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The Ore Deposits of South Africa

J. P. Johnson


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THE ORE DEPOSITS OF SOUTH AFRICA

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OF

SOUTH AFRICA

WITH A CHAPTER ON

HINTS TO PROSPECTORS.

BY

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PART I.

BASE METALS.

WITH DIAGRAMS.

UNIV. OF CALIFORNIA

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PREFACE.

This little volume is intended to meet a demand among those technically connected with the mining industry, for a co-ordinated and condensed account of the ore-deposits at present known in South Africa.

It is also intended as a guide to the prospector. Only an elementary knowledge of geology and some mining experience are necessary in order to understand it. With these qualifications, it will materially assist him in his search for metalliferous mineral occurrences and, so far as simple ores are concerned, should enable him to form some idea of the possibilities of any he may find. Regarding complex ores he will, of course, need metallurgical advice in addition.

Throughout this book the stratigraphy of the country is ignored, the principles of ore deposition being independent of it. Moreover, it is already dealt with in Hatch and Corstorphine's "Geology of South Africa."

Unless otherwise stated the writer has seen the occurrences described.

P.O. Box 6231, Johannesburg,

August, 1908.

CONTENTS.

UNIV. OF CALIFORNIA

The Ore-Deposits of South Africa.

CHAPTER I.

INTRODUCTION.

An understanding of the genesis of an ore occurrence is essential before any exploitation of it is attempted, since it alone enables one to answer the all-important questions, whether it will continue in depth and whether its value will increase or decrease. Our knowledge of the processes of ore-formation is now sufficiently advanced to enable us, in the majority of cases, to answer these questions with confidence, though in other instances it is still impossible to do so.

Primary Ores.

The investigations of the last few years into the genesis of ore-occurrences have resulted in the almost universal acceptance of the theory that they have a magmatic origin, that the deep-seated magmas contain water and dissolved metals which, upon the ascent of the magma into a zone of lessening pressure, escape, penetrate the overlying rocks, and even reach the surface as thermal springs. The immediately resulting ore-occurrences are, in order of formation: (1) Segregations within the magma; (2) Impregnations at or near the point where the volatile substances left the magma; and (3) Deposits by waters condensed at greater distances from the magma on their way to the surface. No better illustration of this theory could be instanced than the great Bushveld laccolith, which is probably unique among plutonic masses in the extent to which its structure has been revealed by denudation, and in the slight amount of distortion to which it has been subjected by subsequent earth movements. This igneous complex consists of a dominant granite core which passes along its circumference, through syenites and gabbrodiorites, into pyroxenite containing ore-bodies of the first class, namely, segregations of titaniferous and chromiferous iron oxides. The rock masses overlying the central granite portion, as well as the upper, and earlier solidified, part of the granite itself, are impregnated with tin and copper minerals, constituting ores

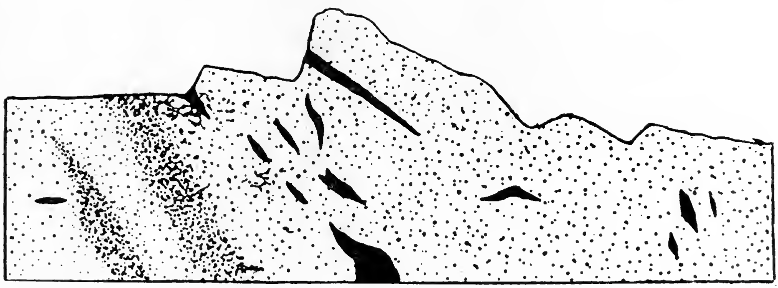

Fig. 1.

Section at Blaafjeld, Scandinavia (after Vogt).

Syenite with 2 per cent. of ilmenite, containing basic pegmatite with 40 per cent. of ilmenite and segregated masses of ilmenite.

of the second class. While the copper-lead-zinc veins in the surrounding strata afford excellent examples of the third class. The kinship between a metalliferous segregation in pyroxenite and a metalliferous deposit in a fissure is, no doubt, very distant, but it is nevertheless real.

In considering the sequence of these ore-occurrences it should be borne in mind that the exterior of the intruded magma will solidify before the interior; that the molten portion of the latter, with its periodically escaping residual water and dissolved metals, would recede more and more from the surface as the whole gradually cooled; and that what was in the earlier stages a zone of gaseous impregnation might at a later period become a zone of deposition from solution. Further, it is probable that at different levels in the superincumbent rocks penetrated by the ascending vapours and solutions, different chemical reactions take place according to the pressure and also to the constitution of the rock, involving the precipitation of different groups of minerals.

