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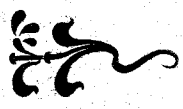
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AUGUST, 1906.

Part 2.

Transactions



of the

Mining and Geological Institute



of India.

Edited by
E. H. Robertson.



Second Edition.

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NOTE TO SECOND EDITION.

As the original impression of this part of the Transactions has been disposed of, a second edition has been printed. It is in every way the same as the first except that the various printer's errors have been corrected. The author wishes, however, to take the opportunity to say that whilst he still believes in the igneous origin of the manganese-silicate rocks of Vizagapatam as put forth on pages 87 to 91, he no longer holds the opinion expressed on page 91 that the manganese-bearing rocks of the Nágpur-Bálághát area of the Central Provinces are also of igneous origin, but believes them to be of metamorphic origin. For fuller details of this theory the reader is referred to the discussion on this paper given on pages 227 to 231 of Part 3 of the "Transactions," and to "Records," Geol. Surv. Ind., XXX, page 39.

ERRATA.

- Page 70, line 21, *for* Singbhum *read* Singhbhum.
- „ 77, line 6, *insert a comma at the end of the line.*
- „ 85, line 6, *insert a hyphen between manganese and ore.*
- „ 90, fig. 5, *for* E.N. *read* E.N.E.
- „ 91, line 21, *insert a hyphen between rhodonite and spessartite.*
- „ 92, line 5, *delete hyphen between Ramdongri and ore.*
- „ „ line 17, *insert a hyphen between spessartite and quartz.*
- „ 93, line 4, *for* almost *read* most.
- „ 94, line 4, *after* spessartite *place a hyphen.*
- „ 97, line 25, *after* felsper *insert a comma.*
- „ 98, line 10, *after* Maclaren *insert a comma.*
- „ 111, last line, 5th column, *for* 5,1221 *read* 5,1221.
- „ 112, line 6, *for* Calcutta *read* Bombay.
line 7, *for* Bombay *read* Calcutta.
- „ 117, last line, 8th column, *for* 252199 *read* 252,199.
9th column, *for* 1,088264 *read* 1,088,264.
- „ 123, last line, *after* Jan *insert a full-stop.*
- „ 134, last line but one, *for* oxgen *read* oxygen.

Manganese in India.*

BY

L. Leigh Fermor, A.R.S.M., F.G.S.

*Read at the General Meeting held at Barakar, March
26th, 1906.*

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I.—INTRODUCTION.¹

Manganese in the elementary form is a metal belonging to the iron group of elements, comprising iron, manganese, cobalt and nickel, which, owing to their more or less similar chemical habits,

¹—Nature of Manganese.

¹ For a very interesting treatment of the subject of this section, and of the uses of manganese, see R. A. F. Penrose, Jr. *An. Rep. Geol. Surv. Arkansas for 1890*, Vol. I, "Manganese: Its Uses, Ores, and Deposits," pp. 1-56.

often occur in association in nature. When pure, metallic manganese is said to be of a greyish-white colour. It is extremely hard, cutting both glass and hardened steel. In the following table some of its physical constants¹ are compared with those of the other members of the group of elements to which it belongs :—

TABLE I.

Physical constants of the manganese-iron group of elements.

	Symbol.	Atomic weight.	Specific gravity.	Atomic volume.	Specific heat.	Melting point.
Manganese	Mn.	55.0	8.00	6.9	0.110	C. 1245°
Iron	Fe.	55.9	7.86	7.1	0.114	1600°
Nickel	Ni.	58.7	8.80	6.7	0.108	1470°
Cobalt	Co.	59.0	8.80	6.7	0.104	1530°

Manganese does not, however, occur in nature in the metallic condition, but in combination, usually in the form of oxide, manganate, carbonate or silicate. Pliny considered manganese oxide to be a variety of magnetite or lodestone, which he called *magnes*. In the middle ages both the black oxide of manganese and the white oxide of magnesium were known as *magnesia*, being distinguished as *magnesia nigra* and *magnesia alba* respectively. From *magnesia nigra* the word *manganesium*, our modern *manganese*, is supposed by some to have been derived by metathesis or interchange of letters.

¹ Roberts-Austen, "An Introduction to the Study of Metallurgy," pp. 72, 73, (1898), with several alterations in accordance with later research.

Until 1740, when Potts¹ distinguished the two, the salts of manganese were confounded with those of iron; but it was not till 1774 that it was suspected by Scheele² that a metal existed in *magnesia nigra*; this was isolated two years later by Dr. Gahn.

Of all the elements manganese is one of the most widely distributed throughout the three kingdoms of nature. It is, to a large extent, co-extensive with iron.

Mineral kingdom.—Of the 900 to 1,000 species of minerals now known to science about 100 of them contain manganese as an essential constituent, while many more frequently contain it in less important quantities. Most of the rocks of the earth's crust contain it, though usually only in small quantities, and it has been calculated by F. W. Clark³ that 0.10% of the earth's crust consists of manganese protoxide (MnO), manganese ranking as the fifteenth most important element in this respect. As the result of the decomposition and denudation of the earth's surface by meteoric agencies, its various constituents get carried either in suspension or solution to the sea. It has been estimated⁴ that one cubic mile of average river water contains in solution 5,703 tons of manganese sesquioxide (Mn₂O₃), and that 6,524 cubic miles of river water are annually discharged into the sea.⁵ This means that about 37,000,000 tons of Mn₂O₃, containing nearly 26,000,000 tons of metallic manganese, are annually brought by rivers into the sea. This manganese becomes deposited at the bottom of the ocean in the form of the concretions so abundantly

¹ "Examen chymicum magnesia vitrariorum, Germanis Braunstein" (Roscoe and Schorlemmer), Vol. II, Part II, p. 2, (1879). [(Penrose).

² Stockholm Memoirs, 1774, [Kongl. Svenska Vetenskaps-Akademiens Handlingar]

³ U.S. Geological Survey, Bulletin No. 228, p. 19, (1904).

⁴ Murray, *Scottish Geographical Mag.*, III, p. 77, (1887).

⁵ Murray, *op. cit.*, IV, p. 41, (1888).

dredged up in nearly all deep-sea exploration work.¹ Manganese is also sometimes found in meteorities.

Animal kingdom.—Manganese “is said to form an essential constituent of the tissues and of the red corpuscles of the blood in the human body, being present in the proportion of one part of manganese to twenty parts of iron.”²

Vegetable kingdom.—Manganese has been found in the ash of many plants, amongst which may be mentioned tea, coffee, potatoes, tobacco, wheat, grapes, and many other vegetables, fruits, and cereals, as well as in the ash of many woods.³ To test the latter I had a bamboo cut from the top of a laterite hill in the Central Provinces. It was divided into short lengths, the outside cut off and rejected and then 533·5 grammes of the wood were incinerated in a platinum crucible yielding 8·8 grammes of ash of a bluish-green colour, and thus testifying to the presence of manganese in the bamboo.

II.—MINERALOGY AND GEOLOGY.

I.—THE MINERALS AND ORES OF MANGANESE.

The recent investigations into the Indian manganese-ore deposits have led to the discovery of several manganese minerals new to India and not a few new to science, though these latter have not yet been thoroughly worked out. The following list enumerates all the Indian manganese minerals at present known :—

Oxides.—Dysluite.

Manganmagnetite.

¹ See especially :—*Challenger Reports*, Vol. on Deep-Sea Deposits (1891).

² Penrose, *loc. cit.*, p. 2.

³ Penrose, *loc. cit.*, p. 2.

Jacobsite?
 Hausmannite?
 Braunite.*
 Pyrolusite.*
 Manganite.*

Manganates.—*Hollandite* and other manganates of Ba, Ca, Mn and Fe corresponding to the formula $R_2 Mn O_6$.
Psilomelane.*
 v. *Wad*.*

Carbonates.—Ankerite?
 Rhodochrosite.*

<i>Silicates.</i> — <i>Blanfordite</i>	}	Manganese-pyroxenes.
Manganhedenbergite		
Rhodonite*		
Two other	}	Manganese-amphibole.
<i>Winchite</i>		
Spessartite*	}	Manganese-garnets.
Aplome		
Piedmontite*		
Carpholite?	}	Manganese-epidote.
Two or more		
		Manganese-micas.

Phosphates.—Triplite.

Niobates.—Columbite.

Tungstates.—Wolfram.

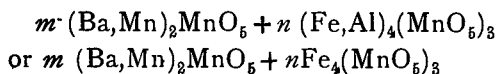
Of the above minerals, dysluite, ankerite (?), aplome, triplite, columbite and wolfram have not been found in association with the Indian manganese-ore deposits and hence require no further mention here.

Amongst the collections of minerals from the manganese-ore deposits, several species and varieties have been found which are apparently new to science; but the only ones which have been sufficiently investigated to be named are those shown in italics in the above list,

Hollandite.—This mineral occurs in the crystalline form in quartz-veins traversing the manganese-ore deposit at Kájlidongri, Jhábua State, Central India. The mineral is greyish-black or quite black with a shining metallic lustre and has a hardness of 6 on the crystal faces and 4 on the striated fracture surfaces. The streak is black. The crystals in their simplest form show what looks like a tetragonal prism surmounted by a flat tetragonal pyramid; but the few angular measurements yet made indicate that the mineral is either orthorhombic or triclinic, more probably the latter, and in either case very closely approaching the tetragonal form. The striations on the prism faces parallel to the vertical axis and the dullness and imperfect character of the pyramid faces have up to the present prevented this question being finally settled. An analysis of a picked sample of this mineral, kindly carried out by Mr. Howard J. Winch, manager and chemist to the Kájlidongri quarry, gave the following result :—

	Per cent.
Silica (SiO ₂) ...	... traces.
Ferric oxide (Fe ₂ O ₃) ...	... 10·56
Alumina (Al ₂ O ₃) ...	... 0·94
Baryta (BaO) ...	... 17·59
Manganese peroxide (MnO ₂) ...	... 65·63
Manganese protoxide (MnO) ...	... 5·12
	} Mn. = 45·45.
	—
	99·84
	—
Specific gravity ...	... 4·95

This analysis corresponds to the following formula :—



according as the alumina be considered an essential constituent or not.¹

For this new mineral I propose the name of *hollandite*, after Mr. T. H. Holland, F.R.S., Director of the Geological Survey of India, and President of this Institute.

I have found a similar mineral in the, at present unexploited manganese-ore deposit of Sitapár, Chhindwára district, Central Provinces. It occurs in intimate association with five other minerals, none of which have yet been specifically determined, except pyrolusite pseudomorphous after manganite.² It has no crystal faces developed, but is otherwise indistinguishable in appearance and hardness from hollandite, the especially characteristic feature of both minerals being the ready way in which they split along very striated planes parallel to the vertical axis. An analysis of a specimen of this mineral having a specific gravity of 4.70 has shown that it also is a manganate of barium, iron and manganese, with a considerable proportion of calcium.

Both these manganates correspond to an hypothetical acid H_4MnO_5 , and there is probably a whole series of compounds derived from this acid by isomorphous replacement. Laspeyres³ has already suggested that psilomelane may conform to this formula of H_4MnO_5 and the analyses Nos. 1, 3 and 4, of some Indian ores, on pp. 47 and 48, *Rec. Geol. Surv. Ind.*, XXXI, (1904), fit in almost exactly with this assumption, the NiO, CoO and Al_2O_3 being also calculated into the formula. Hence we see that there is reason to

¹ Mr. T. R. Blyth, Assistant Curator, Geological Survey of India, has been recently engaged in examining this mineral in a more critical fashion than was possible to Mr. Winch in his rough jungle laboratory, and finds that it contains, besides the constituents found by Mr. Winch, small amounts of lime and magnesia and of one of the rare elements.—June 24th, 1906.

² *Rec. Geol. Surv. Ind.*, XXXIII, p. 232, (1906).

³ Dana's "*System of Mineralogy*," p. 257, 6th Edition.

remove psilomelane from the oxides and to form a new group of minerals corresponding to the hypothetical acid H_4MnO_5 , and that these minerals are perhaps to be regarded as derived by isomorphous replacement from a manganese manganate, Mn_2MnO_5 , as yet undiscovered.

This new group, the *manganates*, will contain hollandite, psilomelane, and the Sitapár manganate.

Blanfordite.—A second very interesting mineral is a pyroxene found in the Kácharwáhi manganese-ore quarry, Nágpur district, C.P. It is notable for its striking and beautiful pleochroism, which even in thin sections is—

a = rose-pink,
 b̄ = bluish lilac,
 c̄ = sky-blue.

In thick sections the a and c̄ axis colours are deep carmine and very rich sky-blue respectively. When fresh, the pyroxene is deep crimson as seen in hand specimens, but it is often altered so as to be chocolate-brown in colour. The mineral is monoclinic, with a small angle of extinction. The crystals noted below show three forms, the prism, clino-pinacoid and clino-dome, and sometimes exhibit basal parting planes best seen in thin sections under the microscope. In sections at right angles to the acute bisectrix a figure can be obtained, but points of emergence of the optic axes lie outside the field of view of the microscope. The specific gravity (as determined with some minute fragments and Sonstadt's solution) is 3.15. Before the blowpipe the mineral fuses easily to a black bead, gives a marked sodium flame and with fluxes gives indications of small quantities of manganese and iron. It occurs partly as a pyroxene-braunite-rock with interstitial apatite, and partly in aggregates and scattered crystals up to an inch long in a rather coarsely crystalline albite-rock. I propose to call this mineral *blanfordite*, after

the late Dr. W. T. Blanford. What is probably the same mineral was also found at Rámdongri, where it occurs in the manganese-ore body in a patch of what must be regarded as a granitic intrusive. This rock is of rather fine grain and is composed of microcline, quartz, plagioclase, and perhaps orthoclase, with some apatite, zircon and brown mica. Monoclinic pyroxenes having exactly the same scheme of pleochroism as blanfordite, but in much paler tints, also occur at Kájlidongri, Jhábua State, C.P., and Jothvád, Nárukot State, Bombay. This scheme of pleochroism can with convenience be designated the *blanfordite type of pleochroism*. These pyroxenes are perhaps related to that from the manganese mines of St. Marcel, Piedmont, Italy, described by S. L. Penfield,¹ as showing a very faint pleochroism in very pale rose and very pale blue.

Winchite.—This is the name which has been bestowed, after Mr. Howard J. Winch of Meghnagar, Central India, upon the blue amphibole, from Kájlidongri, Jhábua State, concerning which a preliminary note has been published in the *Records, Geol. Surv. Ind.*, XXXI, p. 236, (1904). An analysis of this mineral shows it to be closely allied to tremolite in chemical composition, but to contain in addition oxides of iron, soda, potash and manganese, to the last of which it probably owes its colouring.

Of the manganese-minerals given in the list on page 75 there are nine (marked with an asterisk) **Indian manganese-ores.** with which every manganese-miner in India should be familiar, and consequently short notes on them are given below.² Of these the first six are usually regarded as ores.

¹ *Amer. Jour. Sci.*, XLVI, 3rd series, p. 292, (1893).

² Some of the data given are based on the writer's observations and some are taken from Dana's *System of Mineralogy*.

