnetite presuppose the existence of minerals formed under pressure, conditions for the existence of which we have no reason to believe. Accordingly, we are reduced to believing that the magnetite was formed according to some such reaction as that given in Equation (5) above, and that the serpentine was formed according to Equation (4) on page 228.

[1] *Op. cit.*, p. 229.

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Before turning to a consideration of the origin of the chrysotile asbestos, it may be noted that we have been led to postulate an origin for the serpentine different from that given by Hall for the Carolina serpentine. Whereas Hall supposes the formation of olivine, or other metamorphic magnesian silicates, and their alteration by *magmatic* waters to serpentine, we suppose that the Madras serpentine has been formed directly by hydrothermal solutions, accompanying the dolerite sills, acting on the magnesian limestones.

Origin of the serpentine different from that given by Hall for the Carolina serpentine.

Formation of the Madras Chrysotile Asbestos.

We may now turn our attention to the Madras chrysotile asbestos and consider at what geological stage it was formed; whether its formation took place at the time of the formation of the serpentine; or whether the formation of the asbestos succeeded that of the serpentine, and if so, by what geological period?

It will be remembered that Hall considers the formation of the similar Carolina asbestos to have been subsequent to that of the serpentine, and to have been brought about by alteration of the serpentine by meteoric waters in the zone of weathering. In his report on the Thetford asbestos, R. P. D. Graham states[1] that the bulk of modern opinion is in favour of the hypothesis that this asbestos has been formed *in situ* by direct replacement of the massive serpentine. His views coincide with those of Cirkel and Dresser. He adds:—

Graham.

'In addition, as first pointed out by Dresser, there appears to be a constant ratio between the width of any asbestos vein and that of the serpentine band which encloses it. If the chrysotile was deposited in open fissures, as has been held by some, it would be a remarkable circumstance that the openings should have been everywhere strictly proportionate to the thickness of the already formed massive serpentine on their walls. The close interdependence in the volumes of the two varieties affords the most significant evidence yet offered that the one is a direct replacement of the other.'

Dresser.

Dresser states[2] that

'The veins' (of asbestos) 'are usually divided into two parts by a thin seam of iron ore, generally magnetite, which is parallel to the sides and near the centre of the vein. Bordering the veins on each side there is invariably a band of serpentine about three times the width of the vein.'

[1] *Econ. Geol.*, XII, pp. 183-184, (1917). *See*, however, H. H. Hess, *op. cit.*, XXVIII, pp. 634-657, (1933), received whilst this memoir was in the Press.
[2] J. A. Dresser, *Can. Min. Journ.*, XXXV, p. 601, (1914).

Graham's views on the origin of Thetford asbestos.

Graham summarises his views on the origin of the Thetford asbestos as follows[1]:—

'Siliceous magmatic waters, rising along fissures in the cooling and contracting peridotite, have soaked into the rock on either side and brought about its serpentinization. Complete alteration under these conditions was first reached in the layer of rock immediately bordering the fissure, while beyond this the degree of serpentinization decreased more or less gradually outward to the unaffected peridotite. Owing to the tendency for the fissures to open, this bordering layer of serpentine was not subjected to a uniform pressure from all directions, and the growing crystals were able to develop only in the direction of least pressure, normal to the fissure. The rock beyond, remaining essentially a solid mass until its serpentinization became complete, was not materially affected by this circumstance; but as succeeding layers or films, further and further removed from the original fissure, became completely serpentinized, the crystals continued to grow outward, because it was only at their extremities that they were in contact with fresh supplies of material, and also because the lesser pressure normal to the walls aided their growth in this direction. The original walls of the fissures, and also successive zones or layers of rock beyond, have in this way been continually eaten away and destroyed by the serpentinizing waters, and their solution has afforded the material from which the fibers of the chrysotile veins have crystallized; these fibers growing outward as the walls receded further and further through solution.

Ultimately the formation of the chrysotile ceased, either because the supply of serpentinizing waters was discontinued, or because there was no further tendency for the fissures to open; if the latter, this might have been due to the main body of peridotite having reached a temperature in equilibrium with its surroundings and ceased contracting, or to its rate of contraction having become insufficient to counterbalance the expansion attending further serpentinization. In this case the formation of serpentine would still proceed, but the rock affected, being now under a more or less symmetrical pressure, the fibers would not be forced to assume any particular orientation relative to one another, and "massive" material would result. The fact that Dresser found a fairly constant ratio between the width of the chrysotile veins and the serpentine "bands" which enclose them, suggests, however, that the formation of both proceeded side by side and ceased simultaneously, and consequently it may be concluded that it was lack of the necessary reagents which finally determined the width of any chrysotile vein.'

Graham adds[2] that

'According to the above hypothesis, two conditions must be fulfilled before veins of chrysotile can form. These are:—

1. The production of pure serpentine, *i.e.*, the complete serpentinization of all the silicate minerals of the peridotite, or other parent rock, together with the complete removal of all those constituents which are not required for the formation of the serpentine molecule (except perhaps iron ore).

[1] *Econ. Geol.*, XII, pp. 195-196, (1917).
[2] *Loc. cit.*, p. 197.

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2. The pure serpentine, as it crystallizes, must be under a differential pressure *i.e.*, subjected to an expansive strain in one direction, which will determine the direction of elongation of the fibers.'

Graham concludes by stating[1]:—

'It would follow as a corollary to this hypothesis, that chrysotile veins would never be found in cases where there was no contraction of the rock masses to counteract the expansion incident to serpentinization, since in that event, if pure serpentine was formed, the rock would be under essentially the same pressure from all directions; the microscopic fibers would not be constrained to assume any regular orientation, and would give rise to ordinary "massive" serpentine rock.

Thus, where the metamorphism has been brought about by meteoric waters, only massive, and usually impure, serpentine should result, and so far as the writer is aware, chrysotile veins of appreciable width or abundance have never been found associated with massive serpentine which can be shown to have originated in this way. On the other hand, where the serpentine is regard as having been produced through the agency of magmatic waters, and has no associated chrysotile, it is possible that these waters were not genetically connected with the parent rock of the serpentine mass, and only reached upon it long after it had reached the normal temperature and ceased contracting; and in many cases, also, it may be that the metamorphism did not progress so far as to realize the first condition of complete serpentinization.'

It will be seen that the views of Hall and Graham are widely at variance. It is therefore instructive to turn to A. B. Bateman's paper[2] on the origin of the Sierra Ancha asbestos deposit in the Grand Canyon of Arizona. Bateman states that:—

Bateman.

'The chrysotile of the Sierra Ancha deposit must be considered to have grown, not by pushing aside its walls, nor by crystallization in the direction of least pressure resulting from the contracting walls, but by actual replacement of the serpentine composing its walls, through the agency of hydrothermal solutions. The peculiar structure of the chrysotile may have been caused, as is stated by Taber, by the solutions supplying the material for growth at only the base of the crystals.'

Discussion on Bateman's paper is published in other parts of the same journal.[3] F. L. Stillwell[4] has pointed out that in the development of the serpentine, volume changes may have occurred, but they have not disturbed the uniform bedding of the limestone. Accordingly another interpretation of the facts described by Bateman is possible.

Stillwell.

[1] *Op. cit.*, p. 198.
[2] 'An Arizona Asbestos Deposit', *Econ. Geol.* XVIII, pp. 663-680, (1923).
[3] *Econ. Geol.*, XVIII, pp. 681-683, (1923); XIX, pp. 387-388, (1924); XX, pp. 104-105, (1925).
[4] *Op. cit.*, p. 104, (1925).

Taber's views[1] on the origin of chrysotile veins by crystal growth pushing the walls apart are too well known to need repetition.

Taber.

S. B. Keith and G. W. Bain[2] conclude for the chrysotile deposits in north-central Vermont that

Keith and Bain.

'Fracture cleavage and shear cleavage are predominating structures along borders of serpentines. Further adjustment of the rock mass has produced torsion cracks and crush fractures in which the asbestos is found.

Hydrothermal alteration appears along veins in places but seems to have no effect upon the veins themselves. Recrystallization and replacement lack prominent positions in making the chrysotile veins; neither are important enough to change even the general fracture form; both are in evidence but only in minor and relatively unimportant roles.

Fracture filling greatly outweighs replacement or recrystallization as the origin of the chrysotile veins. Detailed study of the serpentines and peridotites, the veins, and the mineral relations in them gives a picture of asbestos as a filling material in torsion cracks and crush fractures.'

These views may be compared with those of C. L. Sagui[3] for the origin of the chrysotile deposits of Cyprus:—

Sagui.

'(*a*) An initial cracking of the country rock seems necessary to start the crystal growth of chrysotile.

(*b*) A moderate pressure seems favourable to the process, as in the deeper zone the veinlets were filled by solid serpentine without a trace of fibrous structure. The progressive harshness of the chrysotile downward points to the same conclusion.

(*c*) Replacement through the agency of hydrothermal solutions seems to have been the principal factor of the process once the conditions stated in (*a*) and (*b*) are established.'

Conclusions regarding the formation of the Madras chrysotile asbestos.

Enough has been written to show that with the very widely differing views for the origin of chrysotile veins held by various authors, the genesis of this mineral is a far from simple problem. However, bearing in mind the conclusions of these authors, the present author has concluded that the asbestos veins found in the serpentinised magnesian Vaimpalli limestones close to their contact with intrusive dolerite sills, owe their origin to the hydrothermal solutions accompanying the dolerites.

[1] S. Taber, 'The Genesis of Asbestos and Asbestiform Minerals', *Trans. Amer. Inst. Min. Eng.*, LVII, pp. 62-87, (1918). *See* also *Bull. Amer. Inst. Min. Eng.*, No. 119, pp. 1973-1998, (November, 1916).
[2] 'Chrysotile Asbestos: I. Chrysotile Veins', *Econ. Geol.* XXVII, p. 188, (1932).
[3] 'Asbestos Deposits of Cyprus', *Econ. Geol.*, XX, pp. 371-375, (1925).

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The first effect of the intrusion was the formation of serpentine, the hydrothermal solutions assisting the reaction between the dolomitic portion of the magnesian limestones and the silica, with the additional formation of calcite and carbon dioxide; and the second effect, perhaps slightly later, was the penetration along cracks in the serpentinised rock[1] by the serpentinising waters and the deposition therein, under pressure, of the chrysotile asbestos, the veins increasing in thickness possibly by partial resolution of the serpentine bordering fissures, but more likely by the pushing apart of the walls by the fresh material deposited. In this connection, it may be noted that fractures are almost certain to have been produced in the magnesian limestones on account of the very large, local, temperature gradients produced by the intrusion of the sills; but it is unlikely that those fractures would occur at any considerable distance from the intruding sill.

It was noted that not all the chrysotile veins in the magnesian limestones are bordered on either side by pure serpentine; some veins show serpentine on one side and others showed none, some veins being in more or less slightly serpentinised magnesian limestone. There also is no definite ratio between the width of the chrysotile veins and the serpentine (when that is present) on either side of it as was noted by Dresser in the South Quebec region. The fibre is almost invariably of the cross-fibre type, slip-fibre being very rare.