Secondary Ores.

At, and within a comparatively short distance of, the surface, ore-bodies are subject to the disintegrating influences of the atmosphere and of descending surface waters. This disintegration, which is chiefly due to the presence of oxidizable minerals, usually extends more or less completely down to the level of the ground water, and its intensity is dependent on the amount of these oxidizable minerals present. In most ore-bodies the original valuable minerals are sulphides which are all readily oxidized, and many of these are converted into soluble compounds, which are carried down by the descending waters and reprecipitated at the bottom of the porous zone of oxidation, in the form of carbonates, chlorides, oxides and silicates. In some cases the compounds in solution, on reaching the unoxidized zone, are reconverted into sulphides.

Thus three zones are frequently encountered in opening up such ore-bodies, namely, (A) A barren zone of disintegrated rock, termed the gossan, (B) A high-grade layer of oxidized or sulphide ore, known as the zone of secondary enrichment, and, (C) The main body of primary low-grade sulphide ore. Fig. 2 shows an actual example.

In other ore-bodies where the valuable mineral—cassiterite for instance—is insoluble, no such chemical concentration takes place, but rich detrital accumulations may result from their denudation.

Most of the metalliferous occurrences being mined at the present day are secondary ore-bodies of the above kinds.

SULPHIDE SEGREGATIONS.

In view of the fact of magmatic differentiation there is nothing astonishing in finding segregations of the oxides, ilmenite, magnetite and chromite, since all are common constituents of basic igneous rocks. Now in Scandinavia, Canada and South Africa, sulphide aggregates (pyrrhotite, pyrite and chalcopyrite, containing a small percentage of nickel and cobalt) have been discovered with such strikingly similar associations, that

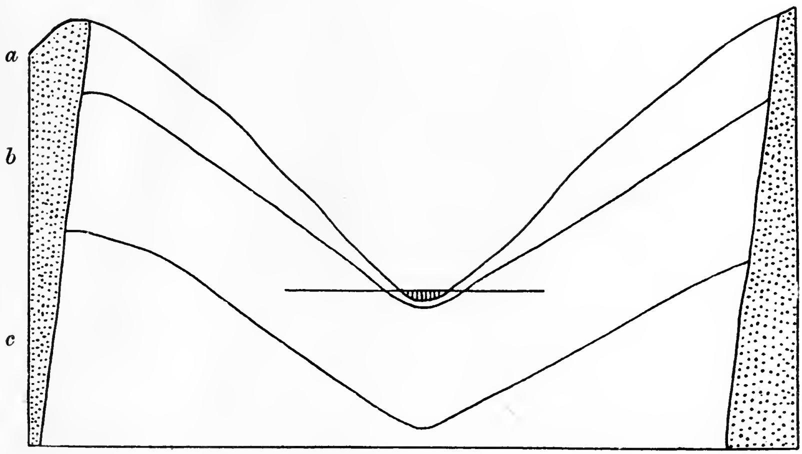

FIG. 2.

Section through Utah and Boston Copper Mines, Bingham, U.S. (after Ingalls).

(*c*) Quartz-porphyry dyke impregnated with primary sulphide (chalcopyrite). Copper contents about 1 per cent. (*a*) Leached zone stained brown with iron oxide and mottled with green and blue copper carbonates. Unpayable. Thickness 30 to 150 feet. (*b*) Zone of secondary sulphide (chalcocite) enrichment. Copper contents 2 per cent. Thickness 100 to 300 feet.

they are regarded by many, with good reason, as magmatic segregations also. Others, however, maintain that they are merely ordinary impregnations. There seems to be one point of difference, namely, that while the oxide segregations, though usually near the margin, are always distinctly within the igneous rock, the sulphide aggregates, on the other hand, are right at the contact of country and intrusive rock, while this last is much altered there. The feature certainly lends some support to the argument of the objectors. In both cases the igneous rock is similar and a gradual passage can be seen between it and the metalliferous masses. The absence of undoubted original sulphides in igneous rocks presents another obstacle to this interpretation of the occurrence. Oxidizing conditions were obviously the rule in fused magmas. At the same time there may have been exceptions. It has been suggested, for instance, that the escape of sulphurous gas through the still molten rock along the contact converted the contained metals into sulphides. The remarkable identity of the occurrences in such widely separated parts of the world, taken in conjunction with their undeniable resemblance to undoubted oxide segregations, makes it highly probable that they are, indeed, segregations also.