Braunite ($3\text{Mn}_2\text{O}_3 \cdot \text{MnSiO}_3$)—sesquioxide of manganese in combination with manganese-silicate. Theoretical maximum % of Mn = 63.59. Hardness (H) = 6 to 7; hence it cannot be scratched with a knife. Specific gravity (G) = 4.75 to 4.82. It crystallizes in the tetragonal system as octahedra, but is usually found massive in India, often showing brilliant shining facets due to its perfect octahedral cleavage. In colour braunite is dark steel-grey to black, with a metallic lustre and blackish streak. Small chips are slightly magnetic. It is the ore, *par excellence*, of the Central Provinces and to a less extent of Jhábua and Vizagapatam.

Pyrolusite (MnO_2)—peroxide of manganese. Theoretical maximum % of Mn = 63.22. It is very soft, soiling the fingers, and is black to bluish-grey or steel-grey in colour; it is often crystalline with a bright metallic lustre and tends to form radiate-concentric masses. G = 4.73 to 4.86. Very handsome specimens are found at Páli, Nágpur district, in cavities in the crystalline limestone. It is also found commonly in the Jabalpur and Vizagapatam districts.

Manganite ($\text{Mn}_2\text{O}_3 \cdot \text{H}_2\text{O}$)—hydrated sesquioxide of manganese. Theoretical maximum % of Mn = 62.50. H = 4; hence can be scratched by knife. G = 4.2 to 4.4. It crystallizes in orthorhombic prisms sometimes elongated to needle-like crystals as in the only undoubted occurrence of this mineral in India, namely a nodule obtained from the Sandur Hills, Madras.¹ Colour, dark steel-grey to iron-black, sometimes with a bronze-like tarnish. Streak, reddish-brown to black.

Psilomelane—a complicated hydrous manganate of manganese and other bases such as barium and iron. On the assumption that this mineral forms with hollandite a group of man-

¹ *Rec. Geol. Surv. Ind.*, XXXIII, p. 229-232, (1906).

ganates, the theoretically highest possible % of Mn will be 67·35 corresponding to the formula $Mn_2 MnO_6$. $H = 5$ to 6; hence it can sometimes be scratched, though with difficulty, by a knife, and sometimes not at all. $G = 3·7$ to 4·7. It is an iron-black to blue or steel-grey mineral occurring both massive and in botryoidal and stalactitic shapes, and usually having a rather dull lustre. It is the most widely spread of all the Indian manganese-ores, and with braunite forms the large bulk of the manganese-ore exported from India.

Wad is a soft, light, porous variety of psilomelane found abundantly in some of the Vizagapatam mines; the Indian wad is not, however, turned to any account.

Rhodochrosite or *dialogite* ($MnCO_3$)—manganese carbonate. Theoretical maximum % of Mn = 47·83. It is white, pink or light brown in colour, with a rather pearly lustre, and is easily scratched by a knife ($H = 3·5$ to 4·5), while it effervesces briskly with warm dilute hydrochloric acid (and is thus distinguished from rhodonite, which it somewhat resembles). $G = 3·45$ and over. This mineral has only been found at two localities in India, namely Gaimukh and Devi in the Chhindwára district, C.P., and there only in small quantities.¹

The manganese-ore being despatched from the Central Provinces consists very largely of an intimate mixture in varying proportions of braunite and psilomelane. This ore is of fine grain, usually very hard and tough, and little crystalline facets of braunite may often be distinguished in the psilomelane-braunite ground-mass. These braunite crystals may increase in size and abundance until almost the whole specimen is coarsely crystalline braunite, as at Thirori, Bálághát district. In other cases the ore may be entirely psilomelane, as at Bálághát itself.

¹ *Rec. Geol. Surv. Ind.*, XXXIII, pp. 211, 212, (1906).

At one locality only—Páli, Nágpur district—has any attempt been made to quarry pyrolusite. In the Vizagapatam district, Madras, on the other hand, the common ore is psilomelane sometimes containing an admixture of more or less braunite, which then appears as little scattered specks, though occasionally found massive. From some of the deposits, abundance of pyrolusite is also obtained. The mineral constitution of the ores from the Kájlidongri mine, Jhábua State, Central India, has not yet been decided, but they have the usual fine-grained appearance, dark-grey colour, and hard, compact character of the ores from the Central Provinces and probably also consist of a braunite-psilomelane mixture.

The range in quality, as shown by analysis, of the ores shipped from the three producing provinces, is given in the following table:—

TABLE 2.

Average analysis of Manganese-ores exported from the three producing provinces.

	Central India.	Central Provinces.	Madras.
Railway lead in miles to shipping port.	361	500-700	56
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Manganese ...	46-48	50-55	43-50
Iron ...	8-9	5-8	5-13
Silica ...	6-9	5-9	2-6
Phosphorus ...	0·08-0·25	0·05-0·12	0·15-0·60
Moisture ...	below 0·25	usually below 1·0	0·5-2·0

The three other minerals which have been asterisked are **Important associated manganese-silicates.** manganese-bearing silicates which, although of no commercial value as long as large quantities of oxide-ores are found in various parts of the world, are so frequently found in association with the economically valuable ores that they require a brief description.

Rhodonite (Mn SiO_3)—metasilicate of manganese. Theoretical maximum % of Mn = 41.86. $H = 5.5$ to 6.5 ; *i.e.*, it is not scratched by a knife. $G = 3.4$ to 3.68 . It is a triclinic pyroxene found under the same circumstances as spessartite (see below), with which it often forms a spessartite-rhodonite-rock with or without quartz. The rhodonite is almost invariably rose-pink (but occasionally greenish-grey), and when orange spessartite is scattered through rose rhodonite, a very beautiful rock is the result. The rhodonite always forms a granular to coarsely crystalline rock, never occurring as crystals with measurable faces. Further, the rhodonite-bearing rocks are often quite black outside, due to oxy-alteration, and the pink colour is only seen on breaking the rock. Rhodonite has been found in the following districts and states:—

Nárukot, Bombay ;
 Jhábuá, Central India ;
 Chhindwára and Nágpur, Central Provinces ;
 Ganjám and Vizagapatam, Madras.

Spessartite or *manganese-garnet* ($3\text{MnO} \cdot \text{Al}_2\text{O}_3 \cdot 3\text{SiO}_2$)—orthosilicate of manganese and alumina. Theoretical maximum % of Mn = 33.24 ; but the actual % of Mn is usually considerably below this figure owing to an isomorphous replacement of manganese by iron and calcium and of alumina

by iron. $H = \text{about } 7$; hence it cannot be scratched by a knife. $G = 4.0$ to 4.3 . Spessartite is the commonest of the Indian manganese-silicates and is an almost invariable associate of the workable deposits of manganese-ore. When well crystallized, as at Chárgáon near Rámtek, Nágpur district, the crystal habit is seen to be trapezohedral.

Fig. 1 represents a very fine trapezohedron of spessartite obtained at Chárgáon, Nágpur district. It is complete in all its twenty-four faces which are beautifully striated parallel to those of the rhomb-dodecahedron.

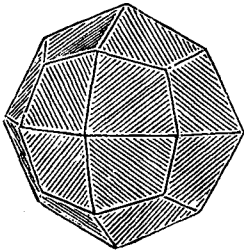


FIG. 1.

Crystal of Spessartite. Nearly twice natural size.

In Fig. 2 is shown a very fine crystallization of the same mineral. When the crystals are not too large, spessartite varies in colour from bright yellow through orange and orange-brown to deep orange-red; but the larger crystals, owing to the density of the colour, often appear dark-brown or even black, as in the specimen shown in Fig. 2; their true colour, however, is seen when they are broken into smaller pieces. The mineral being very prone to alteration is also often blackened owing to the formation of manganese-oxides. One of its commonest modes of occurrence is as a fine-grained very tough spessartite-quartz-rock of cinnamon to yellow or yellow-grey colour. Spessartite has been found in the following districts and states:—

Nárukot, Bombay;

Jhábuá, Central India;

Bhandára, Bálághát, Chhindwára and Nágpur,
Central Provinces;

Ganjám and Vizagapatam, Madras.

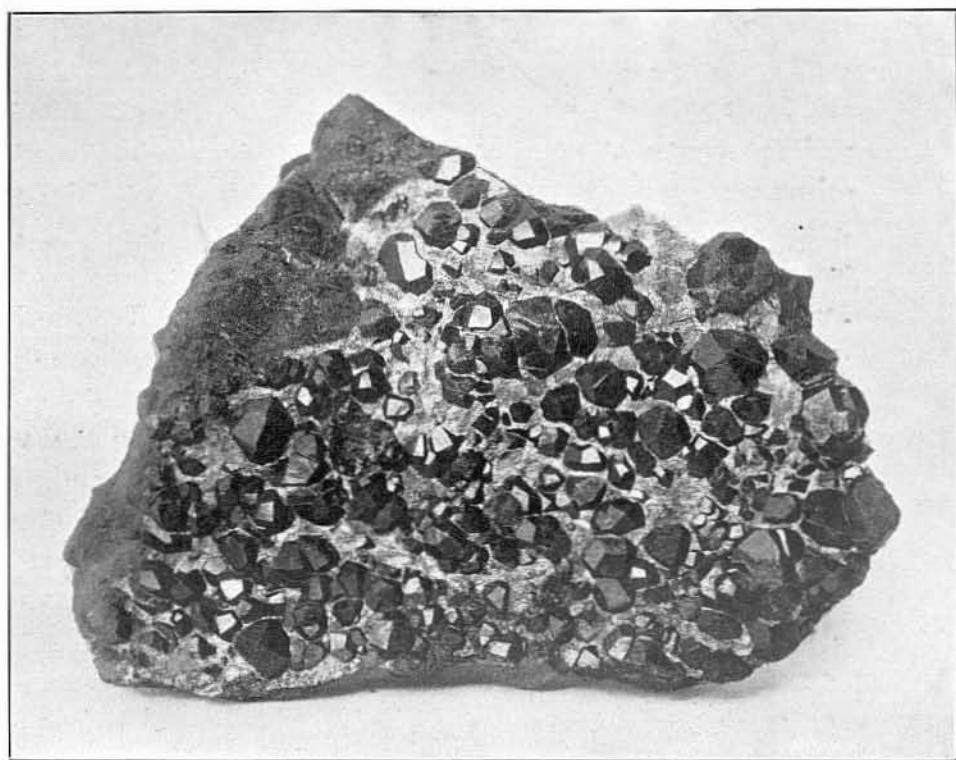


Photo by H. H. W. Garrick.]

**FIG. 2.—Spessartite crystals (trapezohedra) with interstitial quartz, on a basis of manganese-ore.
From Waregáon, Nagpur district. Natural size.**

Piedmontite or *Manganese-epidote* $[\text{Ca}_2(\text{Al},\text{OH})(\text{Al},\text{Mn},\text{Fe})_2(\text{SiO}_4)_3]$ —a complex orthosilicate of calcium, aluminium, manganese and iron. It contains only 3·5 to 10·5 per cent. Mn. $H = 6\cdot5$. $G = 3\cdot40$. It usually occurs in association with crystalline limestones which then often contain bands of nodules of manganese ore. This is a mode of occurrence of manganese at present of no proved economic value, though some attempt has been made to work residual accumulations of these nodules formed by solution and removal of the limestone matrix, as at Junawáni, Nágpur district. The piedmontite occurs in deep purplish crimson grains, and in satiny-looking nodules of the same colour, in the limestone. This mode of occurrence has only been noticed in the Nágpur district; piedmontite also occurs at the Kájlidongri mine, Jhábua State, and near Jámbughoda, Nárúkot State.

2.—ORIGIN AND MODE OF OCCURRENCE OF THE INDIAN MANGANESE-ORE DEPOSITS.¹

Classification. The manganese-ore deposits of India can be classified as follows:—

A. Braunite, psilomelane and pyrolusite associated with, and derived from, manganese-bearing silicates (such as spessartite, rhodonite and less frequently piedmontite) occurring as bands and lenticles in the Archæan schists and gneisses. Examples of these occur in—

- (1) Nárúkot in Bombay;
- (2) Jhábua in Central India;
- (3) *Bálághát, Bhandára, Chhindwára and Nágpur* in the Central Provinces;
- (4) Ganjám and *Vizagapatam* in Madras.

¹ *Rec. Geol. Surv. Ind.*, XXXIII, pp. 94-100, (1906).

B. Psilomelane and pyrolusite superficially formed on the outcrops of rocks of Dhárwár age—

- (1) Singhbhum in Bengal;
- (2) Dhárwár, and Panch Maháls in Bombay;
- (3) Jabalpur in the Central Provinces;
- (4) *Sandur Hills* in Madras.

C. Psilomelane and pyrolusite associated with, or contained in, laterite. Localities :—

- (1) Belgaum and Sátára in Bombay;
- (2) Jabalpur in the Central Provinces.

The localities in italics are those in which economically important deposits have been located and in most cases worked. Belgaum may possibly be added to these in the future. It will be seen that from every point of view, economic, mineralogical and petrological, the chief interest centres in the deposits of Group A.

Manganese-ores have also been found in many other parts of the Indian Empire but not in sufficient quantity to merit notice in this paper.

GROUP A.

As the result of a careful examination of some of the manganese-ore deposits of the Vizagapatam district and especially of the Kodur mines, where the quarrying has now been in progress for over 13 years, it has been found possible to formulate a definite theory as to the origin of the manganese-silicate rocks from which the manganese-ores are regarded as having been derived, at least in part, by chemical alteration, and this theory can be applied in a more or less modified form to the rocks of similar nature occurring in the Archæan complex of other parts of India.

The Vizagapatam district, geologically speaking,

consists of a complex of Archæan rocks which has been separated into three groups—(1) the Khondalite series, (2) the Charnockite series, and (3) the Gneissose granite. The manganese-ore bodies have been found only in close relationship with (1) and (3), and, briefly stated, the conclusions as to their origin are as follows :—

Vizagapatam district,
Madras.

- (a) Rocks containing a large proportion of manganese-silicates, such as spessartite¹ and manganese-pyroxenes, and of which the most general and characteristic type is apatite-spessartite-felspar-rock, have been intruded in Archæan times as part of an igneous magma into the rocks of the Khondalite series.
- (b) Under the influence of chemical waters, doubtless heated, the manganese-silicates have been decomposed, and the manganese has been removed from some parts of the rock-mass and re-deposited in the form of oxides in other parts, and so added to the manganese already there, replacing at the same time any felspar not already decomposed and removed.

This theory can be stated in more precise detail, in a form especially exemplified by the Kodur and Garbhám mines, as follows :—

- (a) The original magma had a composition corresponding to a mixture of apatite, felspar, quartz, spessartite and various manganese-pyroxenes.
- (b) This magma while still molten became differentiated into various units.
- (c) The magma was then erupted and intruded, probably into the rocks of the Khondalite series; on solidifying, the following rocks among others crystallized out :—

¹ An analysis recently made by Mr. J. C. Brown, Geological Survey of India, of the manganese-garnet of Kodur has shown that it is intermediate in composition between spessartite and andradite.—June 24th, 1906.

- (1) Felspar-rock,
- (2) Felspar-quartz-rock,
- (3) Spessartite-felspar-rock,
- (4) Spessartite-pyroxene-felspar-rock,
- (5) Spessartite-pyroxene-rock,
- (6) Spessartite-rock,
- (7) Apatite-spessartite-felspar-rock.

(d) The more basic manganeseiferous rocks 3 to 7 were probably distributed as streaks and patches in the more acid rocks 1 & 2.