Other conditions being equal, magnesian limestones have a better pre-disposing influence for the formation of chrysotile asbestos than dolomites.

The formation of the asbestos is believed to be totally unconnected with meteoric waters and, accordingly, there is no reason why the asbestos in the Ceded districts of Madras should not persist in depth. As, however, the occurrence of the asbestos along the strike of the rocks is very sporadic, the asbestos likely to be met by following the contact zone downwards along the dip must be considered as equally uncertain as that along the strike. The asbestos occurs in the serpentinised magnesian limestones both above and below the intrusive dolerite sills, but only exceptionally below.

[1] The carbon dioxide would escape through these cracks.

CHAPTER VII.

VARIETIES, USES, MINING, MARKETING AND PRICES OF ASBESTOS.

Varieties of Asbestos.

It is convenient for us to note the various kinds of asbestos and their different uses, so that we may be better able to obtain an idea of the value of the Madras asbestos and the uses to which it may be put. In this connection, it must be remembered that throughout this memoir, the term asbestos so far has been used chiefly with reference to the mineral chrysotile and less commonly to amphibole asbestos. However, the term asbestos is a commercial one, applied to a variety of fibrous mineral substances which can readily be parted into their constituent fibres.

Asbestos is a commercial term.

Ladoo.

According to Ladoo[1],

'*Chrysotile* is a fibrous form of serpentine, with which it is always associated. It is a hydrous magnesium silicate, represented by the empirical formula $H_4Mg_3Si_2O_9$, and contains 12·9 per cent. of water of composition. It occurs in aggregates of fine, crystalline silky fibers, which are flexible and have considerable tensile strength. These fibers usually range in length from less than $\frac{1}{4}$ to 1 or $1\frac{1}{2}$ inches, but fibers as long as 5 to 6 inches are sometimes found and an extreme length of 24 inches has been noted. Chrysotile fibers are nearly always brilliant white, but aggregates of fibers may vary from white to pink, through yellowish and yellowish-green to olive-green. Its *Hardness* is 3 to 3·5; *Specific Gravity* 2·2 to 2·3; *Luster* sub-resinous to greasy, pearly and silky.

Crocidolite is a soda-iron, monoclinic amphibole, having the formula $Na\ Fe\ (SiO_3)_2.FeSiO_3$. It is highly fibrous, like chrysotile, but its fibers have a higher tensile strength, and a much lower resistance to heat. Its colour is a characteristic lavender-blue, and it is thus often called "blue asbestos" or "Cape Blue" (from Cape Province, South Africa). Fibers commonly range in length from less than $\frac{1}{8}$ to $1\frac{1}{2}$ inches and rarely exceed 3 inches. It has a specific gravity of 3·20 to 3·30 and a silky luster.

Anthophyllite is an anhydrous iron-magnesium silicate, having the formula $(Fe, Mg)\ SiO_3$. It belongs to the orthorhombic group of the amphiboles. It occurs in rather coarse, fairly long and usually rather brittle fibers of low tensile strength. It is more resistant to heat and to acids than chrysotile, so that anthophyllite low in iron is especially suitable for making chemical filters.

Amosite is an iron-rich anthophylite found chiefly in South Africa. It was thought originally to be a new species and was described by Hall as a monoclinic amphibole. Wherry later examined amosite both chemically and microscopically and found it practically identical with ferroanthophyllite, an orthorhombic amphi-

[1] R. B. Ladoo, 'Non-Metallic Minerals: Occurrence, Preparation, Utilization', New York, pp. 43-44, (1925).

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bole having the formula (Fe, Ca, H_2, Mn)O. Si O_2. When amosite contains considerable soda it approaches crocidolite in composition. Amosite is characterized by a well-developed fibrous structure, having fibers of unusual length. Lengths of 4 to 7 inches are common and an extreme length of a little over 11 inches has been observed. The fibers are flexible, but usually have less tensile strength than chrysotile. Amosite is harder and harsher than chrysotile and is said to cause excessive wear on the teeth of carding machines. It varies in colour from a pale dirty-brown through various shades of gray and pale yellowish green to nearly white. Acids have little effect on amosite and it withstands heat better than crocidolite.

Asbestos, "*amphibole*" *asbestos*, "*hornblende*" *asbestos* and "*Italian*" *asbestos* are various terms given to the monoclinic amphiboles, tremolite (formula $CaMg_3(SiO_3)_4$) and actinolite (formula $Ca(Mg, Fe)_3(SiO_3)_4$) when they occur in fine silky fibers. This is the original type of material to which the mineralogical name "asbestos" was given. The fibers may be fine, silky and of great length, but they usually have little tensile strength. A small amount of Italian amphibole asbestos has been used for spinning, but most of it is too weak. When pure tremolite asbestos is chemically stable and may be used for making chemical filters.'

The following table of analyses is taken from Ladoo and shows the difference in composition between the different kinds of asbestos :—

TABLE IX.—*Analyses of different kinds of Asbestos.*

—	1 Chrysotile.	2 Crocidolite.	3 Amosite.	4 Anthophyllite.	5 Amphibole.
Si O_2	40·49	51·22	49·58	57·12	57·72
Al_2O_3	1·27	..	2·25	0·75	0·53
Fe_2O_3 and Fe O	2·53	34·08	39·64	6·36	2·80
Mg O	41·41	2·48	4·79	29·44	22·61
Ca O	..	0·03	0·53	..	13·84
Na O	..	7·07	..	..	0·50
H_2 O (const.)	14·06	4·50	3·16	5·47	0·81
Mn O_2	..	0·10	..	..	..
K_2 O	..	..	..	..	0·30
TOTALS	99·76	99·48	99·95	99·14	99·11

1. Average of eleven analyses of Canadian chrysotile quoted by Cirkel.[1]
2. Analysis of South Africa crocidolite quoted by Cirkel.[2]
3. Average of seven rather widely varying analyses of amosite from Transvaal, South Africa, quoted by Wherry.[3]
4. Analysis of Georgia anthophyllite quoted in "Asbestos (1913-19)".[4]
5. Analysis of Italian amphibole asbestos quoted by Marcuse.[5]

[1] F. Cirkel, 'Chrysotile-Asbestos: Its Occurrence, Exploitation, Milling, and Uses' Can. *Dept. Mines, Mines Branch*, Bull. 69, p. 31, (1910).
[2] *Op. cit.*, p. 22.
[3] E. T. Wherry, 'Amosite', *Amer. Miner*, VI, No. 12, p. 174, (1921).
[4] *Imp. Miner. Res. Bur.*, p. 6, (1921).
[5] B. Marcuse, 'The Marketing of Asbestos', *Eng. Mining. Journ-Press*, CXIV, No. 7, p. 278, (1922).

Uses of Asbestos.

The commercial application of the various kinds of asbestos has been discussed at length by Cirkel[1], Ross[2] and many other authors. An exhaustive list of asbestos products is given in a recent number of the magazine '*Asbestos*'.

Cirkel, Ross, etc.

According to Ladoo[3],

Ladoo.

'The main uses for asbestos fall into a few fairly well-defined groups, namely: (1) asbestos yarns, cordage, cloth and similar textile products; (2) asbestos paper compressed sheets, blocks, etc.; (3) asbestos-cement products such as asbestos shingles, lumber, corrugated siding, etc.; (4) heat-insulating cements; (5) boiler and pipe coverings (asbestos *plus* basic magnesium carbonate) and corrugated asbestos paper; (6) as an ingredient in paints and roofing cements (shorts, asbestic, ground anthophyllite, etc.); (7) asbestos fibers used as such for filtering, packing, etc.

From primary manufactured products, such as asbestos yarns, cordage and paper, a multitude of secondary finished products are produced, such as automobile brake-band linings, steam packing and pipe coverings. It should be noted that, while very long spinning fiber is essential for some purposes, the bulk of the asbestos marked is for use in products in which much shorter mill fibers may be used.'

Coggin Brown.

Dr. J. Coggin Brown gives an excellent summary of the uses to which asbestos is put[4]:—

'Vein asbestos in its raw state is opened up and dressed in special machinery and then separated into a number of grades depending on the lengths of the fibres as already described. The fibres are used for a variety of purposes without further treatment, and among these may be mentioned insulation of all kinds, the manufacture of non-conducting materials, filtration of water and acids, and packing for every type of steam and water valve stems. The longer fibres are spun into single-ply and multi-ply yarns which are woven into fabrics, ropes and tapes. Spinning machinery has now been developed to such an extent that single threads of asbestos of fair strength can be made of which one hundred yards does not exceed one ounce in weight. The yarns are classified according to their count, quality and finish and have many uses in the electrical and other industries, for plaiting, sewing and binding purposes, etc. Glazed asbestos yarn enters into the composition of incandescent mantles. Asbestos cloth is employed in the manufacture of a great number of asbestos goods, particularly for jointing materials and stuffing-box packings. It is used for the

General.

[1] 'Chrysotile-Asbestos: Its Occurrence, Exploitation, Milling, and Uses', pp. 245-289, (1910).
[2] J. C. Ross, 'Chrysotile Asbestos in Canada', *Bull. Can. Dept. Mines, Mines Branch*, No. 707, pp. 105-132, (1931). This contains an excellent bibliography (pp. 133-139).
[3] R. B. Ladoo, 'Non-Metallic Minerals: (Occurrence, Preparation, Utilization', New York, pp. 64-65, (1925).
[4] 'Notes on Asbestos', *Bull. Ind. Indus. Lab.*, No. 20, pp. 9-12, (1922).

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filtration of acids, water and other liquids. Fire-proof curtains, mattresses, mats, upholsterings, firemen's aprons and suits are made from it. Asbestos webbing is utilized for wrapping electric cables and for the insulation of steam pipes and hot surfaces. Asbestos tubing forms as reliable protection for electric light leads, etc. For the friction linings of brakes on motor vehicles it is practically indispensable and is woven with brass wire in to a solid mass for this purpose.

The shorter fibres are made into millboards, paper, boiler coverings, and compositions, mattress fillings and for the preparation of fireproof plasters, tiles, sheets and slates in the building trade.

Asbestos millboards are largely used in lining ships' bulkheads, railway carriages, retorts, gas stoves and kitchen ranges. Pressed into artistic shapes they form ornamental ceilings and partitions.

Asbestos paper is employed in the manufacture of insulating coverings for pipes and boilers, deck linings and rotproof linings under roofs. The electrical industry consumes large quantities of this material.

Owing to its power of resisting heat without charring and to that it is proof against deterioration in contact with moisture and oil, asbestos forms the foundation of most of the packing and jointing materials used in modern engineering. For ordinary purposes rings, joints and washers are cut from millboard but compressed fibre jointing, made by impregnating special grades of the mineral with suitable cementing solutions and rolling them out into sheets under great pressure, is in considerable demand. For special purposes, such as high pressure and internal combustion work or superheated steam, other substances are sometimes introduced. For example, brass wire is interwoven with asbestos cloth, or thin sheets of metal or of rubber are introduced between the layers, or the cloth itself may be proofed with rubber.