Dyke Segregations and Pegmatites.

Dykes are offshoots from deep-seated magmas that have welled up fault planes during periods of disturbance. They are similar in composition to the portion of the magma from which they come. Magmatic segregations of metalliferous minerals are hence sometimes met with in the form of dykes.

Those very coarse-grained aggregates of quartz and felspar, or of felspar and pyroxene, with or without accessory minerals, known as pegmatites, which are so frequently met with in granite and gabbrodiorite areas, and which are chiefly noted as the source of commercial mica, have long been the subject of speculation. Though generally regarded as modifications of the main body, it is maintained by many that pegmatites, whether in the form of irregular masses or of vein-like dykes, are not differentiations of the magma, but have crystallized under high pressure from the superheated aqueous solutions that remained after its solidification. In other words, that they occupy a position intermediate between igneous masses and mineral veins.

If the conception of the genesis of ore occurrences previously described be correct, it is clear that many substances are more soluble in such residual waters than in the magma itself. Examples of these are tourmaline, fluorite, cassiterite and allied minerals. Now many acid pegmatites actually contain these minerals while their very coarse crystallization is such as would result from the slow cooling necessary if the above contention be correct.

In view of the similarity in constitution between granites and certain mineral veins, for instance, those of the Rooi Berg, this is certainly an attractive theory. The possibility of the tourmaline, fluorite, cassiterite, etc., in the pegmatites, being of a secondary nature, however, must not be overlooked. In fact, a great deal of work will have to be done before this explanation of the origin of pegmatites can be proved or disproved.

Classification of Ore-Occurrences.

A number of classifications of ore-occurrences have been proposed in recent years, but none of them can be said to be satisfactory from the point of view of the mining man. In the following classification the writer has attempted to remedy this defect. The object of classification in scientific and technical subjects is to enable the student to more readily obtain a firm grasp of his subject and of the interrelation of its several branches. In the imparting of knowledge it may be compared to organization (as opposed to muddle) in other branches of human endeavour. Such a classification must present a broad view unobscured by minor details, and is necessarily, to a certain extent, arbitrary. Actually no hard and fast line can be drawn between the different types of ore-occurrences. In such a classification, too, the main sub-divisions at least should be of a kind that would be recognizable in the field without recourse to laboratory investigations. The following is the proposed scheme in brief; the relation of the sub-divisions to the terms Reef and Lode being indicated also. By ore is meant any metalliferous mineral or rock of present or prospective economic value.

	A. Magmatic Segregations.	
	B. Irregular Impregnations.	
Reefs. {	C. Regular Impregnations of a Stratum.	} Lodes.
	D. ,, ,, of a Dyke.	
	E. ,, ,, along contact with a Dyke.	
	F. ,, ,, of the walls of a fissure.	
	G. Regular Crustifications* (in fissures)	
	H. Irregular Crustifications (in pockets).	
	I. Detrital Accumulations.	

The great majority of ore-occurrences fall under the heading of Impregnations and Crustifications. Impregnations are those in which the metalliferous and accompanying minerals are disseminated throughout a pre-existing rock. Crustifications are those in which the metalliferous and accompanying ("gangue") minerals occupy cavities in a rock.

Classification of Igneous Rocks.

The classification of the igneous rocks here employed is that recommended for field use by the authors of the *Quantitative Classification of the Igneous Rocks.* It is a classification based entirely on megascopic characters which, however, in a broad way reflect their chemico-mineralogical constitution. The mining geologist seldom requires to define an igneous rock more exactly, and when it is necessary to do so, a description of its microscopical characters will serve the purpose.

* Crustifications — "Fillings of Fissures and other Cavities," Posepny, *Genesis of Ore Deposits*, p. 12 (1905).

The primary sub-division is into phanerites and aphanites. Phanerites are those whose constituent minerals are sufficiently large to be visible to the unaided eye. Aphanites are those whose constituent minerals are too small to be visible to the naked eye. Those rocks, intermediate between phanerites and aphanites, which consist of megascopic minerals distributed throughout a groundmass of microscopic constituents are termed porphyries.

The major bulk of the phanerites may be referred to three groups, (1) *Granite*, those composed essentially of quartz and felspar, (2) *Syenite*, those composed essentially of felspar and amphiboles or pyroxenes, the former being dominant, and (3) *Gabbrodiorite*, those composed essentially of pyroxene or amphibole and felspar, the latter being subordinate.