(e) Hot mineral waters then attacked these manganeseiferous rocks, probably at once, but at any rate in Archæan times, and as the result of this action manganese-ores were formed in two ways. In many cases manganese was taken into solution and carried to another part of the rock-mass where it was deposited so as to replace all the minerals of the rock, except those containing manganese, which in some cases remained fresh and unaltered and in others were also broken up. (See Fig. 16.) Thus the manganese-ore, resulting from the replacement of rock No. 7, sometimes consists of compact psilomelane studded with bright-red or orange spessartite-garnets, and at other times entirely of manganese-ore. In the case of most of the spessartite-rock, however, the lime, alumina and silica were carried away, leaving a porous mass of iron and manganese oxides which was more or less consolidated by the introduction of more manganese-oxide from other parts of the deposit.

(f) Another result of the series of chemical changes taking place has been the conversion into kaolin and lithomarge of almost all the felspar; and, as a further consequence of the removal of material from one part of the rock-mass to another, there has been a frequent adjustment of equilibrium producing small slips and folds.

Such an explanation as the above satisfies all the requirements of the majority of the Vizagapatam deposits and accounts well for the extraordinary jumble of rocks seen at Kodur.

The accompanying map (Fig. 3) is a rough geological sketch-map of the Kodur mines area. The structure of the ground along the line XY, may either be interpreted as in Fig. 4, on which supposition the manganese-intrusives have found their way along the divisional planes of the scapolitic gneisses regarded as forming a part of the Khondalite series; or the repetition of the same rocks on each side of the

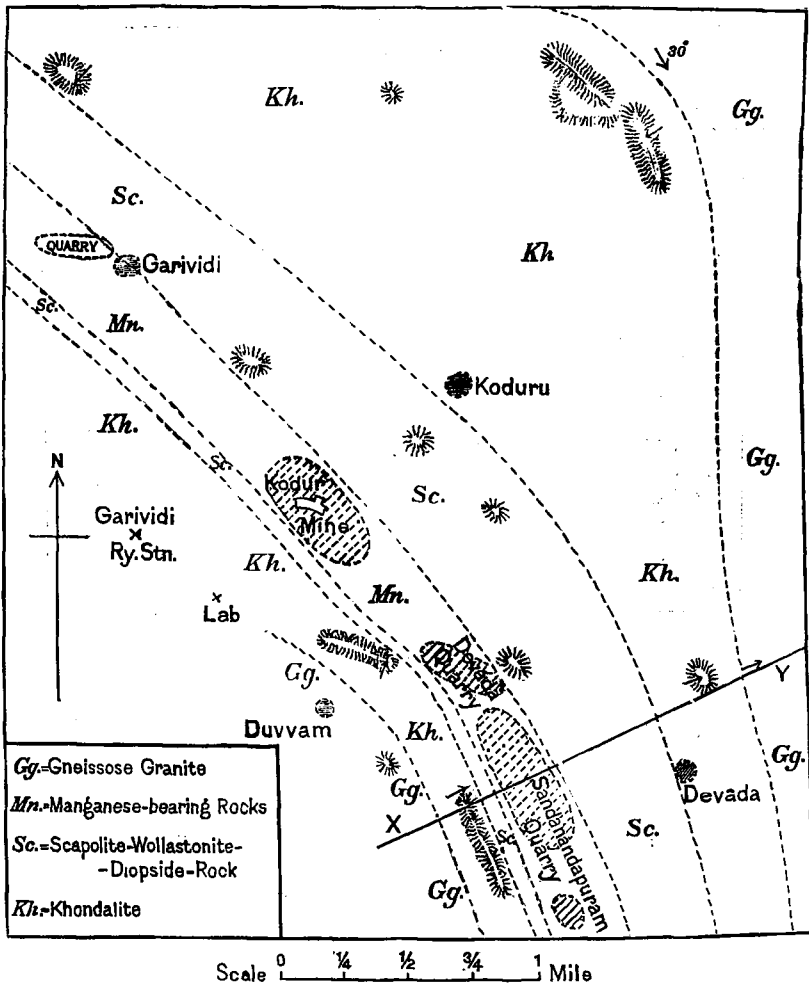


FIG. 3.—Geological Sketch Map of the Kodur Mines, Vizagapatam district.

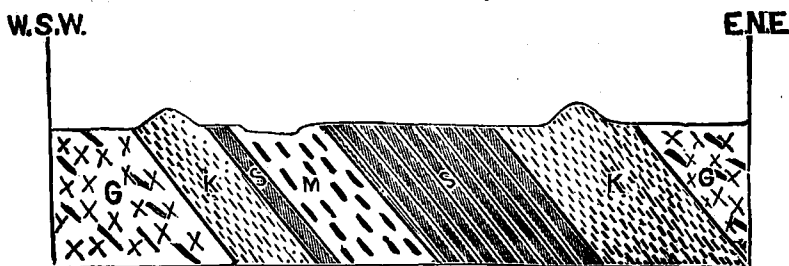


FIG. 4.

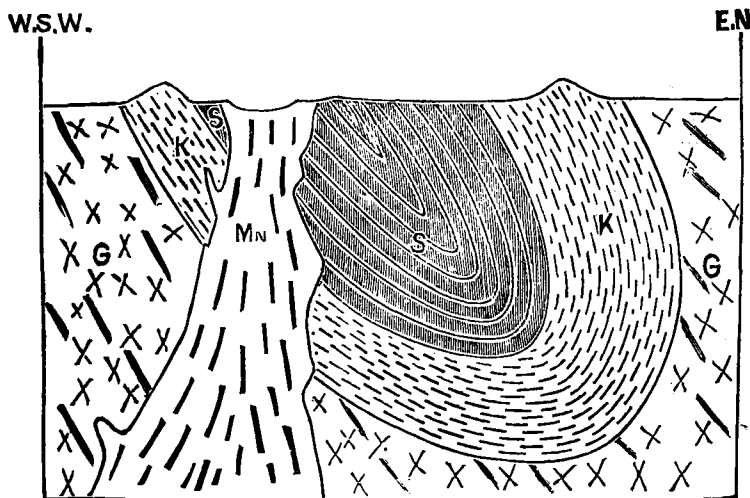


FIG. 5.

G = Gneissose granite ; K = Khondalite ;
 S = Scapolite-wollastonite-diopside-gneiss ;
 Mn = Manganese-intrusives.

Scale :— 0 1/4 1/2 3/4 1 mile.

Heights of hills exaggerated.

FIGS. 4 AND 5.—Alternative interpretations of structure along the line of section XY, in Fig. 3.

ore-band may indicate an overturned synclinal through which the manganiferous intrusives have burst as indicated in Fig. 5. The latter interpretation is perhaps the more likely. Three isolated masses of crystalline limestone found in the midst of manganiferous intrusives in the Kodur mine are to be regarded as xenoliths torn up from below at the time of injection of these intrusives and probably further metamorphosed in the process.

The few occurrences of manganese-ore investigated in the Ganjám district, Madras. the Ganjám district are of no economic value, but are interesting because they are associated in one case with spessartite-felspar-rock and, in another, with apatite-spessartite-rhodonite-rock.

In the Nágpur-Bálághát area, comprising the districts of Bhandára, Bálághát, Chhindwára and Nágpur, the manganese-ore occurs as lenticular bands and masses, intercalated parallel to the strike, in the quartzites, schists and gneisses. The ore is frequently found to pass both laterally and along the strike into partly altered or quite fresh spessartite-quartz-rock, or rhodonite spessartite-quartz-rock. The typical rock from which these manganese-ore deposits have been, at least in part, derived, is this spessartite-quartz-rock, often containing a small quantity of apatite, and usually quite free from felspar.

Although the evidence is not so conclusive as in the Vizagapatam district, yet it seems probable that here also the original manganese-bearing rock was intruded in the molten condition into the metamorphic schists and gneisses. But in this case it is probable that the rocks have often been subjected to intense folding subsequent to the alteration of manganese-silicate to manganese-ore. The effect of this folding has been twofold :—

- (1) To squeeze or roll out the manganese-intrusives so that almost all the bands of manganiferous rock now conform to the strike of the enclosing metamorphic schists and gneisses; the only clear exception yet found is the Rámdongri-ore-body, the boundaries of which are often transgressive with regard to the associated schists and quartzites.
- (2) The manganese-ores, which were perhaps once cavernous, porous and friable, like those of the present day in the Vizagapatam district, have been compressed into a very compact, hard, more or less crystalline form.

The last paragraph indicates the probable reason for the superior physical character of the Nágpur ores over those of Vizagapatam, while their less phosphoric character (see page 82), is due, of course, to the spessartite quartz-rock of the Nágpur area, containing less apatite than the apatite-spessartite-felspar-rock of Vizagapatam.

The ore-bodies often attain great dimensions, and their disposition as irregular lenses along the strike of the enclosing schists naturally influences the miner in laying out the boundaries of his "claims." A deposit near Bálághát is $1\frac{3}{4}$ miles long; at Mánegáon in the Nágpur district the ore-body is $1\frac{1}{2}$ miles long; whilst at Thirori, in the Bálághát district, it is nearly 6 miles in length. As examples of great breadth, may be quoted Kándri, 100 feet thick, of pure ore; and Rámdongri, 1,500 feet of ore and unaltered spessartite-rock. The depth of these ore-bodies is quite unknown, as the so-called mining has so far passed little beyond the quarrying stage.

The question has been frequently asked as to what term

should be applied to describe the form of the manganese-ore deposits, especially those of the Central Provinces; *i.e.*, should they be called veins, reefs, beds, or anything else? *Vein* is almost emphatically the wrong term to apply, while *reef*, although a somewhat looser term, is hardly a suitable one. The ore-bodies often take the form of bands having a fairly constant width over a considerable distance; the divisional planes which are often found parallel to the length of the deposit then frequently impart to it a well-bedded appearance. If it be wished to apply the term *bed* to such an ore-body, it must be with the understanding that the so-called 'bed' does not necessarily extend continuously in depth or along the strike over a large area, as it would in the case of a bed of sandstone or a coal-seam (faults being supposed absent), but that it probably dies out in lenticular fashion within quite a moderate distance. The Kájlidongri deposit is a good example of one with regard to which it seems difficult to object to the term 'bed,' since the ore-bands are intercalated, and folded up, with quartzites so as to exactly resemble a bed. There is no doubt, however, that the most suitable terms are *ore-lenticle* when the ore-body has a decidedly lenticular shape, or *ore-band* when it takes the form of a band extending over a considerable distance. When, however, there is any doubt—as there almost always is—about the shape of the mass of ore, it should be designated by the term, already used several times in this paragraph, *ore-body*. This term is always applicable provided it be confined to the original mass of ore *in situ* and not applied to the talus- or pebble-ore derived from it.

For other modes of occurrence of manganese-ores in the Nágpur area, see under pyrolusite (page 80), and piedmontite (page 85).

The manganese-ore deposit at Kájlidongri near Meghnagar railway station consists of much folded alternating quartzite and manganese-ore layers, associated with spessartite and rhodonite-bearing rocks; it is to be classed with the deposits of the Central Provinces rather than those of Vizagapatam. This deposit is one of the most interesting in India on account of the varieties of minerals it has yielded. These include winchite, a pyroxene allied to blanfordite, and hollandite (see list, page 75), all new species, piedmontite and carpholite (?).

Near Jothvád, about two miles north of Jámbughoda, in the Nárukot State, is a small hill of contorted gneisses which include many bands of manganiferous rocks containing, amongst other minerals, spessartite, rhodonite and piedmontite with very abundant apatite. This hillock is surrounded by porphyritic biotite-granite, which has invaded the gneisses and enclosed in itself portions both of these and of the manganiferous rocks, the latter being in some cases partially converted into manganese-ore. The granite is similar to that of Bundelkhand, and of other areas where there is little doubt of its Archæan age. It seems likely, therefore, from this occurrence, that the development of manganese-ore from the manganiferous silicates took place in Archæan times.

For future reference, I have given below a list of all the manganese-ore deposits of Group A., which were visited by myself or with regard to which I have been able to obtain definite information. At those localities in italics quarrying work of some importance, usually resulting in export, has been carried on.

BOMBAY—

Nárukot State.

1. Jothvád.

CENTRAL INDIA—

Jhábua State.

1. *Kájlidongri.*
2. Rambhápur.

CENTRAL PROVINCES—

Bálághát District.

1. Chándadoh.
2. *Thirori*, Ponia and Jamrapáni.
3. Sonegáon.
4. Arjoni and Jám.
5. Nándgáon.
6. Ramrama.
7. Katangjheri I (Government Forest).
8. Katangjheri II (Málguzári.)
9. *Bálághát.*
10. Ghondi.
11. *Ukua.*

Bhandára District.

1. Kosumbah.
2. Sitapathur.
3. Sukli.
4. Hatora.
5. *Miragpur.*
6. Mohugáon Ghát.
7. Pándarwáni.
8. Sálebaddi.
9. Chikhla II.
10. *Kurmura.*
11. *Chikhla I.*
12. Sitasáongi.

13. Ásalpáni.

14. *Pachdra.*

Chhindwára District.

1. Kachi Dhána.
2. Lakhanwára.
3. Gaimukh.
4. Sitapár.
5. Bichua.
6. Alesur.
7. Devi.
8. Ghoti.
9. Wagora.
10. Gowári Warhona.
11. Dudhára.

Nágpur District.

1. *Kodegáon.*
2. *Gumgáon.*
3. *Rámdongri.*
4. Risára (Reechara).
5. Nándgondi.
6. Sitagondi.
7. *Kándri.*
8. *Mansar.*
9. *Mansar Extension.*
10. *Parsoda.*
11. Borda.
12. Pársioni and Bansinghi.
13. Dúmri Kalán.
14. *Sátak.*
15. *Beldongri.*
16. Nagardhan.
17. *Nandapuri.*
18. *Lohdongri.*
19. *Kácharwáhi.*
20. *Waregáon.*
21. Khandála.

- | | |
|--|---|
| <p>22. <i>Mándri</i>.
 23. <i>Mánegdon</i>.
 24. <i>Guguldoho</i>.
 25. Bhandárbori.
 26. Mohugáon.
 27. <i>Páli</i>.
 28. Ghogara (Pench River).
 29. <i>Mándvi Bir</i>.
 30. <i>Funawáni</i>.
 31. Junapáni.</p> | <p>6. Sivarám.
 7. <i>Perapi</i>.
 8. Itakerlapilli.
 9. Mulagám.
 10. Govindapuram.
 11. <i>Garbhám</i>.
 12. <i>Kotakarra</i>.
 13. Gadasám.
 14. <i>A'vagudem</i>.
 15. <i>Aitemvalsa</i>.
 16. <i>Gotnandi</i>.
 17. <i>Bondapilli</i>.
 18. <i>Garraráju Chipurupalli</i>
 (Garuja).
 19. <i>Perumáli</i>.
 20. <i>Rámabhadrapuram</i>.
 21. Táduru.
 22. Chintelavalsa.
 23. Thonaum.</p> |
|--|---|
- MADRAS—
- Ganjám District.*
1. Boiráni.
 2. Nautan-Barampur.
- Vizagapatam District.*
- | | | |
|---|---|---------------------|
| <ol style="list-style-type: none"> 1. <i>Garividi</i>. 2. <i>Kodur</i>. 3. <i>Duvvám</i>. 4. <i>Deváda</i>. 5. <i>Sandananda-
puram</i>. | } | The Kodur
Mines. |
|---|---|---------------------|

Before leaving this section of the paper it will be interesting to compare the Indian manganese-ore deposits of Group A with those of the Queluz district, State of Minas Geraes, Brazil, the only ones, as far as the writer can discover, which bear any resemblance to those of India. Orville A. Derby,¹ who has studied the Brazilian deposits, ascribes their formation in many cases to the decomposition and leaching of basic mangiferous rocks of which the most important mineral is manganese-garnet (spessartite). These masses of mangiferous rock often occur as dyke-like masses and are considered to be the result of magmatic segregation from a basic

¹ *Amer. Journ. Sci.*, XII, pp. 18-32, (1901).

magma of dioritic, gabbroitic or noritic type, now represented by the very decomposed, and sometimes sheared, clay-like country in which the manganese-ore bodies occur.