Jointing and packing.

The simplest form of packing is the plaited material supplied in coils but packing is also made of rolled asbestos cloth. Strands of antifriction metal may be braided up with the cloth, or studs of the same alloys introduced to give it a metallic wearing surface. Other varieties have rubber cores or strands. Some packings are impregnated with lubricating oils, others have flakes of graphite woven in with them. Asbestos yarn and soapstone packings are also made.

Another important industrial application of asbestos is for the manufacture of non-conducting coverings for boilers, economizers, engines, steam pipes, vats and cold storage installations. Asbestos mattresses and shaped blocks of compressed fibre are prepared in suitable forms for these purposes. Wadding and felt are used in the same way. Removable coverings of corrugated asbestos millboard possess a cellular structure which is desirable for some purposes, while asbestos rope lagging is especially adapted for winding around pipes. Such ropes are sometimes made with a core of kieselguhr. For covering boilers, tanks, flues, pipes, etc., with a non-conducting coating that need not be removed periodically, asbestos compositions are used. These consist of the poorer qualities of the fibre with magnesia, kieselguhr, sodium silicate, barium sulphate and other substances added, mixed with water and applied in the form of a paste to the object which has to be treated.

Lagging and boiler compositions.

Mixed with portland cement asbestos is used in the manufacture of roofing slates and tiles, building sheets, ceilings partitions, floorings, and as fireproof coverings, for wood and metal. A number of patented productions of this nature are on the market and their use is rapidly increasing. Some of them contain admixtures of calcined magnesite, saw dust, chalk, silicate of soda, bitumen, clay, colouring materials, etc. It is noteworthy that the use of asbestos in ordinary moulded cement tiles is of no advantage, and to obtain the increased tensile strength the mixtures in the form of dough are rolled into sheets and then subjected to great pressures. After being stamped into the requisite shapes they are steamed for long periods in special chambers, to produce a microcrystalline structure in the bonding substance, and so render them practically impervious to water. In some methods air-drying is substituted for the steaming process. It is claimed that such goods are practically indestructible, being fire-resisting, weather, rot and insect proof. They are said to harden with age and are of especial value in tropical climates owing to their low conductivity of heat.

Asbestos-cement preparations.

Corrugated portland cement-asbestos compositions are now used as a substitute for galvanized iron roofs, and mixtures of magnesia and asbestos, laid with magnesium chloride as a binder, form excellent floors.

Asbestic is the name given to a fine powder produced by crushing the sand and tailings from the shaking screens of the Canadian asbestos mills. It is generally made in two qualities, 'rough' and 'finish'. The former is applied to the walls of buildings and is then covered with a coating of the latter forming in this way a kind of fireproof stucco.

Asbestos cements are mixtures of low grade fibres with asbestis, portland cement or sand, and are employed in repairing gas retorts, coke ovens and kilns, for filling in cracks around furnaces, fire doors and smoke boxes. Asbestos putty has similar uses.

Other uses.

Blue asbestos, owing to its resistance to acids, is invaluable in chemical, explosives and dye works, for basin rings packings for acid pumps, pipe sockets and filters. Fireproof paints contain a large proportion of asbestos powder. Asbestos washers are indispensable in the lamp industry and in the form of cord and twine the mineral is used to suspend articles in contact with fire. Specially prepared asbestos slabs are finding an increased use for electrical switchboards.

It will be seen later that the author is of the opinion that the future of the asbestos industry in India will depend upon the utilisation of the small-sized fibres and waste material in the manufacture of asbestos cement and other articles in which the length of fibre is not of predominant importance. Therefore we may, with some justification, elaborate on the question of this use of asbestos, which has been merely touched upon by Coggin Brown.

Asbestos cement.

In the 'Mineral Industry during 1930',[1] O. Bowles states :—

Bowles.

'A wider use for asbestos is in prospect in the manufacture of asbestos-cement pipes for water mains, gas mains, and sewers. It is claimed that they cost less

[1] *Mineral Industry*, XXXIX, p. 48, (1931).

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than cast-iron pipes, are more resistant to acids, are better heat insulators, are noncorrosive electrically nonconductive, light in weight, and are more easily placed and joined. Their elastic nature makes them less liable to leakage through traffic vibration. A standard European pipe consists of 80 per cent. cement and 20 per. cent. asbestos.

Corrugated sheeting, consisting of cement and asbestos, is finding important use in the construction of chemical plants or other buildings which are exposed to a corrosive atmosphere. Asbestos-cement wall tiles in a wide range of colors have recently been marketed.'

The application of asbestos cement coating to the surface of wall-boards for both heat insulation and fire-proofing is a new use that is said to promise greater consumption of short fibres.[1]

Mining of Asbestos in the Ceded Districts.

We may now consider the methods of mining which so far have been employed in the development of the asbestos deposits in the Ceded districts of Madras; and, after noting the products and the prices obtained therefor, we may compare those grades and prices with the grades used in other countries and the values assigned to them.

Relatively little proving of the asbestos along the dip has been undertaken and more could be done with advantage. There seems to have been little attempt to mine the asbestos in a systematic matter. The original quarries were made at a number of places along the contact zone, and each has been developed more or less as a separate entity, without much reference to its neighbouring quarries. From the original excavations, drives have followed the tortuous courses of the deposits of good asbestos. Very few attempts have been made to safeguard the miners from falls of the limestone roof and no systematic series of pillars has been left standing. At times, the roof is bad; at others, it is an exceedingly good, massive band of limestone, some two to three feet thick, which forms an ideal roof. No attempt has been made to counteract the deleterious effects of rainwater infiltrating down to the good asbestos, which it stains and spoils.

Little systematic proving of the Madras asbestos.

When the price of asbestos is such that the Brahmanapalle mines can be developed further, then care should be taken to

[1] O. Bowles and B. H. Stoddard, 'Asbestos in 1931', *Mineral Resources of the United States*, 1931, II, p. 209, (1932).

remedy these defects. First of all, drainage should be attended to and a very little money spent in this direction will repay itself many times over. Drives down the dip should be made in the region of good asbestos at regular intervals. They should be of sufficient height to facilitate the haulage and carrying to the surface of the asbestos won from levels off them. As the good asbestos-bearing parts of the blocks between drives are being won, great care should be taken to render those parts safe by the leaving of pillars of suitable dimensions. Later these pillars may be removed, provided adequate support is given to the roof. There is no need for the levels to be of the same height as the main haulage drives; it would indeed be uneconomical for them to be so.

Improvement of the mines.

The author is greatly indebted to Mr. N. Rama Rao, B.Sc., of Pulivendla, in whose charge the dismantled mines of the Mysore Asbestos Mines, Ltd., at Brahmanapalle were entrusted, for much of the remaining information in this section.

Mr. N. Rama Rao.

There are three grades of asbestos commonly found at Brahmanapalle :—golden, white, and greenish. The golden (N 546) is the best quality but it and the other kinds deteriorate on contract with water which has percolated to it through cracks and thus caused it to become hard and brittle.[1]

Kinds of asbestos found.

The usual methods of extraction were by means of hand-drilling, explosives, cold chisels and hammers, gun powder being employed in addition. It is understood that pneumatic drilling had not been employed, though negotiations for such plant had been commenced prior to the dismantling of the plant at Brahmanapalle. The industry gave employment to several hundreds of villagers from Pulivendla, Brahmanapalle, Ippatla, Ramanutiapalle, Lingala, Lopatanutula, and other neighbouring villages.

Methods of extraction.

The approximate costs of extraction per cubic foot of asbestos-rock were in the neighbourhood of Rs. 0-8-0. Allowing 28 cubic feet of asbestos-rock to the ton, this works out at Rs. 14 per ton of asbestos-rock. But

Costs of extraction.

[1] An interesting paper on the cause of brittleness in chrysotile asbestos has recently been published by N. D. Soboleff and M. V. Tatarinoff, *Econ. Geol.*, XXVIII, pp. 171-177 (1933).

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from every ton of rock extracted, only 25 per cent. contains asbestos and the yield of asbestos of all grades from that varies.

The best asbestos is known as 'crudes' and is obtained by hand-cobbing. The crudes obtain the best prices and have the longest fibres, varying from half an inch to one and a half inches in length; these are usually found just above the trap. They are divided into three grades :—

Commercial varieties and milling treatment and costs.

First grade crudes (N 602 from No. 3 Pit).
Second grade crudes (N 603 from Nos. 2 and 3 Pits).
Third grade crudes (N 604 from Nos. 2 and 3 Pits).

The spare fibres from hand-cobbing are collected and, if of sufficient quality and length, they are added to the respective grades of crudes. If they are not of sufficient quality to be so disposed of, they are sold separately as 'fibrous crudes' (N 605). There seems to be little difference in quality, however, between the third grade of crudes and the fibrous crudes.

All asbestos-bearing rock that is not hand-cobbed goes through the mill and from there to the screens. The first fibres collected are known as 'crushed fibres No. 1' (N 606).

That part of the asbestos-rock left after crushing, which still contains asbestos, is treated in the disintegrator, the waste rock of course being discarded. The product from the shakers is collected and called 'fibrous No. 1' (N 607).

What falls through the shakers is sent to the flour mill and the product again put through a smaller screen. The material left on the screen is collected as 'fibrous No. 2' (N 608).

The fine material passing through this second screen has not been marketed as there was no machinery installed at Brahmanapalle suitable for its extraction. It would give 'asbestos powder' were a suitable mill available.

The machinery charges, crushing, cleaning, etc., came to about Rs. 20 per ton.

The carting to Muddanuru station, at mile 155 from Madras on the broad-gauge line to Bombay, cost about Rs. 10 per ton, the station being approximately 27 miles from the Brahmanapalle mines.

Marketing and Prices of Asbestos.

According to the Mysore Asbestos Mines, Ltd., long-fibre asbestos from their mines has been sold for £70 per ton and the views

Prices of Indian asbestos.

of experts in London is given as being that it was equal to the very best Canadian and South African asbestos. On the other hand, it has been stated by a company that the crude asbestos found in India is of 'no value for any purpose except in a very small way for admixture in making up Boiler Covering Compositions'. The Company in question referred to the brittleness of Indian asbestos, but this presumably was apposite of amphibole and not Cuddapah chrysotile asbestos, which is not brittle. The value of Indian crude asbestos was given as Rs. 10-8 per cwt., and those of fibres of various qualities, chiefly of Canadian origin imported into India, were said to range from Rs. 0-9-6 to Rs. 6-8 per lb.

It is extremely interesting to note that there has been a new classification of Canadian asbestos grades introduced recently. According to Bowles and Stoddard[1], this classification may be interpreted as a defensive measure reflecting the pressure of African and Russian competition. The following extract from their paper[2] shows the method of grading asbestos and gives the new classification of the Canadian asbestos grades. The classification could with advantage be adopted by Indian producers.