In addition to these are the rare felspar-less phanerites which are named according to the dominant constituent mineral, *e.g.*, Amphibolite, Pyroxenite, Peridotite, etc.

Since quartz and the felspars are light in colour and the pyroxenes and amphiboles are dark, it is usually possible to infer the end of the scale to which an aphanite inclines. Hence, this factor—whether acid or basic—should be mentioned.

The porphyries are further qualified as Quartz-porphyries, Felspar-porphyries, Pyroxene-porphyries, etc., according to the mineral megascopically developed.

CHAPTER II.

Titaniferous and Chromiferous Iron Oxides.

BUSHVELD LACCOLITH (A).*

Segregations of titaniferous and chromiferous iron oxides occur in the basic margin of the Bushveld laccolith, and although not at present of commercial value as iron ores, since both the titanium and chromium, in the quantities in which they occur in these ore-bodies, cause serious difficulties in their treatment,† must yet sooner or later come within the range of payability, either through scientific investigation overcoming the difficulties or through the exhaustion of the more easily treated ores.

Enormous bodies of the titaniferous ore have been located all along the periphery of the laccolith. The mineral is mainly magnetite, the titanium being present either as a chemical combination in place of some of the iron, or else as a mechanical mixture in the form of ilmenite or rutile.

The chromite bodies, though probably possessing an equally long distribution are not so large. They have been well studied along the southern and eastern margins of the laccolith by Hall and Humphrey, while, more recently, Schoch has also added to our knowledge of them. They are associated with very basic members of the marginal rocks, among which types rich in pyroxenes and poor in felspars are common. The ore occurs in fairly well defined sheets with a dip and strike

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* The letters in brackets indicate the position of the ore-occurrence in the scheme of classification. In this case for example (A) = Magmatic Segregation.

† Although both titanium and chromium impart desirable properties to steel when added in certain small proportions.

roughly parallel to that of the periphery of the laccolith. In thickness they range from five feet downwards, and usually maintain a fairly uniform width for some distance.

In its purest form the ore consists of a black lustrous fine-grained aggregate of chromite, which easily weathers to a friable rock and becomes readily disintegrated into a heavy dark-coloured sand. As the ore becomes less pure pyroxenes appear, and the gradual transition can be traced from black, heavy chromite-ore to less heavy and dark-coloured pyroxenite, containing scattered grains of chromite, and thence into gabbrodiorite.

A little platinum is associated with the chromite.

The southern belt stretches from north-west of the village of Rustenburg to the Crocodile River, a distance of about twenty-eight miles. The farms on which the chromite has been located are: Boschkopje, Boschfontein, the Rustenburg Commonage, Waterval, Arnoldstad, Kronendal, Rietfontein, Kaffirskraal, Dekroon, Brakspruit, Spruitfontein, Rooikopjes, and others. The eastern belt stretches north-westwards from the Steelpoort River, and chromite has been located on the following farms: Hendricksplaats, Mooihoek, Mondagshol, Twyfelaar, Zwartkopjes, Klipfontein, Mooijalijk, Brakfontein, Winterveld, and Jactslust.

When the proportion of chromium is high and that of iron low, this ore is much valued for its chromic oxide. To find a market it must contain not less than fifty per cent. Ore of that standard fetches about 65s. a ton, while better qualities command a premium. The laccolith occurrences hitherto discovered do not come up to the market requirements.

SELUKWE (A).

Mennell states that chromite bodies are found in several places along the great peridotite intrusion that runs from near Fort Impatene to the Zambesi, notably in the Hartley and Lomagundi districts. Mining is carried on in a hill of chromite at Selukwe. This occurrence is about a mile from the peridotite, but may be in an offshoot from it. The writer has not seen this ore-body. The following outputs have been registered :—In 1905, 276 tons; in 1906, 3,371 tons, and in 1907, 8,017 tons.

CHAPTER III.

NICKEL.

INSIZWA (A).

This nickel occurrence is of special interest in that it belongs to the class of magmatic *sulphide* segregations.

The Insizwa range is situated near Mount Ayliff. It is composed of a big gabbrodiorite laccolith intruded into a series of sandstones and shales. The igneous rock has been exposed by denudation all over the upper portion of the range, the sedimentary formation on which it rests constituting the lower slopes. The shales are much altered and indurated at the contact.

The mineral is pyrrhotite, with which is mixed a little chalcopyrite, and, in very subordinate quantity, pyrite. The nickel content averages about seven per cent. Traces of cobalt are also occasionally present.