It will be seen that there is a general analogy between this theory and that which is supposed to explain the formation and structure of the Vizagapatam deposits of India. The analogy, however, only applies to the processes, *i.e.*, the magmatic segregation of the manganiferous rocks from a molten magma, with subsequent chemical changes producing the ore-bodies from the manganiferous rocks and the clays (or lithomarges) from the less manganiferous country-rock—and not to the actual rocks concerned. For in Brazil the residual rock, left after the segregation from the magma of the manganiferous rocks, was of basic character, while in Vizagapatam it was either a felspar- or felspar-quartz-rock, *i.e.*, a more acid rock. The product of segregation in Brazil, moreover, was essentially a manganese-garnet rock sometimes containing an amphibolic (or perhaps pyroxenic) or micaceous mineral, and at other times instead of these latter free (original) manganese-oxide (? polianite) with ilmenite and rutile as accessories and a very small quantity of apatite, while both quartz and graphite, supposed to be subsequent introductions, also occur.¹ As shown on page 88, the typical product of segregation in the Vizagapatam area is a considerably different rock of which the three chief constituents, apatite, spessartite, and felspar are all equally important.

GROUP B.

The manganese-, and manganiferous iron ores of Singhbhum district, Bengal, first noticed by V. Ball,² are very similar to those of Jabalpur. They

¹ This type of rock has been denominated *quelusite* by Derby, *loc. cit.*, p. 30.

² *Mem. Geol. Surv. Ind.*, XVIII, p. 147, (1881).

consist chiefly of psilomelane formed by the superficial replacement of sericite-phyllites, quartzites and felspathic grits which may be doubtfully referred to the Dhárwár system. They are found in the area immediately south of Cháibása and only occur in small quantities very irregularly distributed.

As the chief locality for manganese-ore in the Dhárwár district may be mentioned Chik-Vadvati, Dharwar district, Bombay. Kappatguda Hills, Sangli State, long ago visited by Newbold¹ and recently examined by Mr. J. M. Maclaren who found that the manganese-ores, chiefly psilomelane, of this district, occur on the outcrops of banded, limonitic, jaspery quartzites of Dhárwár age, and his specimens show that they must have had an origin precisely similar to those of the Jabalpur district. They likewise are of no economic value.

The manganese-ores of the Panch Maháls district, Bombay Presidency, consist of psilomelane and pyrolusite, and have been formed by the superficial replacement of slates and quartzites of the Chámpáner series, which is probably the same as the Dhárwárs. The best locality is Sivarájpur, first noticed by the late Dr. W. T. Blanford.² The economic value of these deposits is doubtful.³

The manganese-ores of this district occur in the vicinity of Gosalpur and Sihora in a belt of Dhárwár rocks which stretches for 20 miles in a N.E.-S.W. direction with a maximum width of 7 miles. These rocks are chiefly quartzite, shales, slates, and hematite-schists banded with jaspery quartzite.

¹ *Journ. Roy. As. Soc.*, VII, p. 212, (1843).

² *Mem. Geol. Surv. Ind.*, VI, p. 341, (1869).

³ Manganese-ore is said to have been recently quarried and despatched to Europe from this locality.

The manganese-ores can be divided into two classes:—

1. Manganiferous iron-ore and psilomelane.
2. Pyrolusite.

The banded jasper-hematites have often been converted at the outcrop into large masses of manganiferous limonite forming caps to the ridges in which these rocks occur. This manganiferous limonite is simply limonite veined with psilomelane, which in places forms large segregations. In other cases the hematite-schists have, by the development of little veins of manganese-ore, been converted at the outcrop into manganiferous hematite. The manganese has, in both cases, been no doubt derived from the small percentage of this element contained in the hematite; in some cases this concentration of manganese has proceeded to such an extent that considerable quantities of nodular psilomelane have collected on the hematite outcrops. At the same time, the accompanying jasper, slate, and sericite-phyllites have often been converted into manganese-ore by replacement. The pyrolusite usually occurs as nests and strings in the Gosalpur quartzites of Mr. P. N. Bose¹ and as nodular segregations in the laterite débris often covering these rocks. It, also, has no doubt been derived from the hematite-schists.

Manganese-ores were first noticed in this area by Newbold, and their occurrence has been described by R. B. Foote.² A large ore-body has been recently located at Rámandrug and is now being worked for export. The ore is mainly psilomelane. Mr. C. Aubert has given me the following figures as showing the range in composition of the ores as determined by the analysis of small specimens:—

¹ *Rec. Geol. Surv. Ind.*, XXII, p. 218, (1889); see also *ibid.*, XXI, pp. 71-88, (1888).

² *Mem. Geol. Surv. Ind.*, XXV, pp. 194-196, (1895).

		Per cent.	
Manganese	...	39	to 54
Iron	...	19	to 5
Silica	...	1'0	to 0'43
Phosphorus	...	0'016	to 0'033

GROUP C.

Mr. J. M. Maclaren in 1905 paid a brief visit to the **Belgaum district, Bombay.** manganese-ore deposit at Talevadi, then being developed by Messrs. Jambon & Cie. He found the manganese-ore to occur as more or less spherical concretions in a deposit of laterite 15 to 20 feet thick; they exhibited in the pits sunk a gradual passage downwards into quartz-schist; this in its turn rests on a slightly manganiferous limestone, which, like the quartz-schist, is of Dhárwár age.

The manganese-ores of the Mahábaleshvar and Yeruli **Sátára district, Bombay.** plateaux in the Sátára district occur as concretions of psilomelane in a small thickness of lateritic soil, resting on the Deccan Trap. They never occur in sufficient quantity to pay for extraction, and have probably been formed by concentration of the manganese which all such basic lavas must contain.

The lateritic manganese-ore of the Jabalpur district is so **Jabalpur district, C.P.** insignificant in quantity that it is sufficient to refer to page 99 above and to *Records, Geol. Surv. Ind.*, XII, p. 99, (1879).

III.—MINING AND ECONOMICS.

I.—HISTORY OF THE MANGANESE MINING INDUSTRY IN INDIA.

In spite of the large number of localities for ores of manganese enumerated in Ball's *Economic Geology of India*, published in 1881, it was not until the early nineties that Indian

geologists and miners began to realize the possibilities of India with regard to this mineral. The manganese mining, or rather quarrying, industry had its commencement in 1892 in the Vizagapatam district, Madras Presidency, and the out-

put from this area has constantly increased from 3,130 tons in 1893 to a maximum of 92,458 tons in 1900, since when there has been a gradual decline in output due to some of the deposits having been worked down to a level—only 50 to 100 feet—at which so much water enters the pits that the difficulty of winning the ore has become much increased. The output for 1905 from the mines of this district was 63,679 tons. In 1899 attention was directed to the Nágpur district, Central Provinces, and an initial production of 35,356 tons in 1900 was the result. The industry in this region has, with the exception of a slight check in 1904, due to the low price per unit of manganese, constantly expanded with the discovery and development of many fresh deposits in the Nágpur, Bhandára and Bálághát districts, so that the output for 1905 has reached the unprecedented total of 153,494 tons. Active work is also proceeding at a single deposit in the Jhábuá State, Central India Agency. A start was made in 1903 with an output of 6,800 tons, which rose to 30,251 tons in 1905. The past year also saw the start of the development of a deposit in the Sandur Hills. It is probable that, within the next two or three years, the Chhindwára district, Central Provinces, will be added to the list of producers.¹

The following table shows the output in long tons of manganese-ore from each of the producing provinces since the beginning of the industry :—

¹ Since this paper was read news has been received of the export of manganese-ore from the Shimoga district, Mysore, and the Panch Maháls district, Bombay.—June 24th, 1905.

TABLE 3.

Production of Manganese-ore from 1893 to 1905.

	Central India.	Central Provinces.	Madras.	Total.
1893	.....	.....	3,130	3,130
1894	.....	.....	11,410	11,410
1895	.....	.....	15,816	15,816
1896	.....	.....	56,869	56,869
1897	.....	.....	73,680	73,680
1898	.....	.....	60,449	60,449
1899	.....	.....	87,126	87,126
1900	.....	35,356	92,458	127,814
1901	.....	44,428	76,463	120,891
1902	.....	89,609	68,171	157,780
1903	6,800	101,554	63,452	171,806
1904	11,564	85,034	53,699	150,297
1905	30,251	153,494	63,679	247,422*

* This includes 48 tons raised in the Belgaum district and is only to be regarded as a provisional total. The figures for the C.P. are probably too low.—June 24th, 1905.

MINING AND GEOLOGICAL INSTITUTE OF INDIA.



Photo by L. L. Fernald.

FIG. 7.—Quarrying Manganese-ore at Kajlidongri.—Jhábua State, C.I.

MINING AND GEOLOGICAL INSTITUTE OF INDIA.

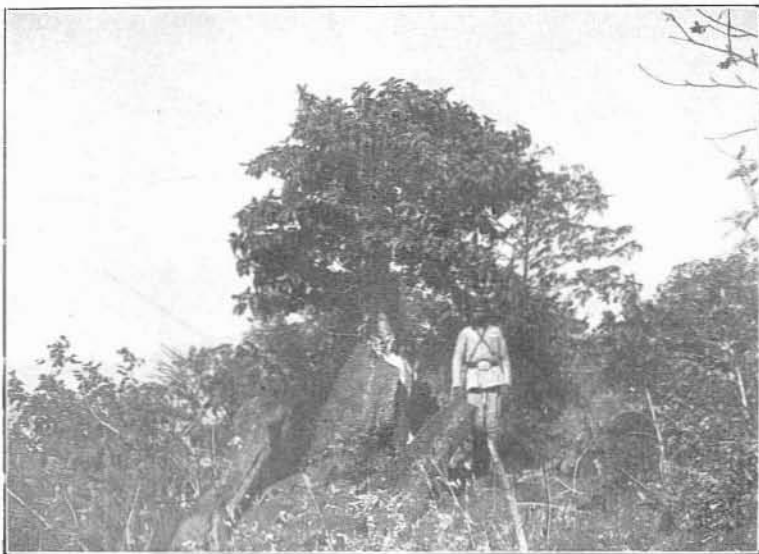


Photo by L. L. Fermor.

FIG. 8.—Outcrop of Manganese-ore on top of Mansar Hill.—
Nágpur District, C.P.

The following diagram expresses these figures graphically.

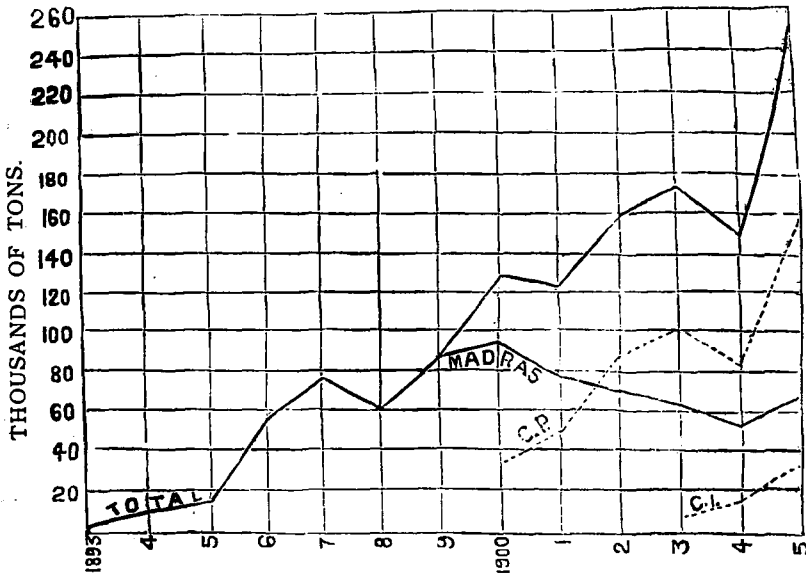


FIG. 6.—Diagram shewing production of Manganese-ore in India since the commencement in 1893.

Thus it will be seen that, taking India as a whole, there is a general tendency for a steady and constant increase in output. But as the rate of increase naturally depends to a large extent on the prices prevailing from year to year, it is necessary to compare the fluctuations in the price per unit of manganese with those of the output.

Table No. 7 (page 113) and the diagram, Fig. 17, (page 115) show the half-yearly prices per unit

Prices.

of manganese c.i.f. at United Kingdom

ports from January 1890 to the present date. Considering only first-grade ore, it will be seen that the Vizagapatam deposits began to export in 1893 when the price was 14 to 15 pence and that those of the Central Provinces came on to the market in 1900 with the price ranging from 13 to 15 pence. In the next four years the production of manganese-ore so increased in various parts of the world that the price gradually fell until 1904 and the beginning of 1905 when it reached its minimum of $8\frac{1}{2}$ to $9\frac{1}{2}$ pence. It was then that many of the deposits in the Central Provinces were closed down, thus accounting for the production of manganese-ore during 1904 being somewhat below that of 1902 and 1903.

During 1905, owing to the disturbances in the Caucasus, the export of manganese-ore from that region was stopped, while there was an improvement in the conditions of the iron and steel industry in the United States. The result has been that steel-makers in Europe and America have been unable to obtain sufficient manganese-ore to meet their requirements. The price has consequently risen by leaps and bounds so that it is said to have recently touched eighteen pence, just double what it was a little over a year ago. The result has been the unprecedented exports in 1905 of India and Brazil, the two most important manganese-ore producing countries after Russia. Throughout India there might be said to exist at present a sort of manganese fever which is leading both to very active prospecting for new deposits, and to the feverish working of the already known deposits with sometimes, it is to be feared, detrimental results to their future prospects, so that it will possibly be found imprac-

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Photo by L. L. Fermor.]

FIG. 9.—Manganese-ore Quarry at Kodegáon.—Nágpur District, C.P.

This has been excavated on a body of manganese-ore, the top of which was just exposed at the surface of an alluvial field. (A) is the original outcrop. On the further side of the quarry a loose pebble-bed of ore (B), covered with alluvial clay (C), is seen resting on the manganese-ore (D) *in situ*. All the rock visible in the quarry is manganese-ore *in situ*. (E) consists of stacked ore ready for carting. (1-11-03.)