New classification of Canadian asbestos.

'The highest grades of chrysotile asbestos, known as crude fibers, are hand-cobbed and not passed through crushers or mills. Crudes and some of the highest-grade mill fibers provide material for spinning. Mill stock is obtained by crushing asbestos-bearing rock, passing it through beaters, and removing fibers by screening and air separation. The product is graded and classified according to length, because both uses and price per ton are governed by length of fiber. Canadian fiber is graded in a standard testing machine that consists of four boxes, three with screen bottoms. The top screen is 2-mesh, 11-gage; the second, 4-mesh, 17-gage; and the third, 10-mesh, 20-gage. The fourth or lowest box retains the finest materials. Sixteen ounces of asbestos are placed in the top box, and the entire set is shaken two minutes at 300 revolutions per minute on a machine with a ¾-inch eccentric. The residue in each box is weighed, and the fibers are graded by the amount that remains in each box. The longer the fiber the larger the proportion in the upper boxes. Fibers designated 2-8-4-2 show 2 ounces in the upper pan, 8 ounces in the second, 4 ounces in the third, and 2 ounces passing through all the screens.

For many years each Canadian company sold its products under its own trade designations. In 1931 Canada placed her products on a higher marketing basis

[1] O. Bowles and B. H. Stoddard, 'Asbestos in 1931', *Mineral Resources of the United States*, 1931, II, p. 209, (1932).
[2] *Loc. cit.*, pp. 205-206.

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by establishing a uniform classification. The mine classes agreed upon by the Quebec producers follow.

New classification of Canadian asbestos.

Group.	Standard designation.	Definition.
1	Crude No. 1 . . .	Crude fiber ¾-inch or longer.
2	Crude No. 2 run-of-mine, and sundry crudes.	Crudes consisting chiefly of fiber ⅜ to ¾ inch.
3	Spinning or textile fiber .	Mill fiber testing 0-8-6-2 and over.
4	Shingle fiber . . .	Mill fiber testing below 0-8-6-2 and including 0-1½-9½-5.
5	Paper fiber	Mill fiber testing below 0-1½-9½-5 to and including 0-0-8-8.
6	Waste, stucco, or plaster .	Mill fiber testing below 0-0-8-8 and above 0-0-5-11.
7	Refuse and shorts . .	Mill fiber testing 0-0-5-11 and below, including material testing below 0-0-1·15 if it weighs 35 pounds or cubic foot, loose measure.
8	Sand	Fine asbestos and rock weighing 35 to 75 pounds per cubic foot, loose less per measure.
9	Gravel and stone . .	Mill products weighing 75 pounds or more per cubic foot, loose measure.

Mill fibers, including groups 3 to 8, are divided into 36 subgrades, which are fully defined in a recent report by Duresne and Larochelle.'[1]

[1] A. O. Duresne and E. Larochelle, 'The Classification of Canadian Chrysotile Asbestos', *Can. Min. Met. Bull.*, No. 240, pp. 224-232, (1932). Compare with the grades of the chrysotile asbestos from the Krasnouralsky mine in the Ural Mountains, as given by V. Arshinov and B. Merenkov, *Trans. Inst. Econ. Min.*, U. S. S. R., No. 45, p. 80, (1930).

World prices of asbestos.

According to Bowles and Stoddard[1], the prices of asbestos in 1931 were lower than in the preceding year :—

'Crude No. 1 quoted at $350 to $400 a ton in December, 1930, dropped to between $250 and $300 in January, 1931, but increased to $400 a ton before the end of the year' (1931). 'Crude No. 2, quoted at $250 to $275 in December, 1930, dropped to $200 a ton in January, 1931, and did not recover throughout the year. Shingle and cement stock maintained prices equivalent to those quoted late in 1930, but the price of paper stock in 1931 was much lower than in 1930. With building and automobile manufacture far below normal, the asbestos market was sluggish, and the volume of material was exceptionally small.'

[1] *Loc. cit.*, p. 208.

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CHAPTER VIII.

THE ASBESTOS INDUSTRY IN INDIA.

As a natural consequence of the preceding chapters of this memoir, the question arises as to what extent is the asbestos industry important as far as India is concerned. As statistics are the best answer that can be given to this question, the figures given in this chapter should prove of interest to those seeking information in this connection.

Production of Asbestos in India.

The total quantity and value of the asbestos produced in India during the period from 1906, when the first figures are available, to 1932, are given in Table X which follows :—

Table X.—Quantity and Value of Asbestos produced in India during the years 1906 to 1932.

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TABLE X.—*Quantity and Value of Asbestos produced in India during the years 1906 to 1932.*

Year.	RAJPUTANA: AJMER-MERWARA.			BIHAR AND ORISSA: SERAIKELA STATE.			CENTRAL PROVINCES: BHANDARA.			MADRAS: CUDDAPAH.			MYSORE: BANGALORE.			MYSORE: HASSAN.			INDIA. TOTAL.		
	Quantity.	Value.		Quantity.	Value.		Quantity.	Value.		Quantity.	Value.		Quantity.	Value.		Quantity.	Value.		Quantity.	Value.	
	Tons.	Rs.	£	Tons.	Rs.	£	Tons.	Rs.	£	Tons.	Rs.	£	Tons.	Rs.	£	Tons.	Rs.	£	Tons.	Rs.	£
1906	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	20·6	(a)	..	20·6	(a)	..
1907	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1908	..	..	..	..	..	..	18·0	(a)	..	..	..	..	..	..	..	..	..	..	18·0	(a)	..
1909	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1910	..	..	..	..	..	..	3·0	90	6	..	..	..	..	..	..	..	..	..	3·0	90	6
1911	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1912	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1913	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1914	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	5·0	344	23	5·0	344	23
1915	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1916	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	5·0	330	22	5·0	330	22
1917	..	..	..	..	..	..	7·0	540	36	..	..	..	..	..	..	141·0	4,000	267	148·0	4,540	303
1918	..	..	..	..	..	..	13·0	1,108	74	..	..	..	..	..	..	344·0	13,360	891	357·0	14,468	965
1919	..	..	..	..	..	..	9·0	1,396	121	..	..	..	..	..	..	379·0	15,160	1,318	388·0	16,556	1,439
1920	..	..	..	..	..	..	..	..	..	..	..	..	107·0	4,280	428	1,711·0	68,440	6,844	1,818·0	72,720	7,272
1921	..	..	..	11·5	1,100	73	..	..	..	..	..	..	67·0	2,680	179	237·0	9,480	632	315·5	13,260	884
1922	..	..	..	..	..	..	14·0	1,400	93	..	..	..	..	..	..	228·0	9,120	608	242·0	10,520	701
1923	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	247·0	9,880	659	247·0	9,880	659
1924	..	..	..	92·0	11,550	831	19·8	1,876	135	13·5	5,400	388	..	..	..	..	..	..	125·3	18,826	1,354
1925	..	..	..	..	..	..	..	..	..	16·0	4,796	361	..	..	..	..	..	..	16·0	4,796	361
1926	..	..	..	40·0	5,000	373	..	..	..	18·4	5,529	413	..	..	..	..	..	..	58·4	10,529	786
1927	5·7	1,150	86	40·0	5,800	432	..	..	..	22·0	6,604	493	..	..	..	..	..	..	67·7	13,554	1,011
1928	..	..	..	148·0	20,460	1,527	..	..	..	8·5	1,275	95	..	..	..	..	..	..	156·5	21,735	1,622
1929	..	..	..	80 0	10,000	746	..	..	..	88·4	3,160	236	..	..	..	150·0	3,000	224	318·4	16,160	1,206
1930	..	..	..	..	..	..	..	..	..	33·2	1,190	88	..	..	..	..	..	..	33·2	1,190	88
1931	6·0	70	5	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	6·0	70	5
1932	..	..	..	90·0	9,000	677	..	..	..	..	..	..	..	..	..	..	..	..	90·0	9,000	677
TOTAL	11·7	1,220	91	501·5	62,910	4,659	83·8	6,410	465	200·0	27,954	2,074	174·0	6,960	607	3,467·6	1,33,114	11,488	4,438·6	2,38,568	19,384

(a) Value not known.

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It will be seen from the figures in the table that by far the greatest amount of asbestos produced in India has been obtained from the Hassan district of the Mysore State; but since production ceased there, a certain amount has been obtained from the Seraikela State in Bihar and Orissa and from the Ceded districts of Madras, with which latter deposits we have been particularly concerned in this memoir. The Hassan asbestos and the Seraikela asbestos are of the amphibole type, whereas the Cuddapah asbestos is chrysotile.

Mysore the greatest production.

It will also be noted that in the past 26 years, 4,438·6 tons of asbestos valued at Rs. 2,38,568 have been produced in India. During the years 1916 to 1932 inclusive, approximately 4,400 tons of Indian asbestos of a total value of Rs. 2,38,000 were produced. These figures pale into insignificance when compared with those of the imports into India of manufactured asbestos as given in Tables XV and XVI on pages 258 to 261; but they are none the less interesting.

Production very small compared with imports.

Exports of Asbestos from India.

It may naturally be asked, what happens to the asbestos produced in India? Is it utilised locally, or is it exported?

A certain amount of Indian asbestos has undoubtedly been exported, but as asbestos is not specified separately in the export trade returns collected by the Director-General of Commercial Intelligence and Statistics, and as figures for its exports are not maintained by the various Collectors of Customs, the author has been unsuccessful in his attempt to ascertain what proportion of the local product is exported.

It is known, however, that the Mysore Asbestos Mines, Ltd., shipped the amounts given below in Table XI:—

TABLE XI.—*Exports of Indian Asbestos.*

Year.	Quantity.	Destination.
	Lbs.	
1929	163,500	Belgium.
February, 1930	26,270	London.
	25,600	Belgium.
	3,900	London.
TOTAL	219,270	

All this asbestos was produced from the mines in the Pulivendla taluk of the Cuddapah district. The 1929 exports account for 84·3 tons of the total production of 88·4 tons from the Cuddapah district in that year. No other figures are available, but it seems certain that far more than the 98 tons accounted for above has found its way to foreign markets.

It is interesting to note here that the Asbestos and Belting Co., Ltd., imports finished asbestos goods made from South African or Canadian asbestos and purchases locally comparatively small quantities of asbestos for use on application work.

World Production of Asbestos.

It is instructive to turn to the interesting figures of world production given in Table XII on this and the next page. They have been taken from the valuable Statistical Summary for 1929-1931 published in 1932 by the Imperial Institute on page 34 of 'The Mineral Industry of the British Empire and Foreign Countries'.