The sulphides are disseminated throughout the marginal portion of the gabbrodiorite, and increase in quantity towards the contact where they form lenticular aggregates, and also slightly impregnate the wall rock.

This mode of occurrence of the ore is strictly homologous with that of the well known Scandinavian and Canadian bodies, while the comparative freshness of the igneous rock in this instance seems for the first time to place sulphide segregation beyond doubt.

The occurrence is at present only in the prospecting stage, but there can be no doubt that sooner or later it will become of economic importance.

CHAPTER IV.

Copper.

OOKIEP (A).

The Ookiep and neighbouring mines are situated in Little Namaqualand.

The writer has not seen them, the following account being derived from a paper* by Kuntz :—

The surrounding district is occupied by granite and associated schists. This formation is traversed by five parallel west and east lines of crush along which dykes of gabbrodiorite have risen. It is in these dykes that the copper occurs.

The dykes outcrop prominently. In some cases they are traceable for miles without break, but in others are in evidence only from point to point, with big gaps between.

The copper-bearing minerals, chiefly bornite and chalcopyrite, are disseminated in minute quantities throughout the whole of the gabbrodiorite, and in spots almost entirely replace it.

While the entire mass of the gabbrodiorite thus contains traces of copper and rich patches occur here and there throughout, it is only in a few places that it is of a payable nature. In these places the ore occurs in the form of very large and high-grade pockets.

Kuntz considers that these pockets have been formed at points where the dykes are intersected by later faults.

On the most southern line are situated the abandoned mines of Spektakel and Springbok, from which large quantities of

* J. Kuntz, Transactions Geological Society of South Africa, VII., p. 70-72 (1904).

high-grade ore were obtained, together with the less productive workings of Koperberg.

On the second line occur the mines of Nababeep, Ookiep, and Narap. A plan and section, reproduced herewith (fig. 3), of the Ookiep pocket is given by Kuntz in his paper. Its shape is oblong, with a peculiar prolongation along the cross break.

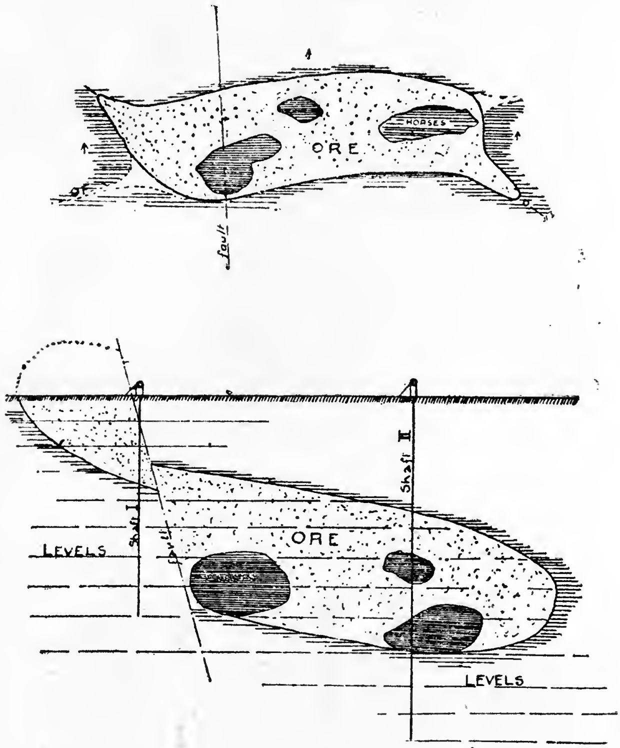

Fig. 3.

Plan and section of Ookiep Copper Mine (after Kuntz).

Its extent from west to east is nearly a thousand feet, its greatest width is about two hundred feet, and its greatest thickness (vertical) three hundred feet.

The Nababeep is a similar enormous ore-body, while Narap is only a small pocket and has been abandoned.

On the fourth line lies the Tweefontein mine, which is probably the most instructive to the geologist. Kuntz also gives a plan and section of this mine, while Ronaldson* has figured a further section, reproduced herewith (fig. 4), made at a later date. It consists of three pockets. Ore-bodies No.