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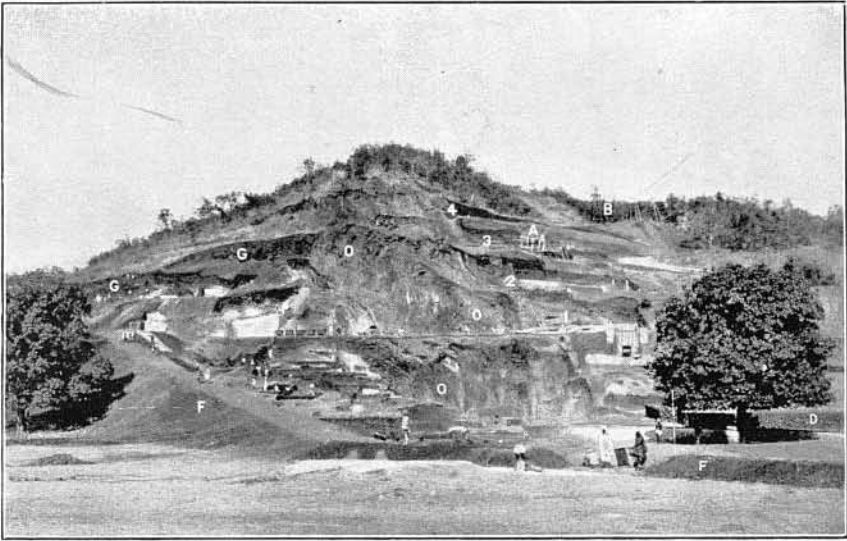


Photo by L. L. Fermor.

FIG. 10.—General view of the Manganese-Quarry at Kándri.—Nágpur District, C.P.

It shows the well-defined ore-body (O) running across the centre of the plate from the base to the summit of the hill (250 feet high). The ore-body is being attacked by means of the four levels, 1, 2, 3 and 4, approaching it from the right-hand side. The embankments formed of the waste material are seen running away to the right from the working faces in O. A is the upper trestle of the aerial ropeway in use at the time of my visit (18-1-04), and B is the first trestle of a new ropeway since completed. D=stacks of ore ready for carting. F=an inclined way since completed. At G are shown workings in the talus-ore derived from the ore-body.

licable, when the next drop in prices comes, to work certain deposits which, if rationally treated, would yield a constant supply of ore.

To understand the prominent position which India has **Comparison with** now taken amongst the manganese-ore **foreign production.** producing countries of the world, it is only necessary to refer to the following table showing the last reported production or exports of the principal producers.

TABLE 4.

Principal sources of Manganese-ore, and latest reported productions.

Country.	Year.	Production.	Country.	Year.	Production.
Russia (Exports) ¹ ...	1905	388,231	France ⁴ ...	1903	11,417
Brazil (Exports) ¹ ...	1905	262,416	Austria ⁵ ...	1904	10,189 (<i>m</i>)
India ² ...	1905	247,462	Turkey (Exports) ¹ ...	1905	8,164
Cuba ³ ...	1904	33,152 (<i>m</i>)	Chili (Exports) ¹ ...	1904	6,337
Spain (Exports) ¹ ...	1905	30,507	Greece (Exports) ¹ ...	1905	4,645
United Kingdom ⁶ ...	1905	14,352	Japan (Exports) ¹ ...	1905	3,944
Hungary ⁴ ...	1903	12,490 (<i>m</i>)	Borneo ⁵ ...	...	...

Manganiferous iron-ore is produced in important quantity by the four countries shown in table 5.

¹ Figures compiled and kindly supplied by Messrs. Macqueen Bros., London.

² From figures obtained from various sources. Probably an under-estimate.

³ "The Mineral Industry," 1904.

⁴ "The Production of Manganese Ores in 1904," by J. Birkinbine, U.S. Geol.

Surv.

⁵ Apparently soon to become an important producer of manganese-ore.

⁶ *The Mining Journal*, March 3, 1906, p. 287.

(*m*) Metric tons; otherwise in long tons.

TABLE 5.

Principal sources of Manganiferous Iron-ore and latest reported productions.

Country.	Year.	Production.
		Tons.
United States ¹	1904	383,246
Greece (Exports) ²	1904	239,635 (<i>m</i>)
Germany ²	1904	52,886 (<i>m</i>)
Belgium ²	1903	6,100 (<i>m</i>)

2.—MINING METHODS.

From the point of view of extraction of ore, the Indian manganese-ore deposits can be divided into two groups, namely:—

General description.

- (a) those which form small hills ranging in height from 50 or 100 up to 250, 300, or even more, feet above the surrounding country; and
- (b) those of which the highest points are—or rather *were*—either but a few feet above the plains or else just on a level with them.

¹ "The Production of Manganese Ores in 1904," by J. Birkinbine, U.S. Geol. Surv.

² "The Mineral Industry," 1904.

(*m*) Metric tons; otherwise in long tons.

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Photo by L. L. Fermor.]

FIG. 11.—Drilling Holes for Blasting the Manganese-ore.—Kándri.

Working-face in level 2 of *Kándri* quarry. Except for a little of the country—possibly a metamorphosed grey-wacké—seen in the bottom right-hand corner, all the rock visible is merchantable manganese-ore. The well-marked slickensiding with cross-jointing divides the ore into large columnar prisms dipping at about 28° to E 25° S. The men are engaged in drilling holes for blasting, after which large prismatic blocks of ore can be easily prized out with crow-bars. (18-1-04.)

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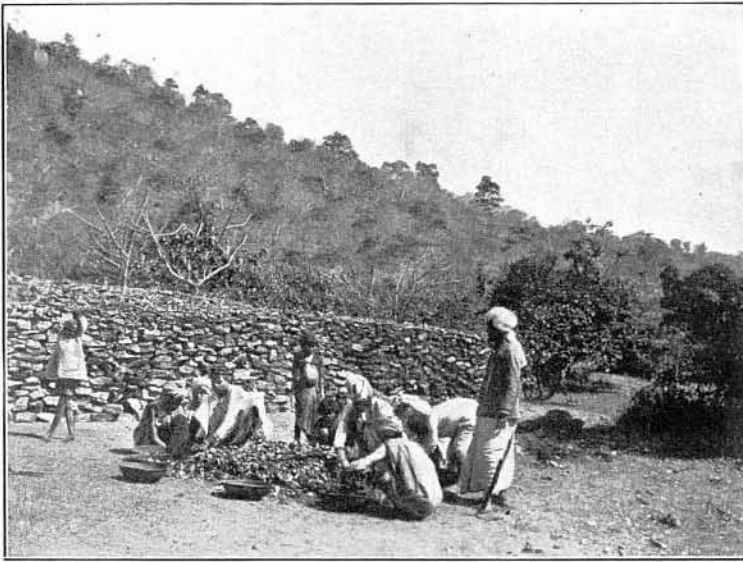


Photo by L. L. Fermor.]

FIG. 12.—Sampling Manganese-ore at Mansar.

The ore was taken from holes selected at regular intervals in the stack of ore shown, broken up by cobbing-hammers and then reduced by coning and rejecting alternate sextants of the spread-out cone. This operation was repeated until the sample had been reduced to the required bulk. The coolies are engaged in rejecting alternate sextants (28-1-04.)

In the former category may be placed the Jhábua deposit and many of those of the Central Provinces such as Kándri (see Fig. 10); while in the latter may be placed those of Madras and the remainder of those of the Central Provinces such as Kodur (Figs. 13 and 14), and Kodegáon (Fig. 9) respectively. In either case the excavations can only be described as quarries. Moreover, owing to the ease with which a large quantity of high-grade ore can be won, the methods of 'mining' employed are usually very crude. Thus ore has often been recklessly extracted to meet present demands and contracts without any regard either to geological considerations or to the future working of the deposit. This has frequently resulted in the subsequent discovery, either that the waste or *mati* has been dumped on to the hidden extension of the ore-body, or that so much dead-work will be necessary before the miner can work at a slightly increased depth, that it becomes a matter of doubt if the deposit can any longer be profitably exploited; such want of foresight and reckless working leads, of course, to a grievous waste of the country's mineral resources.

The only difference introduced by the situation of the deposit is that when working on a hill large quantities of ore can often be won for many years before quarrying down to the level of the surrounding plains. Consequently, there are no drainage troubles, and, as has been done at two 'mines,' Kándri (Fig. 10) and Mansar, the labour of transporting the ore can be greatly facilitated by the erection of aerial ropeways and inclined planes. On the other hand, in the case of an open quarry commenced at the level of the plains, as soon as a depth of 20 to 40 feet is reached, water troubles begin, so that extensive pumping is required, as at Kodur (Fig. 13); and eventually a depth is reached at which it becomes a matter of great difficulty to *quarry* the ore. It is

then that proper *mining* operations become necessary; but it is more than doubtful if true manganese-mining can pay in India as long as there are so many deposits of manganese-ore in the world, the mineral wealth of which is to be extracted by the simple methods usually employed.

In both classes of quarries nearly all work is done by hand. When in very hard, compact masses, the ore is first hand-drilled (Fig. 11) and then blasted. Otherwise it is simply prized out with crowbars, advantage being taken of the divisional planes of the ore-body when such are present. The huge blocks thus detached are broken up with heavy sledge-hammers and then, with but few exceptions, carried down the hill, or up out of the quarry, as the case may be, on the heads of women and children. At quite a number of quarries light rails have been put down to facilitate the disposal of both manganese-ore and waste. The ore is, if necessary, cleaned by women, children and old men, with small cobbing-hammers and finally piled into rectangular stacks ready for measurement. Where a chemist is employed, the stacks are usually sampled (Fig. 12) and assayed separately, and the ore then carted or trammed—usually the former—to the railway station, where the products of different quarries are often mixed or blended so as to yield a cargo of a certain standard (Fig. 15).

As a further result of the abundance of easily-won ore, there seems to be but little desire to scientifically ascertain the structure, and consequently the future prospects, of the deposits; and yet a few inexpensive cross-cuts at regular intervals would often yield a world of information. Instead of this, it is customary, in the case of open quarries in the ground, simply to follow an ore-body along its strike and to remove the over-burden of alluvium or soil as required, without any knowledge of what is to be expected next.

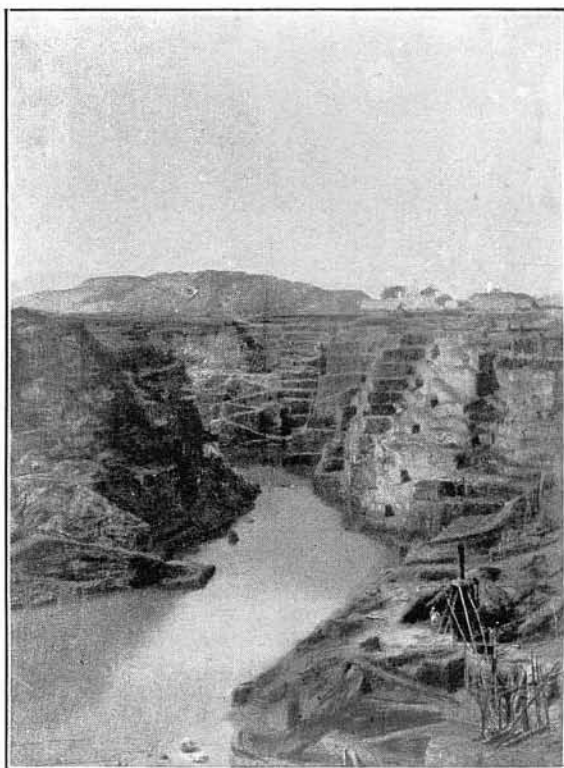


Photo by L. L. Fermor.]

FIG. 13.—General view from E.N.E. of the Manganese-ore Quarry, Kodur.—
Vizagapatam District, Madras.

The mound seen in the background is a waste-dump or *mati*-heap. The pumping-engines in the lower right-hand corner are for pumping out the water which accumulates in the pit during the rains, and when this has been accomplished, keeping down the constant influx of subterranean water. The step-like walls of the pit are necessary on account of the very soft rock—lithomarge, ochre and wad—of which they are composed.

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Photo by L. L. Fermor.]

FIG. 14.—East End of Kodur Quarry.

The tunnels shown were made in an abortive attempt to 'mine' the ore-body by following it into the lithomarge. But owing to the soft character of the latter, the galleries could not be properly supported and it has been found necessary to quarry away both ore and country. The banded and streaked character of the country (lithomarge of different colours with wad and ochres) is seen at several points such as A, A, A. The ore and waste is carried out of the pit on the heads of coolies. (4-1-05.)

As a favourable contrast to these strictures on the methods of working, one or two deposits deserve especial mention. In the first place the working of Kándri—a hill 250 feet high—may be extolled as a model of how such a deposit should be developed. The ore-deposit, which forms a sort of backbone to the hill, is attacked by a series of levels at different heights, exposing both the ore-body and the country. As these are removed, the waste is conveyed by trucks on tram-lines and dumped over the end of the level remote from the working-face, so that the levels are constantly being extended away from the ore-body, the rails keeping pace with this growth. By means of a system of two aerial ropeways, an inclined plane and some zig-zag tramways, the labour of transport is greatly reduced. A general view of the workings is shown in Fig. 10.

The Bálághát deposit, also, is being well developed and has the advantage of an inclined haulage plane by which the ore is let down in trucks some 200 feet to a shoot for delivering ore into railway waggons on a small 2-mile branch line connecting up with Bálághát Ry. Stn., B.N.R.

Finally, as the best example of the way to develop a deposit in a scientific fashion with a series of cross-cuts at intervals, enabling a rough estimate of ore-reserves to be formed, and serving also as passages for tram-lines, it is necessary to mention the Kájlidongri mine, Jhábua State, where the ore-deposit forms a long low mound rising some 60 to 70 feet above the *nálds* on either side (see Fig. 7).

3.—ECONOMIC CONSIDERATIONS.

Both in Jhábua State, where the population is mainly Bhil, and in the Central Provinces where the inhabitants are chiefly Gonds and Hindus, labour is rather scarce and difficult to obtain. Consequently it is frequently imported. In the former case, Gujerátis from Ahmadabád, and in the latter, coolies from other districts of the Central Provinces, such as Raipur, have been tried. The best labour is undoubtedly that of Vizagapatam, where the Telugu-speaking natives accept smaller wages and seem to work considerably harder than the aboriginal people of Central India and the Central Provinces. The wages for the quarrymen range in different areas from two to four annas a day, and for women and children from one to two annas. The beneficial effect of manganese-mining on the native population was very noticeable during the last famine in the Central Provinces, when the natives round Rámtek, finding constant employment and wages in the neighbouring manganese-mines, to a large extent escaped from the worst effects of the famine. The following table¹ shows the daily² number of workers—men, women and children—employed in the manganese-quarries from 1895 to 1904.

¹ Compiled from the Annual Reports of the Inspector of Mines.

² In most cases the *average* daily number.

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Photo by L. L. Fernald.]

FIG. 15.—Unloading Manganese-ore from Buffalo-carts at Garividi Ry. Stn., E.C.R., Vizagapatam District.

A hill of scapolitic gneiss in the distance. (6-1-05.)

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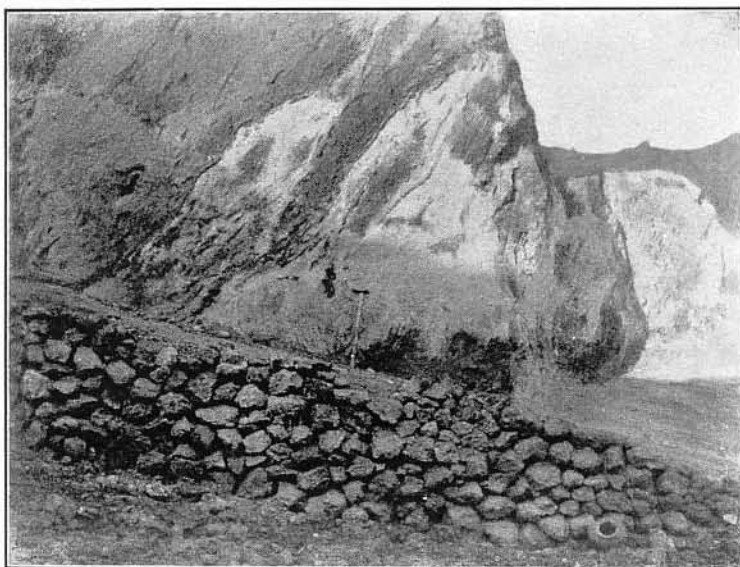


Photo by L. L. Fermor.]