TABLE XII.—*The World's Production of Asbestos during the years 1929 to 1931 (long tons).*

Producing country.	1929.	1930.	1931.
BRITISH EMPIRE.			
Southern Rhodesia	38,066	33,720	21,466
Union of South Africa (*b*)	28,717	23,083	11,480
Canada—			
Chrysotile	294,804	251,019	141,470
Crude	*4,286*	*3,546*	*2,202*
Spinning stocks	*17,514*	*12,886*	*10,115*
Shingle stocks	*30,391*	*20,170*	*9,782*
Millboard and paper stocks	*82,046*	*71,544*	*33,260*
Fillers, floats and other short fibres	*143,624*	*106,508*	*79,674*
Sand, gravel and crushed rock	*16,943*	*36,365*	*6,437*
Actinolite	27	30	31
Cyprus	14,110	7,256	1,138
India	318	33	6
Australia	256	82	128
	376,000	315,000	176,000

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TABLE XII.—*The World's Production of Asbestos during the years 1929 to 1931* (*long tons*)—contd.

Producing country.	1929.	1930.	1931.
FOREIGN COUNTRIES.			
Finland (Amphibole)	1,600	1,061	(*a*)
France	740	(*a*)	(*a*)
Greece	..	..	2
Italy	2,586	710	(*a*)
Russia	38,425	53,228	66,000
Mozambique	..	16	(*a*)
United States (sales)—			
Amphibole	1,046	526	331
Chrysotile	1,771	3,262	2,551
China	273	310	260
Japan (estimated)	1,000	1,000	1,000
Turkey	..	..	4
TOTAL	47,000	61,000	72,000
WORLD'S TOTAL	423,000	376,000	248,000

(*a*) Information not available.
(*b*) Production is not available by kinds, but sales (in long tons) were as follows:—

——	1929.	1930.	1931.
Amosite	8,268	2,930	1,863
Blue	5,384	4,894	3,259
Chrysotile	15,845	9,392	8,873

It will be seen that India's production is a very small fraction of the world's production. Her six tons in 1931 is insignificant when compared with the 248,000 tons world production in that year. Her largest production since 1921 was the 318 tons produced in 1929, which is a very small proportion of the 423,000 produced in the whole world during that year.

India's insignificant production.

Canada is the largest producer, followed by Russia and Rhodesia. Extremely interesting comments on the asbestos industry in foreign countries are given in the 'Annual Report of the Quebec Bureau of Mines for 1931'[1], to which reference may be made, particularly with regard to the Russian situation. The comments of Bowles and Stoddard[2] with regard to the last 20 years also merit attention.

Canada the largest producer.

[1] Pt. A., Mining Operations and Statistics, pp. 45-52, (1932).
[2] *Mineral Resources of the United States*, 1931, Pt. II, p. 208, (1932).

They state that from 1912 to 1915 inclusive, Canada had a monopoly on exports to the United States. From 1916 to 1926 inclusive, Africa was a keen competitor. Beginning in 1927 and continuing through 1931, Russia also competed with Africa and Canada for the trade of the United States.

Are the largest producers of asbestos the largest manufacturing countries? and which of these countries supply India's needs of manufactured asbestos goods? In Table XIII, which contains information taken from pages 35 and 36 of the Statistical Summary for 1929-1931 of 'The Mineral Industry of the British Empire and Foreign Countries', issued in 1932 by the Imperial Institute, the exports during these years of asbestos from all countries are given. Reference may be made to pages 37 to 40 of this publication for details of the amount of asbestos, manufactured and unmanufactured, imported into the various countries of the world during the years 1929 to 1931.

The chief exporting countries.

TABLE XIII.—*The Exports of Asbestos during the years 1929 to 1931* (*long tons*).

Exporting country and description.	1929.	1930.	1931.
BRITISH EMPIRE.			
United Kingdom—			
Unmanufactured—			
Crude and fibre	589	691	712
Waste, including asbestic	14	19	58
Manufactured	33,189	28,088	21,398
Southern Rhodesia—			
Unmanufactured	40,773	31,543	25 607
Manufactured	(*£113*)	(*£19*)	..
Union of South Africa—			
Unmanufactured	10,329	10,756	13,526
Manufactured (*£ South African*)	(*£1,192*)	(*£281*)	(*£82*)
Canada—			
Unmanufactured	128,326	93,091	63,366
Sand and waste	132,415	117,177	79,049
Manufactured	(*£23,289*)	(*£11,015*)	(*£24,071*)
British Malaya (including re-exports)—			
Manufactured	202	124	86

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TABLE XIII.—*The Exports of Asbestos during the years 1929 to 1931* (*long tons*)—contd.

Exporting country and description.	1929.	1930.	1931.
BRITISH EMPIRE—*contd.*			
Cyprus—			
Unmanufactured	13,796	5,399	3,571
Australia (including re-exports)—			
Packing (£ *Australian*)	(£*1,692*)	(£*935*)	(£*1,684*)
New Zealand—			
Manufactured (£ *New Zealand*)	..	..	(£*10*)
FOREIGN COUNTRIES.			
Austria—			
Unmanufactured	104	114	81
Spun and woven	146	128	76
Paper and board	154	141	130
Cement sheets	82	54	25
Other manufactures	7	14	9
Belgium-Luxemburg E. U.—			
Unmanufactured	2,114	314	237
Spun and woven	131	114	63
Paper and board	646	484	339
Other manufactures	52	50	22
Czechoslovakia—			
Unmanufactured	98	264	462
Spun and woven	63	28	54
Paper and board	561	554	541
Other manufactures	112	141	102
France—			
Spun and woven	547	395	258
Paper and board	644	262	295
Germany—			
Unmanufactured	574	392	553
Spun and woven	861	1,133	1,131
Paper and board	3,396	2,781	2,557
Other manufactures	582	570	535
Italy—			
Unmanufactured	2,860	349	141
Spun and woven	271	278	151
Paper and board	87	59	52
Cement products	12,433	10,762	7,368
Other manufactures	47	19	72
Netherlands	287	227	5

TABLE XIII.—*The Exports of Asbestos during the years 1929 to 1931* (*long tons*)—contd.

Exporting country and description.	1929.	1930.	1931.
FOREIGN COUNTRIES—*contd.*			
Poland—			
Unmanufactured	8	..	6
Manufactured	6	5	54
Russia	12,404	15,500	13,030
Spain—			
Unmanufactured	..	30	180
Manufactured	6	94	76
Sweden—			
Unmanufactured	2	1	2
Manufactured	9	7	5
Switzerland (including mica)—			
Unmanufactured	23	8	9
Manufactured	485	437	293
United States—			
Unmanufactured	633	688	1,530
Spun and woven	884	797	567
Paper and board	759	856	567
Brake linings	(£*313,071*)	(£*282,202*)	(£*249,000*)
Pipe covering and cement	3,076	2,976	938
Roofing squares	(£*123,620*)	(£*80,838*)	(£*109,000*)
Other manufactures	2,184	2,138	1,068
Japan	(£*17,599*)	(£*18,883*)	(£*15,992*)

Imports of Asbestos into India.

In Table XIV, figures for the imports into India of raw asbestos for packing and the share thereof of each province are given for the financial years 1919-20 to 1931-32 inclusive. In Table XV, the corresponding figures are given for manufactured asbestos used as packing. In Table XVI, the corresponding figures are given for manufactured asbestos other than packing. The very interesting figures in these three tables have been extracted from various 'Annual Statements of the Sea-Borne Trade of British India with the British Empire and Foreign Countries', compiled by the Director-General of Commercial Intelligence and Statistics, Calcutta.

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TABLE XIV.—*Imports of Raw Asbestos into India, and the share thereof*

Country of consignment.	1919-20.		1920-21.		1921-22.		1922-23.		1923-24.		1924-25.	
	Cwts.	Rs.	Cwts.	Rs.	Cwts.	Rs.	Cwts.	Rs.	Cwts.	Rs.	Cwts.	Rs.
United Kingdom . .	39	4,530	3	710	6	820	..	..	126	3,125	..	..
Other British Possessions	..	..	..	..	..	..	..	..	..	28	5	550
TOTAL BRITISH EMPIRE .	39	4,530	3	710	6	820	..	..	126	3,153	5	550
Germany . . .	..	..	..	..	..	..	..	..	..	..	..	..
Share of Bengal . .	20	3,680	..	..	..	45	..	..	..	13	..	..
„ *Bombay* . .	19	850	3	610	6	775	..	..	126	3,125	..	..
„ *Sind* . .	..	..	..	..	..	..	..	..	..	..	..	..
„ *Madras* . .	..	..	..	100	..	..	..	..	..	15	5	550
TOTAL .	39	4,530	3	710	6	820	..	..	126	3,153	5	550

of each Province, during the financial years 1919-20 to 1931-32.

1925-26.		1926-27.		1927-28.		1928-29.		1929-30.		1930-31.		1931-32.	
Cwts.	Rs.	Cwts.	Rs.	Cwts.	Rs.	Cwts.	Rs.	Cwts.	Rs.	Cwts.	Rs.	Cwts.	Rs.
.	..	..	..	..	..	..	..	..	..	..	..	..	..
..	20	..	..	..	..	..	..	..	..	..	..	..	..
..	20	2	95	..	41	32	414	33	263	..	..	..	..
98	1,050	..	..	..	..	..	..	..	..	..	..	..	..
..	..	2	95	..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..	..	..	..	..
98	1,050	..	..	..	41	3	202	..	..	..	..	..	..
..	20	..	..	..	..	29	212	33	263	..	..	..	..
98	1,070	2	95	..	41	32	414	33	263	..	..	..	..

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TABLE XV.—*Imports into India of Manufactured Asbestos for Packing and the share thereof of each Province, during the financial years 1920-21 to 1931-32.*[2]

Country of consignment.	1920-21.	1921-22.	1922-23.	1923-24.
	Rs.	Rs.	Rs.	Rs.
United Kingdom	7,58,160	3,50,428	3,58,693	4,03,139
Straits Settlements (including Labuan)	..	3,345	..	445
Egypt [1]	..	..	1,396	..
Transvaal	..	..	..	..
Other British Possessions	370	135	116	25
TOTAL BRITISH EMPIRE	7,58,530	3,53,908	3,60,205	4,03,609
Germany	..	141	1,630	2,483
Netherlands	..	..	..	..
Belgium	1,520	80	3,775	16,893
Luxemburg	..	..	..	1,955
France	..	..	..	..
Italy	..	..	..	..
Austria	..	..	..	..
Czechoslovakia	..	..	..	..
Serb Croat Slovene State	..	..	..	..
Asiatic Turkey	10	..	..	..
Japan	7,840	54,761	98,957	48,024
United States of America—				
Vid Atlantic Coast	3,550	22,594	14,255	2,340
Vid Pacific Coast	..	..	..	..
Other Foreign Countries	..	..	612	706
TOTAL FOREIGN COUNTRIES	12,920	77,576	1,19,229	72,401
Share of Bengal	3,63,950	2,19,133	1,82,477	2,07,874
,, *Bombay*	2,29,130	77,696	1,30,185	1,63,554
,, *Sind*	8,120	42,851	6,245	12,121
,, *Madras*	40,510	30,190	32,013	24,704
,, *Burma*	1,29,740	61,614	1,28,514	67,757
TOTAL	7,71,450	4,31,484	4,79,434	4,76,010

[1] Shown as a foreign country from 1923-24.