FIG. 16.—Manganese-ore (black) forming by Replacement of Quartz-Felspar-Rock (white) at Garbhám.—Vizagapatam District, Madras.

Just to the left of the sledge-hammer is a nodule of manganese-ore right in the quartz-felspar rock. (23-12-04.)

TABLE 6.

*Daily number of workers employed on the Manganese-quarries
from 1895 to 1904.*

Year ending.	Bombay.	Central Provinces.	Madras.	Total.
30th June 1895	600 to 1,100	600 to 1,100
30th June 1896	1,200	1,200
31st December 1897	2,750	2,750
31st December 1898	3,530	3,530
31st December 1899	4,780	4,780
31st December 1900	4,242	4,242
31st December 1901	1,460	2,770	4,230
31st December 1902	2,081	3,966	6,047
31st December 1903	4,003	2,939	6,942
31st December 1904 ...	125	2,010	1,980	4,115
31st December 1905 ...	48	2,566	2,508	5,122

The chief items of expenditure incurred by the time the manganese-ore has reached a European or American port are those of freight, and these may be divided into :—

(1) the cost of carting or tramping to the railway station, which rises as high as Rs. 3 or Rs. 4 per ton in cases of carting over long distances—20 miles and upwards—but is usually much less and often, where tram-lines have been laid down, only a matter of annas ;

¹ To this is to be added 876, the number of workers at the Kájlidongri mine, making a total of 5,998 for 1905.

(2) the cost of railing the ore to the sea-ports, which on the scale of $\frac{1}{10}$ th pie per maund per mile, works out as follows:—

	Rs.	As.	P.
Meghnagar (Central India) to Bombay (361 miles)	5	2	1
Nágpur to Calcutta (520 miles).	7	6	1
Nágpur to Bombay (701 miles)	9	15	3
Garividi to Vizagapatam (56 miles)	0	12	9

(3) the cost of shipping from one of the above ports to Europe or America; this usually amounts to from 15 to 17 shillings per ton.

The remaining items of expenditure are cost of extraction, rent, establishment charges, depreciation of plant, royalties, cost of handling the ore at railway stations and ports, port dues, and agency and sampling charges at the port of destination. But these, even taken all together, are small compared with the total freight charges.

Taking the average manganese contents of the ores as 50%, it is seen that freight is also being paid on the remaining 50% of oxygen, silicon, iron, etc., which are either not wanted or else are not usually paid for. It is obvious that a great saving could be effected by the manufacture in India of the ferro-manganese and spiegel-eisen into which a very large proportion of these manganese-ores are converted. It will probably only need another slump in prices, a little worse than that of 1904, to either close down the majority of the manganese-quarries or to compel the owners to manufacture ferro-manganese locally, either for export as such or for use in the country when steel manufacture commences on a serious scale.

There are indications also that the cost of freight under (1) will, in many cases, be reduced in the future by the con-

struction of more tramways, and that many deposits, such as those of the Chhindwára district, Central Provinces, at present unworkable on account of their distance from the railway, will be connected up to the railway system of the country.

The prices per ton of manganese-ore obtained at the port of destination are subject to great variation according to the price per unit of manganese. The following table (No. 7) and the diagram

Prices and Valuation.

TABLE 7.

Variation in the Price of Manganese-ore c.i.f. at United Kingdom Ports.

Date.	First-grade ore.	Second-grade ore.	Third-grade ore.
	50 per cent. Mn. and upwards.	47-50 per cent. Mn.	40-47 per cent. Mn.
	<i>Pence per unit.</i>	<i>Pence per unit.</i>	<i>Pence per unit.</i>
January 1890	18-20	16-17	14-15
July 1890	16-18	14-15	12-13
January 1891	15-17	12-14	12-14
July 1891	15-16	12-15	10-12
January 1892	14-16	12-14	9-12
July 1892	14½-15	13½-14	9-12
January 1893	14½-15	13½-14	9-12
July 1893	14-14½	11-13	9-11
January 1894	11½-12	9½-11	8-10
July 1894	10½-11½	9½-10½	8-10

Date.	First-grade ore.		Second-grade ore.		Third-grade ore.	
	50 per cent. Mn. and upwards.		47-50 per cent. Mn.		40-47 per cent. Mn.	
	<i>Pence per unit.</i>		<i>Pence per unit.</i>		<i>Pence per unit.</i>	
January 1895	10½-11½	9-10	8-9	
July 1895	10-11	9-10	7½-9	
January 1896	11-13	10-12	9-11	
July 1896	11-13	10-12	9-11	
January 1897	11-13½	10-12	8-11	
July 1897	9½-13	9-12	7½-10½	
January 1898	9-12	8½-11	7½-10½	
July 1898	9-12	8½-11	7½-10½	
January 1899	10-12½	9-11	7½-10½	
July 1899	12-14	10½-11½	8-10	
January 1900	13-15	12-13	10-12	
July 1900	13½-15	11½-12½	10-12	
January 1901	12-14	11-12	11-12	
July 1901	10½-11	9-10	-8	
January 1902	9½-10½	9-9½	8-9	
July 1902	9½-10½	9-9½	8-9	
January 1903	10-10½	8½-9	7½-8½	
July 1903	10-10½	8-9	7½-8½	
January 1904	9-9½	8-9	6-8	
July 1904	9-9½	8-9	6-8	
January 1905	8¾-9¼	7½-8½	6-8	
July 1905	9-10	8-9	6-8	
January 1906	11-12	9-10½	7-9	
May 1906	14-15	10-12	8-10	

(Fig. 17) show the fluctuations in the price per unit of manganese-ore of different grades since 1890, as quoted by the Mining Journal. The connection between the ruling prices and the output of manganese-ore has already been considered (page 104).

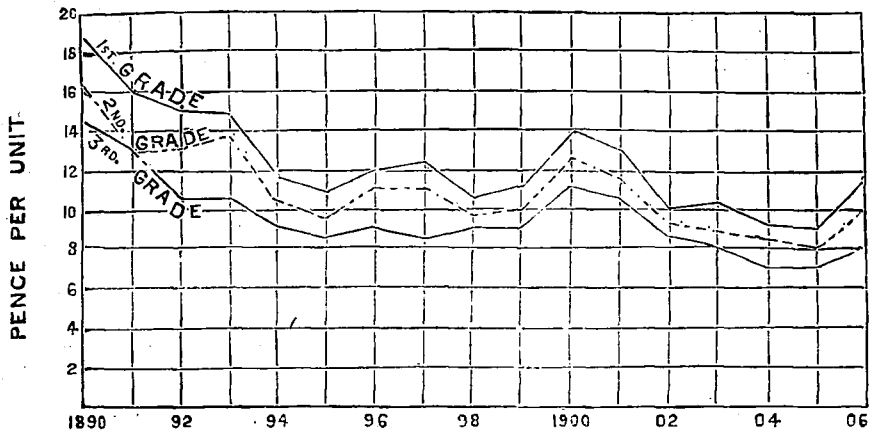


FIG. 17.—Variation in the Prices of Manganese-ore at United Kingdom Ports since 1890.

The prices given above are for the three grades into which manganese-ores are classified:—

1st grade	...	...	50% Mn and upwards.
2nd do.	...	...	47-50% Mn.
3rd do.	...	...	40-47% Mn.

The average price paid at the end of 1904 for ore carrying 50% and upwards of metallic manganese being taken as 9 pence, then a 52% ore would be valued at $\frac{52 \times 9}{18} = 39$ shillings per ton.

For steel-making, manganese-ore should not contain more than 0·15 % of phosphorus or 10 % of silica, and on this basis ores delivered at the works of the Carnegie Steel Company at Pittsburg or Bessemer, Pa., U.S.A., are subject to acceptance or refusal at the buyer's option if containing less than 40 % of manganese or either phosphorus or silica in excess of the above limits. The Illinois Steel Co., according to a schedule based on ores containing not more than 8 % of silica and 0·1 % of phosphorus, make deductions from the price of the ore of 15c. per ton for each 1 % of silica in excess of 8 % and of 1c. per unit of manganese for each 0·02 % of phosphorus in excess of 0·1 %.¹ An additional price per unit of iron present in the ore is sometimes paid by the steel-makers, but the practice as regards this varies. It will be noticed (see analyses on page 82) that the phosphorus contents of both the Central India and Madras ores exceed the above limits considerably. These ores, however, are sent to the Continent for mixing with iron-ores in the blast-furnace burden to produce a pig, low in sulphur but high in manganese and phosphorus, for use in the basic Bessemer process.

The following table shows the destination of the manganese-ore exported from India from the year 1895-96 to 1904-1905.²

Distribution of the exported Indian manganese-ore.

¹ Quite recently the schedule for both companies has been altered to a basis of 8 % of silica and 0·25 % phosphorus, deductions being made for every 1 % of silica and 0·2 % of phosphorus above these limits. Ore containing less than 40 % of manganese, or more than 12 % of silica, or 0·27 % phosphorus, is subject to acceptance or refusal at the buyer's option.

² Annual statements of Trade and Navigation of British India.

TABLE 8.

*Distribution of exported Indian Manganese-ore for the years
1895-96 to 1904-05.*

Year.	United Kingdom.	Belgium.	France.	Germany.	Holland.	Egypt.	United States.	Other countries.	Total re- corded ex- port for the year.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.		Tons.
1895-1896	19,358	...	...	...	...	...	3,400	...	22,758
1896-1897	42,630	...	...	...	...	...	4,700	...	47,330
1897-1898	54,279	...	...	...	...	...	24,550	...	78,829
1898-1899	51,931	...	...	...	...	...	10,944	...	62,875
1899-1900	63,175	5,350	...	...	8,350	...	18,350	...	95,225
1900-1901	86,269	13,300	5,850	...	16,500	3,400	5,350	...	130,669
1901-1902	65,150	...	...	11,300	...	15,000	41,720	...	133,170
1902-1903	95,540	1,000	...	10,734	5,050	...	42,950	Italy-1 cwt. Japan-1 cwt.	155,274
1903-1904	110,506	19,288	2,050	9,985	3,500	...	35,860	..	181,189
1904-1905	64,705	25,015	10,800	...	5,300	10,750	64,375	...	180,945
Total sent to each country.	653,543	63,953	18,700	32,019	38,700	29,150	252,199	...	1,088,264

The three great steel-producing countries—England, United States and Germany—take a large proportion of our manganese-ore; the exports to Holland and Belgium shown in the above table were in part for transmission to Germany, whilst the consignments sent to Egypt were booked to Port Said to await delivery to ports further west.

4.—USES OF MANGANESE.

It has already been shown how widespread is the element manganese in nature. The following list¹ will give

¹ Based on that of Penrose, An. Rep. of the Geol. Surv. of Arkansas for 1890; Vol. I. "Manganese: its Uses, Ores and Deposits," p. 7.

some idea of the numerous uses to which it has been applied by man :—

- | | | | |
|--|-----|--|---|
| I.—Alloys | ... | { Ferro-manganese.
Spiegel-eisen.
Manganese-steel. | } Alloys of manganese and iron. |
| | | { Ferro-silicon. | } Alloy of manganese, iron and silicon. |
| | | { Manganese-bronze | } Alloy of manganese and copper with or without iron. |
| | | { Silver-bronze. | } Alloy of manganese, aluminium, zinc and copper. |
| | | { Alloys of manganese with aluminium, zinc, tin, lead, magnesium, etc. | |
| II.—Oxidizers | { | Manufacture of chlorine, bromine and bleaching powder.
Decolourizer of glass.
Dryer in varnishes and paints.
Leclanché's cell.
Preparation of oxygen on a small scale.
Manufacture of disinfectants (manganates and permanganates). | |
| III.—Colouring materials | { | Calico-printing and dyeing
Colouring glass, pottery, tiles and bricks. | |
| | | { Paints | ... { Green.
Violet. |
| IV.—Various lesser chemical, manufacturing and medical purposes.
V.—Occasionally as a gem when in the form of rhodonite or spessarite.
VI.—Occasionally as a flux in smelting silver-ores. | | | |

In all probability at least 90 % of the world's output of **Spiegel-eisen and ferro-manganese.** manganese-ore is consumed in the manufacture of iron and steel. The manganese-ore is first smelted in blast-furnaces into either spiegel-eisen or ferro-manganese. *Spiegel-eisen* is an alloy of iron

and manganese containing usually 5 to 27 % of manganese and 4 to 5 % of carbon. *Ferro-manganese* is a similar alloy containing from 27 to 86 % of manganese and about 6 to 7 % of carbon. These two alloys are largely used in the Bessemer and open-hearth processes for making both acid and basic mild steel, and are in all cases added at the end of the process, and this chiefly for two purposes:—

- (1) to remove any oxygen taken up by the bath of molten metal.
- (2) to supply the requisite amount of carbon to the steel.

A small proportion of the manganese remains in the metal, but by far the larger proportion of it passes into the slag.

Manganese-steel contains a considerably higher percentage of manganese than is present in all ordinary steels. With amounts of manganese between 7 and 20 % an extraordinarily strong, tough, and practically non-magnetic metal is the result. These alloys were investigated by Hadfield, and the well-known Hadfield Era steel contains about 13 % of manganese and 1 % of carbon; although, on account of its extreme hardness, very difficult to work, it is now being extensively used for many purposes where combined hardness, toughness and consequent great power to resist grinding wear are required. Among such applications may be mentioned all kinds of mining machinery, especially that used for milling and crushing, such as jaws of rock-breakers, crusher-heads, rolls, etc., and also for mine-car wheels and dredging machinery. Manganese-steel has also been used for tools such as axes and razors. It is interesting to notice in this latter connection that at Ghogra in the Jabalpur district, Central Provinces, a manganiferous iron-ore is still being smelted in small native iron-furnaces, and

Kheri.

that the product is a rather hard steely iron known as *kheri*, in great demand in the surrounding country where the *lohars* weld it on to ordinary locally made soft iron to form the edges of axes and scythes, the striking faces of hammers and the heads of anvils. Though it has not yet been analytically tested, yet this *kheri* perhaps owes its superior hardness over the local soft iron to a certain percentage of manganese derived from the ore.¹

Turning now to the other uses of manganese we find that, from very ancient times, there has probably been a small consumption of manganese-ore by the natives of India for colouring glasses and enamels, it being possible to impart green, violet, brown and black tints by the use of this substance. Messrs. Burn and Co., moreover, use a small amount of manganese-ore from the Jabalpur district for imparting dark brown and black body colours of earthenware, such as tiles, and for producing chocolate and black glazes on ordinary biscuit-ware, such as tea-pots. I am not aware that manganese-ore has been used in India for any other of the purposes enumerated, but considering the large consumption of bleaching powder in paper mills, one would think it would be worth while manufacturing this substance in India.

Moreover, I would draw attention to the fact that many of the manganese-ore deposits of the Central Provinces contain considerable quantities of rhodonite, at present being consigned to the dump-heap; but that the rhodonite from other parts of the world, especially the Ural Mountains, is often used as an ornamental stone. It would be difficult to find a more beautiful ornamental stone than the pink rhodonite with delicate veins of

Glass, enamel, pottery.
Ornamental applications.