1924-25.	1925-26.	1926-27.	1927-28.	1928-29.	1929-30.	1930-31.	1931-32.
Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.
3,50,551	3,44,460	3,79,178	6,55,840	3,94,133	4,72,876	3,43,447	1,91,613
3,889	..	616	440	1,483	..	..	..
..	..	..	..	..	..	..	..
..	10,149	..	..	..	..	..	..
..	..	101	..	396	415	2	172
3,54,440	3,54,609	3,79,895	6,56,280	3,96,012	4,73,291	3,43,449	1,91,785
12,937	14,354	17,244	9,195	17,373	25,176	1,15,879	27,408
..	..	1,396	1,149	751	2,522	3,386	3,365
18,936	10,486	8,273	7,096	6,063	9,947	11,333	5,856
..	..	..	..	..	..	..	..
13,962	3,659	5,172	2,182	5	1,138	1,122	..
..	..	..	..	..	..	4,797	..
..	..	..	622	1,320	..	2,513	4,312
..	..	..	..	..	6,917	2,353	2,410
..	..	..	..	..	1,177	..	..
..	..	..	..	..	..	..	..
52,332	29,066	26,354	20,597	19,329	41,618	20,243	10,656
15,428	7,788	17,921	6,168	11,626	12,596	9,964	7,558
..	..	187	609	639	..	..	761
116	1,096	42	..	..	17	4	15
1,13,711	66,449	76,589	47,618	57,106	1,01,108	1,71,594	62,341
1,82,276	1,41,242	1,40,819	1,64,145	1,74,709	1,98,736	1,42,533	67,756
1,68,896	1,42,846	1,52,616	1,16,736	1,08,994	1,66,690	2,38,012	94,497
16,780	16,234	19,192	28,667	35,250	47,837	20,967	17,019
17,592	43,643	36,722	27,926	24,494	60,900	30,076	21,227
82,607	77,093	1,07,135	3,66,424	1,09,671	1,00,236	83,455	53,627
4,68,151	4,21,058	4,56,484	7,03,898	4,53,118	5,74,399	5,15,043	2,54,126

[2] No details are available for the year 1919-20.

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TABLE XVI.—*Imports into India of Manufactured Asbestos other than Packing, and the share thereof of each Province, during the financial years 1919-20 to 1931-32.*

Country of consignment.	1919-20.	1920-21.	1921-22.	1922-23.	1923-24.	1924-25.	1925-26.	1926-27.	1927-28.	1928-29.	1929-30.	1930-31.	1931-32.
	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.
United Kingdom	2,43,900	9,75,090	6,47,930	5,90,942	5,21,664	7,61,330	10,60,906	15,60,187	23,33,086	20,90,037	16,94,857	14,37,198	9,24,518
Ceylon	100	240	2,150	459	13	241	3,738	991	90	115	198	1,807	1,732
Straits Settlements (including Labuan)	..	..	..	..	..	..	..	138	1,285	431	2,155	..	2
New South Wales	2,300	..	..	..	..	..	..	..	..	..	..	..	..
Canada	..	..	..	..	..	..	..	330	..	2,990	7,048	4,601	2,722
Other British Possessions	10	..	327	..	205	..	..	..	..	392	..	827	..
TOTAL BRITISH EMPIRE	2,46,310	9,75,330	6,50,407	5,91,401	5,21,882	7,61,571	10,64,644	15,61,646	23,34,461	20,93,965	17,04,258	14,44,433	9,28,974
Germany	..	1,330	8,241	4,761	11,310	31,905	47,965	45,029	42,754	65,095	83,250	1,83,443	90,105
Netherlands	2,010	16,510	9,202	..	..	4,380	9,345	21,944	2,369	7,174	2,886	216	9,380
Belgium	..	35,400	35,418	55,977	76,704	88,324	84,400	1,05,331	1,40,567	2,14,502	2,79,989	2,22,794	38,562
Switzerland	..	..	13,478	..	..	..	5,337	..	..	..	..	..	..
Italy	..	34,280	5,298	11,578	54,339	2,31,523	1,85,351	4,31,050	4,53,294	3,67,339	4,73,692	2,38,620	1,31,236
Austria	..	..	4,608	..	..	831	7,186	2,788	9,527	31,415	19,154	16,815	2,948
France	..	..	..	705	..	1,304	19,069	17,484	2,870	1,457	9,456	16,020	5,374
Czechoslovakia	..	..	..	..	..	..	797	2,265	3,078	1,271	8,105	10,121	4,834
Serb-Croat Slovene State	..	..	..	..	..	..	..	..	..	..	12,609	1,22,458	53,548
Asiatic Turkey	..	10	18,578	..	..	..	..	..	..	..	..	..	..
China (exclusive of Hong Kong and Macao)	1,020	..	..	..	..	.	..	..	..	..	..	..	..
Japan	10,810	6,250	11,507	17,980	6,896	9,112	5,518	1,488	5,791	3,456	4,110	12,738	459
United States of America—													
Vid Atlantic Coast	41,890	28,480	41,743	23,662	30,403	22,531	19,155	36,987	50,350	64,090	73,081	50,068	23,003
Vid Pacific Coast	..	..	..	..	..	..	1,105	10	..	..	837	3,714	..
Argentina	..	..	..	..	..	..	..	1,603	..	..	..	..	..
Other Foreign Countries	..	..	..	..	..	..	..	..	126	55	3	..	7
TOTAL FOREIGN COUNTRIES	55,730	1,22,260	1,48,073	1,14,663	1,79,652	3,89,910	3,85,228	6,65,979	7,10,666	7,55,854	9,67,172	8,77,007	3,59,456
Share of Bengal	1,16,160	2,83,170	2,42,146	2,75,030	2,84,099	6,33,176	4,15,532	8,92,935	12,00,375	11,51,211	10,71,404	6,99,911	5,12,110
,, *Bombay*	1,44,460	6,19,880	3,98,322	3,13,937	3,09,747	3,43,502	6,06,463	7,77,772	7,34,132	9,13,565	8,09,235	7,98,220	3,08,806
,, *Sind*	7,370	72,230	8,314	13,470	9,619	10,886	25,533	50,644	2,21,708	2,31,788	2,99,181	3,52,423	1,80,843
,, *Madras*	680	48,890	58,103	43,018	21,500	55,044	1,42,378	2,42,535	5,84,561	3,38,396	3,52,295	2,83,014	2,14,744
,, *Burma*	33,370	73,420	91,595	60,609	76,569	1,08,873	2,59,966	2,63,739	3,04,351	2,14,859	1,39,315	1,87,872	71,927
TOTAL	3,02,040	10,97,590	7,98,480	7,06,064	7,01,534	11,51,481	14,49,872	22,27,625	30,45,127	28,49,819	26,71,430	23,21,440	12,88,430

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It will be seen from the figures in Table XIV that the imports into India of raw asbestos were practically negligible and now have ceased. This is very important as it shows that there has been very little, and there is at present no, indigenous industry in India for the manufacture of asbestos products from raw asbestos.

Imports of raw asbestos negligible.

During 1931-32, the chief supplier of India's needs of manufactured asbestos, both for packing and for uses other than packing, was the United Kingdom. The United Kingdom has always held pride of place in this respect. With the passing of years, the demand has been variable; but the proportion supplied by other countries has gradually increased, though not regularly. In 1920-21, the first financial year for which separate figures are available, the United Kingdom supplied Rs. 7,58,160 of packing and Rs. 9,75,090 of other manufactured asbestos, against a total of Rs. 12,920 of packing and Rs. 1,22,260 of other manufactured asbestos supplied by foreign countries. In 1930-31, the United Kingdom supplied Rs. 1,91,613 of packing and Rs. 9,24,518 of other manufactured asbestos, against a total of Rs. 62,341 of packing and Rs. 3,59,456 of other manufactured asbestos supplied by foreign countries. These figures show that serious competition has been met in the Indian market by the United Kingdom. Germany and Japan have been the chief rivals in the supply of packing, with a constant smaller supply from the Atlantic Coast of the United States. Italy, generally, has been the chief supplier of other manufactured asbestos, with Belgium second and Germany and the United States not far behind; Germany has risen now to second place and the Serb-Croat Slovene State has appeared prominently.

The United Kingdom the chief supplier to India of manufactured asbestos.

The figures given in Tables XIV to XVI have been summarised in Table XVII. It will be seen that the largest imports into India of asbestos were made during the financial years 1927-28, 1928-29 and 1929-30, in that order.

Summarised table.

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TABLE XVII.—*Total value of all kinds of Asbestos imported into India during the financial years 1919-20 to 1931-32.*

From	1919-20.	1920-21.	1921-22.	1922-23.	1923-24.	1924-25.	1925-26.	1926-27.	1927-28.	1928-29.	1929-30.	1930-31.	1931-32.
	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.
BRITISH EMPIRE.													
Raw	4,530	710	820	..	3,153	550	20	95	41	414	263	..	..
Manufactured—													
Packing . . .	(a)	7,58,530	3,53,903	3,60,205	4,03,609	3,54,440	3,54,609	3,79,895	6,56,280	3,96,012	4,73,291	3,43,449	1,91,785
Other than packing. .	2,46,310	9,75,330	6,50,407	5,91,401	5,21,882	7,61,571	10,64,644	15,61,646	23,34,461	20,93,965	17,04,258	14,44,433	9,28,974
TOTAL BRITISH EMPIRE	2,50,840	17,34,570	10,05,135	9,51,606	9,28,644	11,16,561	14,19,273	19,41,636	29,90,782	24,90,391	21,77,812	17,87,882	11,20,759
FOREIGN COUNTRIES.													
Raw	..	..	..	..	..	..	1,050	..	..	..	..	..	..
Manufactured—													
Packing. . . .	(a)	12,920	77,576	1,19,229	72,401	1,13,711	66,449	76,589	47,618	57,106	1,01,108	1,71,594	62,341
Other than packing. .	55,730	1,22,260	1,48,073	1,14,663	1,79,652	3,89,910	3,85,228	6,65,979	7,10,666	7,55,854	9,67,172	8,77,007	3,59,456
TOTAL FOREIGN COUNTRIES	55,730	1,35,180	2,25,649	2,33,892	2,52,053	5,03,621	4,52,727	7,42,568	7,58,284	8,12,960	10,68,280	10,48,601	4,21,797
GRAND TOTAL .	3,06,570	18,69,750	12,30,784	11,85,498	11,80,697	16,20,182	18,72,000	26,84,204	37,49,066	33,03,351	32,46,092	28,36,483	15,42,556

(a) Figures not available.

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Similar figures are given in Table XVIII for the calendar years 1919 to 1932 inclusive, as these may be useful for comparison with other countries. They have been compiled from various 'Accounts relating to the Sea-Borne Trade of British India with the British Empire and Foreign Countries', published annually by the Director-General of Commercial Intelligence and Statistics, Calcutta.

Statistics for calendar years.

TABLE XVIII.—*Value of Imports into India of all kinds of Asbestos during the calendar years 1919 to 1932.*

Year.	Raw.	Manufactured.		Total.
		Asbestos packing.	Manufactures other than packing.	
	Rs.	Rs.	Rs.	Rs.
1919 . .	(*a*) 3,120	..	(*a*)2,07,270	2,10,390
1920 . .	1,970	(*b*)5,86,190	9,19,140	15,07,300
1921 . .	930	5,01,526	8,56,796	13,59,252
1922 . .	45	4,59,944	7,18,583	11,78,572
1923 . .	3,125	5,24,818	7,42,068	12,70,011
1924 . .	578	4,45,904	8,74,020	13,20,502
1925 . .	1,070	4,14,331	15,09,657	19,25,058
1926 . .	..	4,34,717	19,74,944	24,09,661
1927 . .	136	7,45,320	29,07,977	36,53,433
1928 . .	414	4,33,058	29,84,083	34,17,555
1929 . .	263	5,52,274	26,39,170	31,91,707
1930 . .	..	4,79,893	23,05,968	27,85,861
1931 . .	..	3,71,145	17,06,961	20,78,106
1932 . .	..	2,60,925	9,72,745	12,33,670

(*a*) Separately recorded from April, 1919. Figures for 1919 are for the nine months, April to December, 1919.
(*b*) Separately recorded from April, 1920. Figures for 1920 are for the nine months, April to December, 1920.

Future of the Asbestos Industry in India.

The value of manufactured asbestos used for packing and for other purposes, imported into British India during the year 1932, amounted to over 12 lakhs of rupees. This figure is smaller than the values of the amounts imported during each of the years 1923 to 1931 inclusive, but is somewhat greater than the figure for 1922. It would appear, therefore, that there is scope for the annual consumption in India of at least some 20 lakhs of rupees worth of manufactured asbestos; and it is likely that the consumption would increase were there an indigenous manufacturing industry.

Scope for consumption of Rs. 20 lakhs of asbestos annually.

Would manufacturers be compelled to import asbestos raw fibre in order to run the industry profitably? Would it pay them to work the known deposits of asbestos in India? Foreign fibre at present pays 25 per cent. duty and so the local article has a big preference as the royalty on it is only $2\frac{1}{2}$ per cent. of the sale value at the pit's mouth. What are the available reserves of Indian asbestos? Are they sufficient for the needs of the manufacturer?

Import duty and royalty.

A glance through the summary of the asbestos occurrences in India other than in the Ceded districts of Madras, which forms Chapter V of this memoir, shows that no attempt whatsoever has been made to estimate the amount of asbestos available in India. It is not possible to do this with the amount of data we have in our possession at present. In the Ceded districts of Madras, there has also been no systematic proving of reserves, and here, also, it is impossible to give now even a rough approximation of the potential reserves of asbestos in, *say*, the Brahmanapalle-Lopatanutula area.

No attempt yet made to estimate the reserves of asbestos in India.

There is no doubt that there is available in India material suitable for use in an asbestos cement manufacturing works. The short-fibre material used in this process is usually waste material from the mills, which otherwise would not find ready application. Whether or not there would be a sufficient supply of that material is very debatable and requires careful proving of deposits. It is thought, however, that the future development of the asbestos deposits of India will be found to depend upon the creation of an indigenous manufacturing industry, and not in the development of an export trade in crude asbestos fibres. As the local industry develops, it will be

Possibility of manufacturing asbestos cement.

noticed that more uses are found for the different fibre products, crude and mill. With the development of an export trade in crude fibres, the mill material must invariably largely be wasted unless local uses for it are found, because world competition at present is, and in the future will be, so keen that only the very best crude material will find a ready market.

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As far as possible, the latitude and longitude according to the latest available maps, and the number of the relevant map, have been given in the text when any particular locality is mentioned for the first time. To avoid repetition, this information has been omitted from this Index.

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ENTRANCE TO AN ASBESTOS PIT SOUTH OF LINGALA, PULIVENDLA TALUK, CUDDAPAH DISTRICT.



P. L. Dutta, Photo. *G. S. I., Calcutta.*

VEINS OF ASBESTOS IN LIGHT APPLE-GREEN SERPENTINISED ROCK (N 548), 1¼ MILES WEST (A LITTLE NORTH) OF IPPATLA, PULIVENDLA TALUK, CUDDAPAH DISTRICT.

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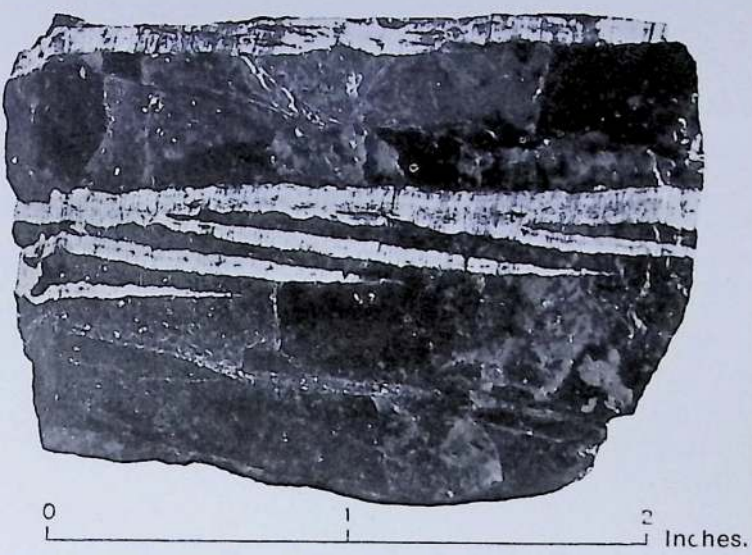
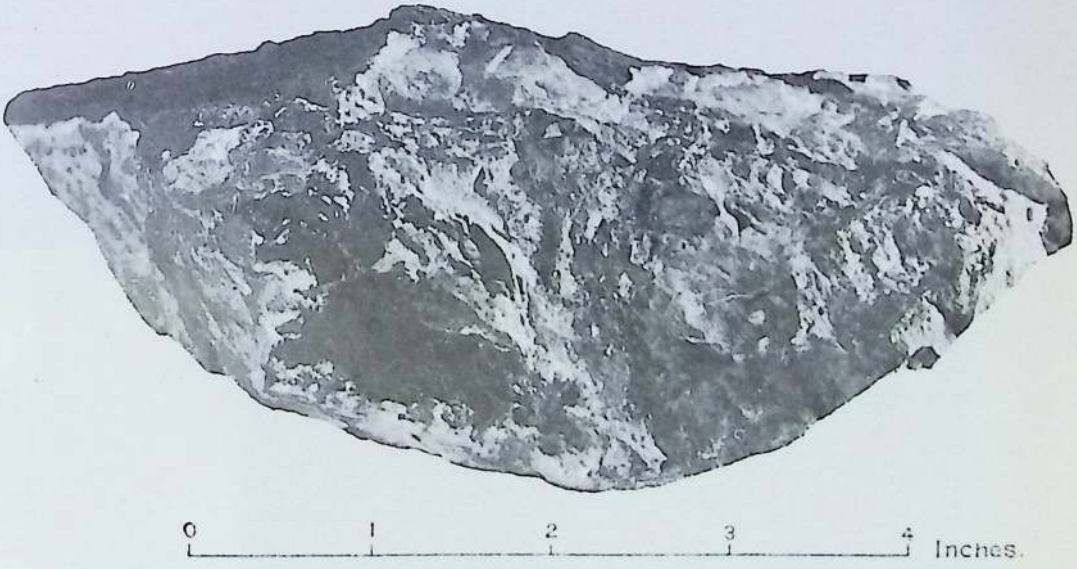


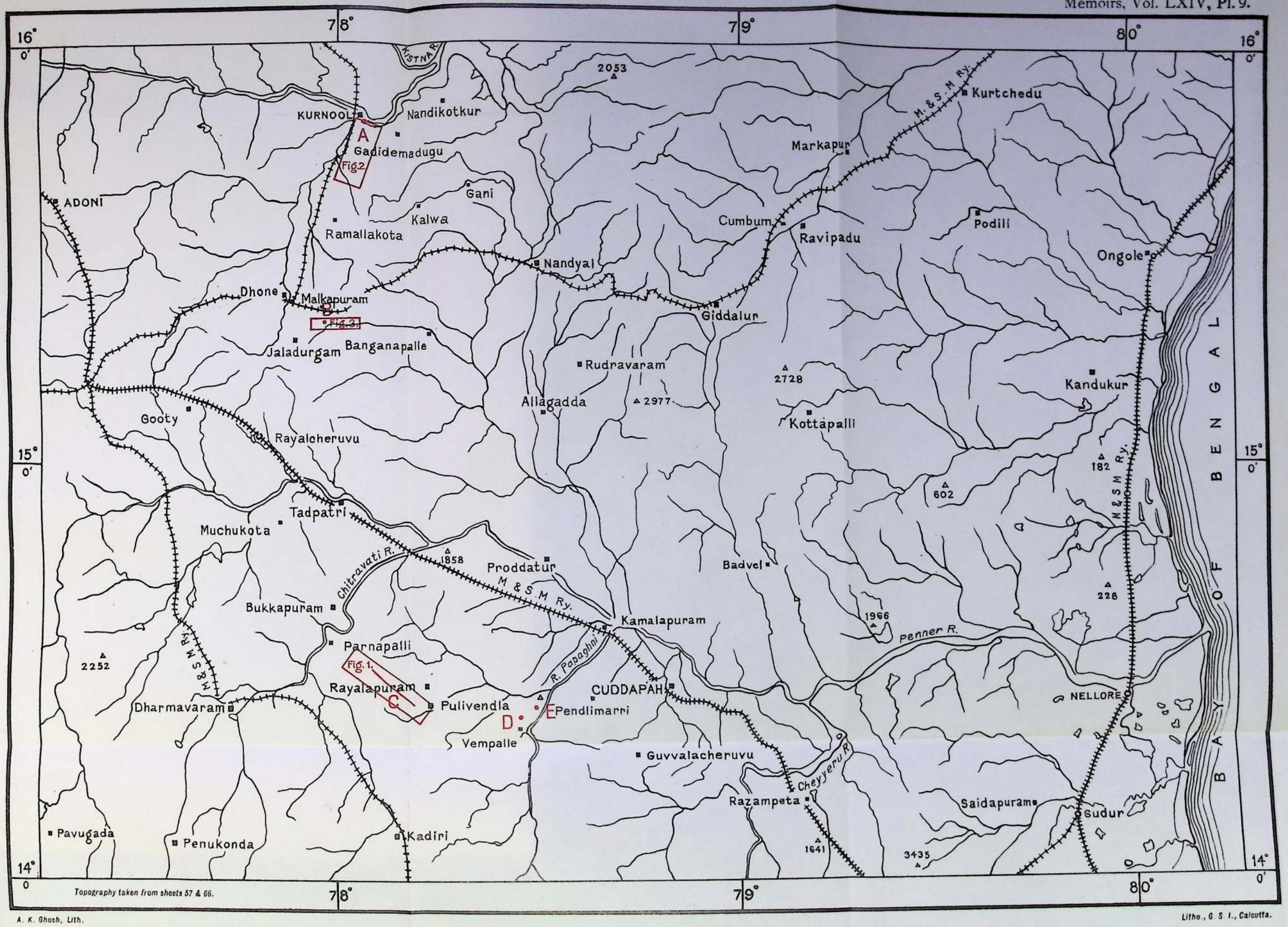
FIG. 1. BRANCHING CROSS-FIBRED VEINS OF ASBESTOS IN DARK GREEN SERPENTINISED ROCK (N 549), THREE-QUARTERS OF A MILE SOUTH OF CHINNAKUDALA, PULIVENDLA TALUK, CUDDAPAH DISTRICT.