¹ Mallet, *Rec. G. S. I.* XVI, p. 101, (1883).

black manganese-oxide, such as occurs at Mánegáon, Nágpur district, or than the rhodonite studded with orange spessartite, such as is found at Chárgáon, Nágpur district, and in the Chhindwára district. In the United States, moreover, spessartite when found clear and transparent is sometimes turned to account as a very beautiful gem-stone of orange and red colours.¹ I have not seen any Indian spessartite, except very small crystals, sufficiently clear for this purpose, but it is as well to keep it in view.

5.—FUTURE PROSPECTS OF THE MANGANESE-ORE MINING INDUSTRY IN INDIA.

It will be noticed that no estimate has been given in this paper of the quantities of manganese-ore available in the deposits. This is not, however, because there is any need for pessimism on the subject. It is true that in the Vizagapatam district it is becoming more difficult to quarry the ore owing to the increasing depth at which it has to be worked; but in the Central Provinces there are several deposits concerning which it is easy to form estimates indicating the presence of millions of tons of ore easy to win. Owing, however, to the insufficient work which has been carried out in the way of cross-cuts and bore-holes, as already mentioned (page 108), these estimates are more or less of guesses, but there can be no doubt whatever of their general correctness in pointing to the presence in the Central Provinces of vast quantities of easily quarried manganese-ore.

Nevertheless, at the present rate of output, with the rejection of all but first-grade ore, there does not seem to be much doubt that within a comparatively small period of time, which one might guess at 30 to 50 years, the majority of the

¹ Kunz, "Gems and Precious Stones of North America," p. 79, (1890).

deposits at present known will have been worked out as far as the application of present methods of extraction are concerned. There will then still be left, both in the ground and on the dump-heaps, millions of tons of second and third-grade ores and vast quantities of manganese-silicate rock consisting largely of spessartite and rhodonite, and often carrying as much as 30 or 40 per cent of manganese.

This might be considered as rather an alarming prospect but for two counterbalancing considerations. One is that the deposits of manganese-oxide ores throughout the world are strictly limited in quantity, so that within a comparatively short time, which might be guessed as 100 years as a maximum, unless several fresh areas containing such deposits be discovered, all the easily won ores will have been removed from the earth. Long before that time, however, the price per unit of manganese will rise sufficiently to enable the lower grade ores of the world, if not smelted on the spot, to be transported profitably to the smelting centres. Long before that time also the increasing difficulty and cost of getting manganese-oxide ores will probably compel metallurgists to turn their attention to the silicate-ores.

The second consideration is that long before that time, and let us hope in only a few years from the present, ferro-manganese smelting will probably have been introduced into India, thus rendering valuable the low-grade ores at present rejected, and so to a certain extent conserving the higher grade ores.

We are thus able to picture that within a comparatively small number of years, the easily-won high-grade Indian oxide-ores will become quite limited in quantity, and that, with the rising prices due to a similar state of affairs in other parts of the world, the manganese-miners will then find it just as profitable to work the lower grade ores and sort over

their dump-heaps as the tin-miners recently have in Cornwall to search their waste heaps for wolfram. Following this, will come the time when spessartite and rhodonite will be regarded as ores and just as eagerly sought as 50 per cent. oxide-ores now are.

Keeping in view these three stages of manganese-mining—high-grade oxide-ores, low-grade oxide-ores, and silicate-ores, being each in turn the substance sought—it can confidently be predicted that manganese-“quarrying,” and later on perhaps, manganese-“mining,” has in India a long and prosperous future with possibly, however, bad times at intervals.

Nevertheless, it would not be out of place to draw attention to the desirability of stocking the low-grade and silicate-ores separately from the country-rock of quartzite, mica-schist, gneiss or lithomarge, with which they are often indiscriminately mixed when consigned to the waste-heaps.

Another aspect of the question has already been noticed by Mr. Holland,¹ namely, the heavy loss which India, to all intents and purposes, suffers by exporting the raw ore. The average price that Indian manganese-ore fetches at its destination is about Rs. 30 per ton, and of this only about one-half goes to India, being divided between railways, carters, miners and land-owners. The remaining Rs. 15 goes mainly in freight charges. The manganese then comes back to India in the form of the steel it has helped to make, and India pays both the foreign manufacturer's profits and the cost of return carriage. A recent quotation in the *Engineering and Mining Journal*² gives the price per ton of 80% ferro-manganese as \$75 to \$175, equivalent to about Rs. 265 to Rs. 546. It becomes obvious from this how desirable it is to

¹ *Rec. Geol. Surv. Ind.*, XXXII, p. 62, (1905).

² Jan 27th, 1906, p. 212.

manufacture ferro-manganese in India and thus keep in the country a proportion of the profits involved in its manufacture, even if the larger part of the ferro-manganese so made has still to be exported. The time must come, however, when the manufacture of iron and steel will be one of India's most important industries, and then, of course, India will consume a large proportion of its own ferro-manganese.

IV.—CONCLUSION.

It has been my aim in this paper to put before the members of the Institute a general account of the manganese-ore deposits of India and of the industry which depends upon them. Under present conditions it would be difficult to arouse more interest in them from the economic aspect, but I hope that this paper will help to a better understanding of the structure and nature of the deposits with a consequent more scientific method of working them, and that it will arouse interest in them from the mineralogical point of view by drawing attention to the fact that the Indian manganese-ore deposits are wonderful repositories of rare and often exceedingly beautiful minerals. Mr. F. R. Mallet,¹ in 1887, remarked on the paucity of well-crystallized and beautiful minerals which have been found in India, and he rightly ascribed this to the small amount of mining which had been seriously attempted. Now that manganese-mining has become so important, a magnificent opportunity presents itself for the collection of such minerals, and manganese-miners would be conferring an obligation on science if they would interest themselves in the matter, and keep on the look-out for the occasional fine crystallizations which must occur even in the most solid-looking ore-bodies, and which the geologist, during

¹ *Manual of Geology of India*, IV, Mineralogy, Preface, pp. v & vi.

a brief visit to the mine, would only light upon by the happiest chance.

Finally, I should like to take this opportunity of expressing my thanks to the managers of the manganese-mines for the courtesy with which they gave me every facility for examining their properties.

V.—GEOGRAPHICAL INDEX.

	Latitude, N.	Longitude, E.
A		
Aitemvalsa	18° 23'	83° 39'
Alesur	21° 43'	78° 57'
Arjoni	21° 46'	79° 57'
Asalpáni	21° 30'	79° 43'
Avagudem	18° 21'	83° 36'
B		
Bálághát	21° 48'	80° 15'
Bansinghi	21° 22'	79° 12'
Beldongri	21° 20'	79° 21'
Bhandárbori	21° 24'	79° 31'
Bichua	21° 42'	78° 55'
Boiráni	19° 35'	84° 49'
Bondapilli	18° 22'	83° 39'
Borda	21° 27'	79° 42'
C		
Cháibása	22° 33'	85° 52'
Chándadoh	21° 42'	79° 44'
Chárgáon	21° 24'	79° 21'
Chikhla I	21° 33'	79° 49'
Chikhla II	21° 41'	79° 58'
Chik-Vadvati	15° 10'	75° 47'
Chintelavalsa	18° 25'	83° 17'

				Latitude, N.	Longitude, E.
D					
Deváda	...	...	...	18° 15'	83° 38'
Devi	...	...	...	21° 42'	78° 57'
Dudhára	...	...	...	21° 30'	78° 57'
Dumri Kalán	...	...	...	21° 20'	79° 18'
Duvvám	...	...	...	18° 15'	83° 36'
G					
Gadasám	...	...	...	18° 21'	83° 28'
Gaimukh	...	...	...	21° 45'	78° 54'
Garbhám	...	...	...	18° 22'	83° 31'
Garividi	...	...	...	18° 17'	83° 36'
Garraráju Chipurupalli (Garuja)	...	...	...	18° 24'	83° 41'
Ghogara (Pench River)	...	...	...	21° 23'	79° 14'
Ghogra	...	...	...	23° 20'	80° 15'
Ghondi	...	...	...	21° 56'	80° 29'
Ghoti	...	...	...	21° 38'	78° 56'
Gosalpur	...	...	...	23° 24'	80° 7'
Gotnandi	...	...	...	18° 23'	83° 39'
Govindapuram	...	...	...	18° 15'	83° 45'
Gowári Warhona	...	...	...	21° 32'	78° 53'
Guguldoho	...	...	...	21° 26'	79° 29'
Gumgáon	...	...	...	21° 24'	79° 3'
H					
Hatora	...	...	...	21° 37'	79° 52'
I					
Itakerlapilli	...	...	...	18° 15'	83° 40'
J					
Jám ...	...	...	...	21° 45'	79° 57'
Jámbughoda	...	...	...	22° 22'	73° 48'
Jamrapáni	...	...	...	21° 40'	79° 47'
Jothvád	...	...	...	22° 23'	73° 47'
Junapáni	...	...	...	21° 29'	79° 23'
Junawáni	...	...	...	21° 29'	79° 21'

	Latitude, N.	Longitude, E.
K		
Kácharwáhi	21° 20'	79° 27'
Kachi Dhána	21° 43'	78° 51'
Kájlidongri	22° 57'	74° 31'
Kándri	21° 25'	79° 20'
Katangjheri I (Govt. Forest)	21° 51'	80° 0'
Katangjheri II (Málguzári)	21° 50'	80° 1'
Khandála	21° 20'	79° 29'
Kodegáon	21° 25'	79° 1'
Kodur	18° 16'	83° 37'
Kosumbah	21° 38'	79° 42'
Kotakarra	18° 22'	83° 33'
Kurmura	21° 32'	79° 44'
L		
Lakhanwára	21° 45'	78° 54'
Lohdongri	21° 20'	79° 25'
M		
Mahábaleshvar	17° 56'	73° 43'
Mándri	21° 25'	79° 28'
Mándvi Bir	21° 29'	79° 17'
Mánegáon	21° 26'	79° 28'
Mansar	21° 24'	79° 20'
Miragpur	21° 38'	79° 54'
Mohugáon	21° 27'	79° 5'
Mohugáon Ghát	21° 37'	79° 54'
Mulagám	18° 14'	83° 41'
N		
Nagardhan	21° 20'	79° 23'
Nandapuri	21° 20'	79° 23'
Nándgáon	21° 49'	79° 58'
Nándgondi	21° 30'	79° 7'
Nautan-Bárapur	19° 36'	85° 6'

				Latitude, N.	Longitude, E.
P					
Pachára	...	...	...	21° 27'	79° 50'
Páli	...	...	...	21° 26'	79° 15'
Páandarwáni	...	...	...	21° 37'	79° 54'
Pársioni	...	...	...	21° 22'	79° 13'
Parsoda	...	...	...	21° 23'	79° 22'
Pench River—see Ghogara	...	...	...	...	...
Perapi	...	...	...	18° 16'	83° 41'
Perumáli	...	...	...	18° 26'	83° 38'
Ponia	...	...	...	21° 43'	79° 49'
R					
Rámabhadrapuram	...	...	...	18° 30'	83° 20'
Rámandrug	...	...	...	15° 7'	76° 32'
Rambhápur	...	...	...	22° 55'	74° 32'
Rámdongri	...	...	...	21° 25'	79° 5'
Ramrama	...	...	...	21° 51'	79° 59'
Rámtek	...	...	...	21° 24'	79° 23'
Risára (Reechara)	...	...	...	21° 28'	79° 3'
S					
Sálebaddi	...	...	...	21° 40'	79° 56'
Sandanandapuram	...	...	...	18° 14'	83° 37'
Sátak	...	...	...	21° 20'	79° 20'
Sihora	...	...	...	23° 29'	80° 10'
Sitagondi	...	...	...	21° 29'	79° 8'
Sitapár	...	...	...	21° 44'	78° 56'
Sitapathur	...	...	...	21° 42'	79° 44'
Sitasáongi	...	...	...	21° 31'	79° 48'
Sivarám	...	...	...	18° 16'	83° 39'
Sivarájpur	...	...	...	22° 25'	73° 40'
Sonegáon	...	...	...	21° 41'	79° 50'
Sukli	...	...	...	21° 40'	79° 44'
T					
Táduru	...	...	...	18° 25'	83° 13'
Talevadi	...	...	...	15° 33'	74° 24'
Thirori	...	...	...	21° 41'	79° 47'
Thontaum	...	...	...	18° 39'	83° 11'

	Latitude, N.	Longitude, E.
U		
Ukua	21° 58'	80° 32'
W		
Wagora	21° 36'	78° 52'
Waregáon	21° 20'	79° 28'
Y		
Yeruli	18° 2'	73° 54'

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NOTES, ABSTRACTS, AND REVIEWS.

NEW MANGANESE-ORE OCCURRENCES IN BRITISH NORTH BORNEO (Neue Manganerz-Vorkommen in Britisch Nord-Borneo), by Dr. Arthur Dieseldorff. *Zeitschrift für prak. Geol.* XIV, pp. 10, 11, (1906).

This short note gives a brief account of the numerous deposits of manganese-ore recently discovered in the Marudu Bay area of British North Borneo, Taritipan being the centre. The ore-bodies crop out over a large area of country, and quarrying is being vigorously prosecuted at several localities. The ore-bodies are of large size and are accompanied by jaspery or flinty siliceous schists (Kiesel-schiefern). The chief ore is psilomelane, but in some places, such as Kakukuja, pyrolusite is also found.

All the ores (except the pyrolusite which contains as much as 8 per cent. BaO) are free from copper, arsenic, nickel and baryta, and contain only very small quantities of phosphorus and sulphur.

The following analyses show the quality of the ores: —

	Average sam- ple of ship car- goes (I).	Sample from selected ship car- goes (II).
Manganese	49-51 %	51-53 %
Silica	15	8-10
Phosphorus	0'03	0'04
Sulphur	0'035	0'04

It is stated that the average ore exported from the different deposits consists of 65 per cent. of No. I, and 35 per cent. of No. II, and that the average of all the ores is 50'4 per cent. Mn and 14'6 per cent. SiO₂. The ore being very hard psilomelane it absorbs, even in the rains, only up to 6 per cent. of water. Iron is under 2 per cent.

It will be noticed that though these ores are superior to the Indian manganese-ores as regards phosphorus contents, yet they are extremely high in silica, so high in fact that the average ore lies outside the limits of silica (8-10 per cent.) usually permitted. It is said, however, that the ores are being actively exported, and it is estimated that the least quantity which will be exported for the next 25 years will be 50,000 tons per annum.

The possibility of manufacturing ferro-manganese on the spot is also considered. It appears that an excellent limestone is available as a flux but that wood-charcoal would have to be used as fuel.

L. L. FERMOR.

ON THE MANUFACTURE OF FERRO-MANGANESE (Über die Herstellung von Ferromangan) by Director Oscar Simmersbach, Düsseldorf. *Berg- und Hüttenmännische Rundschau*, I, 305-308 (1905).

The literature on the subject of the manufacture of ferro-manganese is very scanty, and hence this paper is to be welcomed as it contains in a comparatively small space most of the essential facts bearing on this question.

According to the author, spiegel-eisen contains up to 27% manganese, at which point the alloys completely lose the magnetic properties hitherto possessed. With 27% and upwards of manganese, the alloys are known as ferro-manganese. Dr. Prieger of Bonn first showed it to be possible to alloy manganese with iron in high proportions and thus laid the scientific foundations of the manufacture of ferro-manganese. The work of W. Henderson of Glasgow on this subject appears to have been later than that of Prieger.