P. L. Dutta, Photos. *G. S. I., Calcutta.*

FIG. 2. MAGNETITE IN APPLE-GREEN SERPENTINISED ROCK (N 574), A QUARTER OF A MILE SOUTH-EAST OF MALKAPURAM, DHONE TALUK, KURNOOL DISTRICT.

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Topography taken from sheets 57 & 66.

A. K. Ghosh, Lith.

Litho., G. S. I., Calcutta.

MAP SHOWING THE OCCURRENCE OF ASBESTOS IN THE CEDED DISTRICTS OF MADRAS AND, ALSO, THE POSITIONS OF THE MAPS FORMING PLATE 10.

By A. L. COULSON, GEOLOGICAL SURVEY OF INDIA.

Scale, 1 inch = 16 miles.

A Joharapuram, Kurnool taluk, Kurnool district.
B Malkapuram, Dhone taluk, Kurnool district.
C Brahmanapalle-Lopatanutula area, Pulivendla taluk, Cuddapah district.
D Vempalle, Pulivendla taluk, Cuddapah district.
E Rajupalem, Kamalapuram taluk, Cuddapah district.

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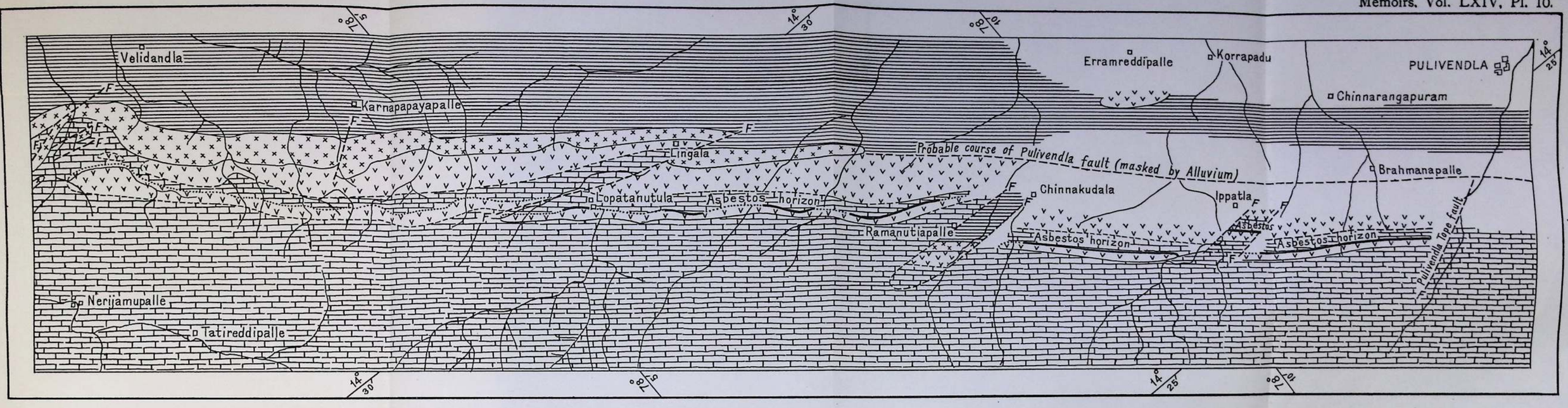


Fig. 1: Geological sketch map (parts of sheets 57 J/2 and 57 J/3) showing the position of the asbestos horizon (dotted and full line) in the Vaimpalli limestones in the Brahmanapalle-Lopatanutula area in the Pulivendla taluk of the Cuddapah district. The barren extension of this horizon (dotted line) to the Tadpatri taluk of the Anantapur district is also shown.

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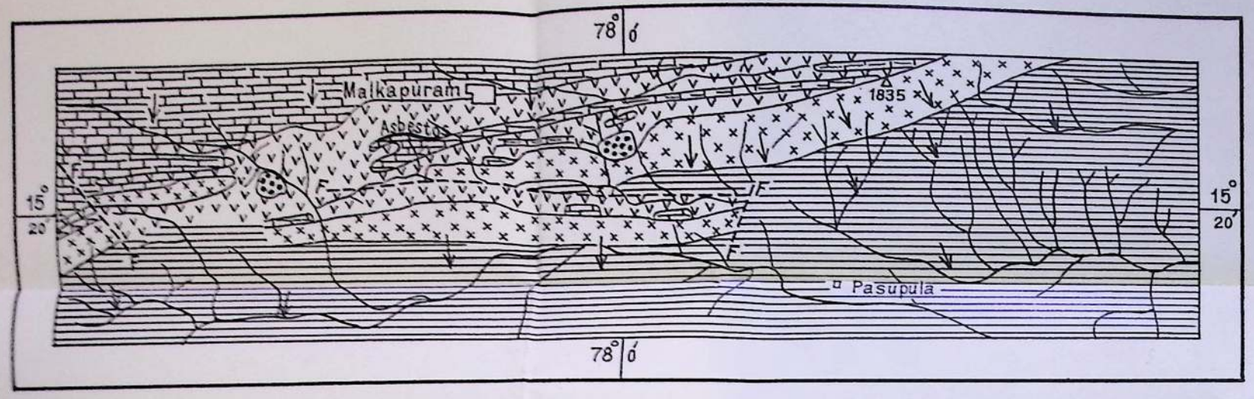


Fig. 3. Geological sketch map (parts of sheets 57E/15 and 57 I/3) of parts of the Dhone taluk of Kurnool district and of Banganapalle State in the vicinity of Malkapuram, showing the position of the asbestos occurrence.

INDEX.

- Not mapped or alluvium
- Tufa (Fig. 3 only)
- KURNOOL SERIES
  - Paniam quartzites
  - Jammalamadugu limestones
  - Banganapalli sandstones

Unconformity.

- CUDDAPAH SYSTEM
  - CHEYAIR SERIES
    - Tadpatri shales
    - Pulivendla quartzites
  - PAPAGHNI SERIES
    - Vaimpalli limestones and shales
    - Gulcheru quartzites

Unconformity.

- Crystallines, Schists, etc.
- Intrusive trap sills

By A. L. COULSON,
GEOLOGICAL SURVEY OF INDIA.
Scale, 1 inch = 1 mile.

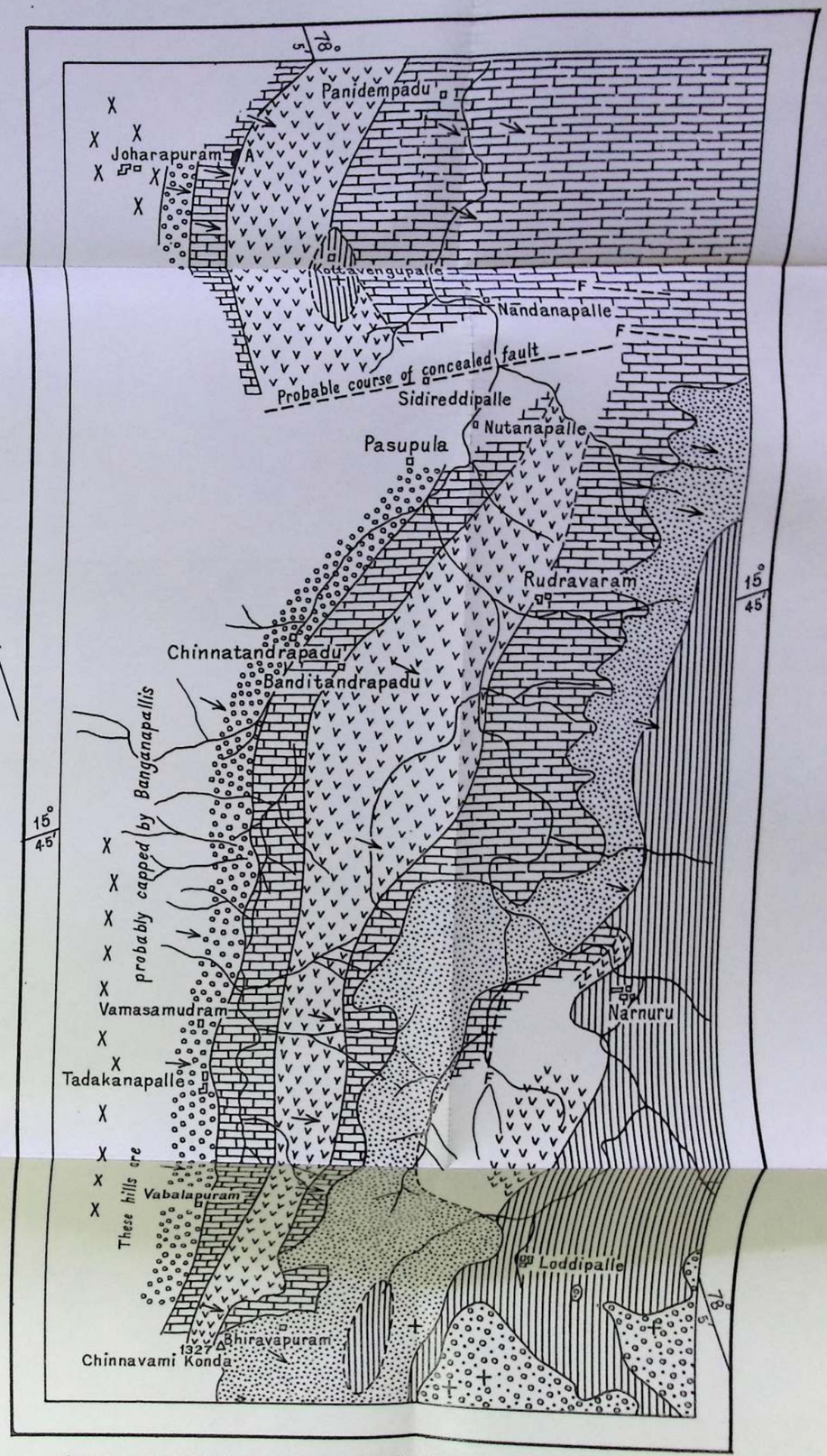


Fig. 2. Geological sketch map (parts of sheets 57 I/1 and 57 I/2) of the area to the south of Kurnool. (A=Asbestos)

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