The author states that the ores best suited for the manufacture of ferro-manganese in the blast-furnace are rhodochrosite and manganite, but that these ores, as well as hausmannite and psilomelane¹ are not

¹ He gives the formula Mn_2O_8 for psilomelane. This is, of course, incorrect as this mineral is usually, and probably correctly, regarded as a manganate corresponding to the hypothetical acid H_4MnO_5 ; psilomelane, moreover, is one of the commonest and most widespread of the ores of manganese, at least as far as India and Borneo are concerned. Considering also the important position as a producer of manganese-ore which India now takes, braunite ($3Mn_2O_8 \cdot MnSiO_8$), which together with psilomelane constitutes the main bulk of the ore exported, certainly requires mention.—L. L. F.

so abundant and widespread in nature as pyrolusite and wad. The valuation of manganese-ores depends largely on the percentage of phosphorus present and to a less degree on the percentage of silica; for both these constituents influence the quality of the ferro-manganese. Spiegel-eisen with 20% Mn should not contain more than 0.1% P, and for every 10% Mn above this the phosphorus contents should not increase by more than 0.02%, so that ferro-manganese with 80% Mn should not contain more than $0.1 + (6 \times 0.02) = 0.22\%$ P. The standard for silicon is spiegel-eisen containing 20% Mn and 1% silicon with a permissible increase of 0.1% Si for every 10% increase in the manganese; hence 80% ferro-manganese should not contain more than $1.0 + (6 \times 0.1) = 1.6\%$ silicon.

Those oxides of manganese, such as pyrolusite and psilomelane, which contain a high proportion of oxygen, are changed whilst still at the comparatively low temperature of the upper part of the blast-furnace into lower states of oxidation ($3\text{MnO}_2 = \text{Mn}_3\text{O}_4 + \text{O}_2$), the oxygen set free uniting with the carbon of the fuel. At lower levels the following change takes place:— $\text{Mn}_3\text{O}_4 + \text{CO} = 3\text{MnO} + \text{CO}_2$. Both these reactions take place with considerable development of heat so that the walls and throat of the furnace are quickly destroyed. This also leads to an increased consumption of fuel, and the question therefore arises as to whether in smelting ores rich in oxygen it would not be desirable to previously roast them by means of the gases which can be drawn off at the mouth of the furnace. Lower down still the manganese-protioxide is reduced by the solid carbon in accordance with the equation $\text{MnO} + \text{C} = \text{Mn} + \text{CO}$; but also partly according to the equation $\text{MnO} + \text{CO} = \text{Mn} + \text{CO}_2$.

In manufacturing ferro-manganese the consumption of fuel is much greater than in smelting cast-iron. The chief reason for this is the necessity of maintaining a higher temperature owing to the fact that the heat of the oxidation of manganese referred to the unit of oxygen is greater than that of iron, so that more heat is consumed in breaking down the oxides of manganese. In general, while 100% of coke is required for the reduction of iron, 250% is required for the reduction of manganese.

The charge must be calculated so that the oxygen of the earthy bases, lime, magnesia and alumina, is at least as great as the oxygen

of the silica. The chief point seems to be that the slag must be sufficiently basic, as otherwise not only is too little manganese reduced but there is then a risk of producing, at the high temperatures prevailing, a silicate of ferro-manganese instead of ferro-manganese itself. Good ferro-manganese slags contain 7 to 10% Mn according to the composition of the ferro-manganese, but up to 18 or 20% Mn is not uncommonly found in the slag when easily fusible ores are smelted.

The profiles of three blast-furnaces, from South Russia, Austria and Germany, respectively, are given, together with a table of analyses of ferro-manganese slags produced from them.

In addition to the loss of manganese by passage into the slag, volatilization of manganese also takes place in the blast-furnace, because the volatilization temperature of manganese lies below that of the production of ferro-manganese. The loss due to this cause ranges up to 17% and over of the original manganese-contents. This manganese becomes oxidized in the throat of the furnace and the brown smoke thus produced quickly destroys the conduits, as it forms readily fusible silicates with the stone-work. Considerable losses of manganese also take place on tapping, owing partly to volatilization from the molten bath of metal, and partly to oxidation by the air; but by shutting off the blast these losses can be much reduced.

A table of analyses of ferro-manganese from various localities shows the following limits:—

	Per cent.
Manganese	... 76 to 85
Iron	... 14 to 6
Phosphorus	... 0·20 to 0·36
Carbon	... 5·98 to 7·20
Silicon	... 0·50 to 1·47

A table of the cost of production in South Russia of 80% ferro-manganese and 20% spiegel-eisen gives the total cost per ton as 183·18 and 95·97 marks respectively, corresponding roughly to £9-3-0 and £4-16-0 respectively.

Owing to the decomposition which ferro-manganese suffers when exposed to the weather, it is necessary to store it under cover.

L. L. FERMOR.

THE DEMAND FOR MANGANESE-ORES (Die Deckung des Bedarfs an Manganerzen), by W. Venator. *Stahl u. Eisen*, January 15, and February 1, 1906; 17 pages. Translated in the Mining Journal, LXXIX, 178, 179, 243, 277, (1906).

This paper gives an account of the various factors which create a demand for manganese-ores, of their valuation, and of their production and consumption by various countries. Taking an average of 1 per cent. of metallic manganese as necessary per ton of steel produced, the author is able to account for the annual consumption of about 900,000 tons of 50 per cent. ore (900,000 to 1,000,000 tons of ore of various grades is the world's annual output).

The method of working manganese-ore deposits is almost universally primitive, but the author mentions some experiments which have been conducted in Germany and which indicate the possibility of concentrating low grade siliceous ores so as to produce a higher grade less siliceous material. The advantages of a briquetting process, could a satisfactory one be devised, for treating such friable and wet ores as those of Brazil, are also discussed.

A short account is given, taking more the form of a list, of the manganese-ore localities of each producing country. There are several mistakes in the orthography of the names of Indian localities. Two statements to which exception must be taken are (1) that Russia, at the present time, possesses nearly a monopoly of high-grade manganese-ores, and (2) that the Russian deposits are the thickest known. In the first place India and Brazil together produce annually from 300,000 to 500,000 tons of manganese-ore (mostly high-grade), while the annual Russian production averages about 500,000 tons, but has probably been during the last year (1905) below the total of Indian and Brazilian production. In the second place the ores of the Caucasus, from which by far the largest proportion of the Russian manganese-ores come, occur in a bed which averages only some 5 to 8 feet in thickness, while many of the Brazilian and Indian deposits are from 50 to 100, or even more, feet thick.

L. L. FERMOR.



MAP OF THE CHIEF OCCURRENCES
of
MANGANESE-ORE IN INDIA.

INDEX TO NUMBERS.

(Manganese-ore deposits of proved economic value are found in the Districts and States underlined.)

BENGAL

- 1. Kálahandi
- 2. Singhbhum

BOMBAY

- 3. Belgaum and North Kanara
- 4. Bijapur
- 5. Dhárwár (Sangli State)
- 6. Nárukot and Panch Maháls
- 7. Sátára

BURMA

- 8. Mergui

CENTRAL INDIA

- 9. Dhár and Indore
- 10. Gwalior
- 11. Jhábuá

CENTRAL PROVINCES

- 12. Bálághát
- 13. Bhandára
- 14. Chhindwára
- 15. Hoshangábád
- 16. Jabalpur
- 17. Nágpur
- 18. Wun

HAIDARABAD

- 19. Bidar

MADRAS

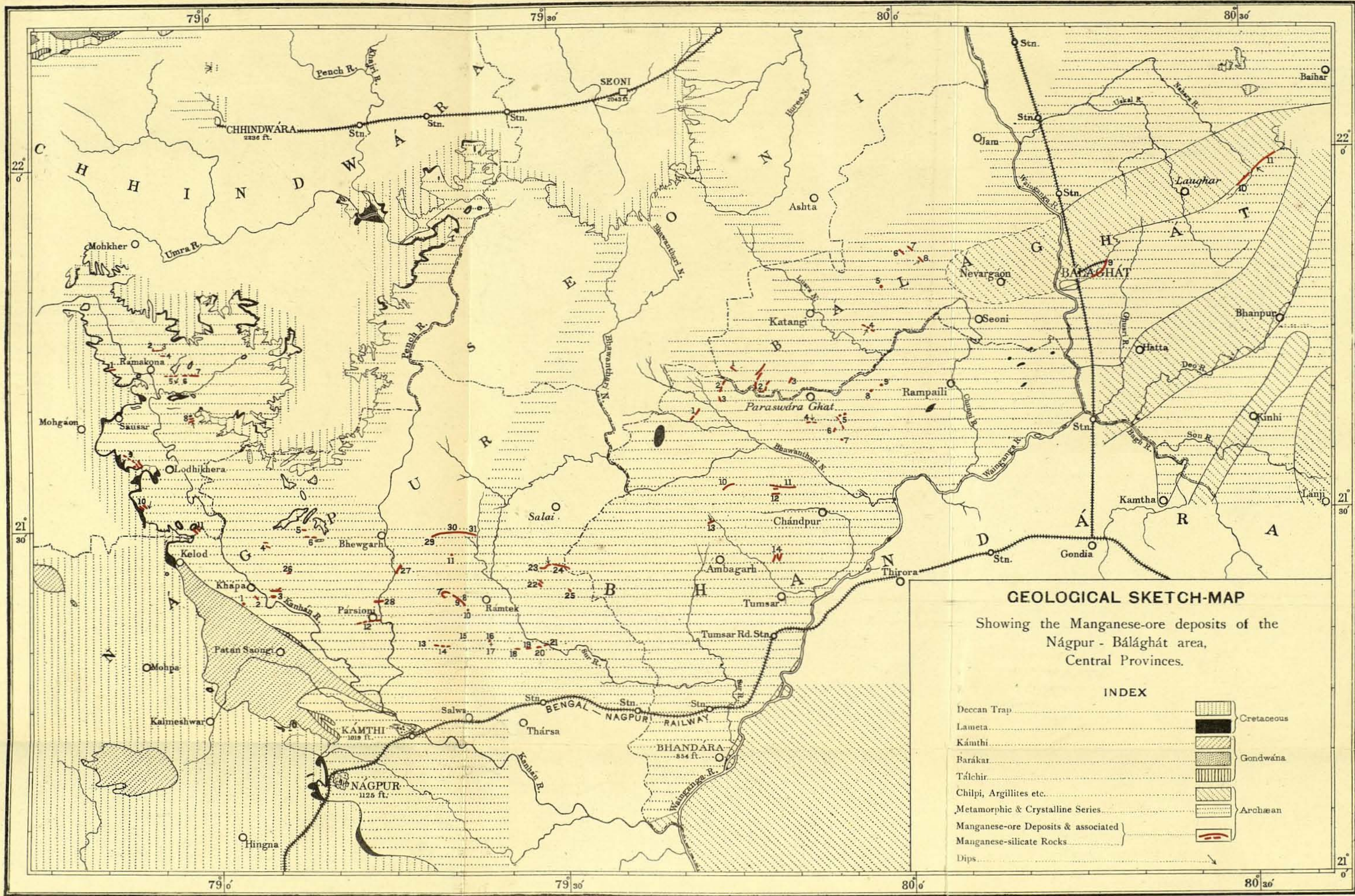
- 20. Bellary (Sandur Hills)
- 21. Ganjám
- 22. Vizagapatam

MYSORE

- 23. Chitaldrug
- 24. Shimoga

REFERENCE.

- British India - counties under British administration, Pink Tint
 - Native states, Yellow
 - Border tribes under British control, Burnt Sienna
 - Afghanistan, Light Blue
 - Foreign possessions in India, Green
 - Railways opened, Green
 - Rivers, Blue
- The numerals denote the height above sea level in feet.
This Map is intended only to exhibit the principal places, chief rivers &c. in India.



GEOLOGICAL SKETCH-MAP

Showing the Manganese-ore deposits of the Nagpur - Balaghát area, Central Provinces.

INDEX	
Deccan Trap	
Lameta	
Kamthi	
Barakar	
Talchir	
Chilpi, Argillites etc.	
Metamorphic & Crystalline Series	
Manganese-ore Deposits & associated	
Manganese-silicate Rocks	
Dips	

Index to Numbers.

Balaghát district.

1. Chandadoh
2. Thirori, Ponia and Jámrapáni
3. Songaon
4. Arjoni and Jám
5. Nandgaon
6. Ramrama
7. Katangjheri I (Govt. Forest)
8. Katangjheri II (Málguzári)
9. Balaghát
10. Ghondi
11. Ukua

Bhandára district.

1. Kosumbah
2. Sitapathur
3. Sukli
4. Hatora
5. Miragpur
6. Mohugaon Ghát
7. Pandarwáni
8. Sálebaddi
9. Chikhlia II
10. Kurmura
11. Chikhlia I
12. Sitasáongi
13. Asalpáni
14. Pachára

Chhindwára district.

1. Kachi Dhana
2. Lakhawára
3. Gaimukh
4. Sitapar
5. Bichua
6. Alesur
7. Devi
8. Ghoti
9. Wagora
10. Gowári Warhona
11. Dudhára

Nágpur district.

1. Kodegaon
2. Gumgaon
3. Rámdongri
4. Risára (Reechara)
5. Nándgondi
6. Sitagondi
7. Kándri
8. Mansar
9. Mansar Extension
10. Parsoda
11. Borda
12. Parsioni and Bansinghi
13. Dumri Kalán
14. Sátak
15. Beldongri
16. Nagardhan
17. Nandapur
18. Lohdongri
19. Kacharwahi
20. Waregaon
21. Khandáia
22. Mándri
23. Mánegaon
24. Guguldoh
25. Bhandárbori
26. Mohugaon
27. Páli
28. (Pench River) Ghogara
29. Mándvi Bir
30. Junawani
31. Junapáni

Geology compiled from the maps of W. T. Blandford, P. N. Bose, P. N. Datta, L. L. Fermor, E. J. Jones & Lala Kishen Singh.

Scale, 1 inch = 2 miles



MAP
OF A PORTION OF THE
VIZAGAPATAM DISTRICT
MADRAS PRESIDENCY
showing the
MANGANESE-ORE LOCALITIES.

Scale 1" = 4 Miles.

LEGEND.

Index to Manganese-ore Localities.
+ Indicates situation of deposit. When this is not known the village name is underlined in red.

1 Garividi	13 Gadasam
2 Kodur	14 Aragudem
3 Duvrām	15 Aitemvalsā
4 Devāda	16 Gotnandi
5 Sandanandapuram	17 Bondapilli
6 Sivaram	18 Gurrarāju Chipurupalli (Garuja)
7 Perapi	19 Perumāli
8 Itaklerapilli	20 Rāmabhadrapuram
9 Mulgām	21 Tāduru
10 Govindapuram	22 Chintelavalsā
11 Garbhām	23 Thonaum
12 Kotakarra (I & II)	

Geology.

The whole area of this map is occupied by Archean rocks well exposed in the Eastern Ghāts, the fringe of which appears at the western edge of the map, where they have been mapped as—

- (1) Gneissose Granite
- (2) Charnockite Series
- (3) Khondalite Series

The larger part of the area, however, is occupied by plains of which the geology is largely obscured by alluvium and where these three groups of rocks have not been separately mapped.