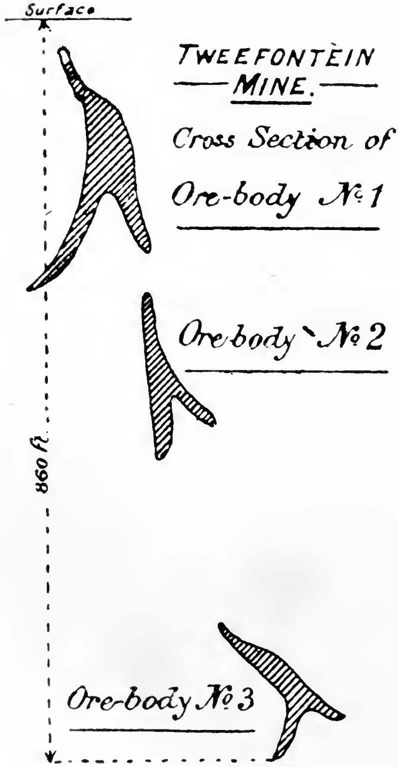

Fig. 4.

Section through Tweefontein Copper Mine (after Ronaldson).

1 and No. 2 are situated about 700 feet apart on the strike, both outcropping at the surface but at different elevations. Ore-body No. 3 immediately underlies No. 2. The dimensions of these pockets, in the order given, are :—Greatest

* J. H. Ronaldson, Trans. Geol. Soc. S. Africa, VIII., p. 165 (1905).

length, 540, 550, and 760 feet; greatest depth, 240, 225, 300; and greatest width, 75, 50, and 60 feet.

On the remaining two lines are a number of abandoned mines and prospects.

At the surface the copper sulphides are, of course, mainly changed to malachite and azurite, while the red and black oxides, cuprite and tenorite, and the green silicate, chrysocolla, as well as copper itself, occur in small quantity.

Kuntz considers the copper sulphide to be an original constituent of the dykes, in other words, that the dykes are intruded portions of a magmatic sulphide segregation, the payable pockets being secondary enrichments.

The following figures have been compiled* of the output of this field :—

From the opening of the mines in 1852 to the end of 1862 : Springbok, Spektakel, and Ookiep produced 18,999 long tons. From 1862 to 1882 (20 years) Ookiep produced 164,025, Spektakel 14,765, and Trial Mines 1,057. The average copper content of this ore was 29·5 per cent.

From the beginning of 1883 to the end of 1904 the production in long tons was :—

Ookiep	534,626,	averaging	20·20	per cent.	copper
Spektakel ...	19,636	,,	31·85	,,	,,
Springbok ...	332	,,	30·50	,,	,,
Nababeep ...	114,332	,,	6·16	,,	,,
Ookiep, E. ...	19,022	,,	5·02	,,	,,
Koperberg ...	6,087	,,	9·49	,,	,,
Narap	1,326	,,	13·05	,,	,,
Tweefontein ...	138,683	,,	25·40	,,	,,
Flat Mine ...	5,000	,,	20·00	,,	,,
Hester Maria ...	3,500	,,	20·00	,,	,,

As many of the above percentages of copper contents are those of the ore subsequent to concentration, it is impossible to

* T. Quentrall and J. H. Ronaldson, Report to Government, Capetown (1905).

arrive, approximately even, at the average value of the ore mined and raised, but much of it from Springbok, Spektakel, and Ookiep mines has been abnormally rich.

MESSINA (F).

The Messina copper belt is situated in the west angle between the Zand River and the south bank of the Limpopo. It is nearly twenty miles in length and extends in a north-easterly direction from the "farm" Oostenryk, through Papenbril, Vogelsang, Berkenrode (on which the Messina mine is located) and Uitenpas, to Artonvilla. It consists of a line of crush in the schistose granite country, impregnated with copper minerals and contains a number of well-defined fissures, the walls of which have been impregnated and here and there completely replaced by lenticular bodies of copper sulphide. The whole belt is riddled with old Kaffir workings which reach a depth of seventy feet and are situated on lenses of rich ore. They are probably the most extensive of their kind in South Africa, and many thousand tons of copper must have been extracted from them.

The Messina is the only mine so far opened up on this belt. Most of the development has been done on the two main lodes whose strike is indicated by the two chief lines of old workings shown in the accompanying plan (fig. 5). The northern of these lodes has been opened up for a length of 800 feet, and the southern for 500 feet, the maximum depth being 200 and 300 feet respectively. The accompanying longitudinal sections (fig. 6) through them, showing the bodies of rich ore (20 per cent. copper) so far encountered and stoped out, and those extracted at the surface by the old workers, well illustrate the mode of occurrence. The mineral encountered so far is almost entirely chalcocite, there being very little bornite or chalcopyrite and hardly any of the oxidation products (malachite, etc.) which, however, probably constituted the ore

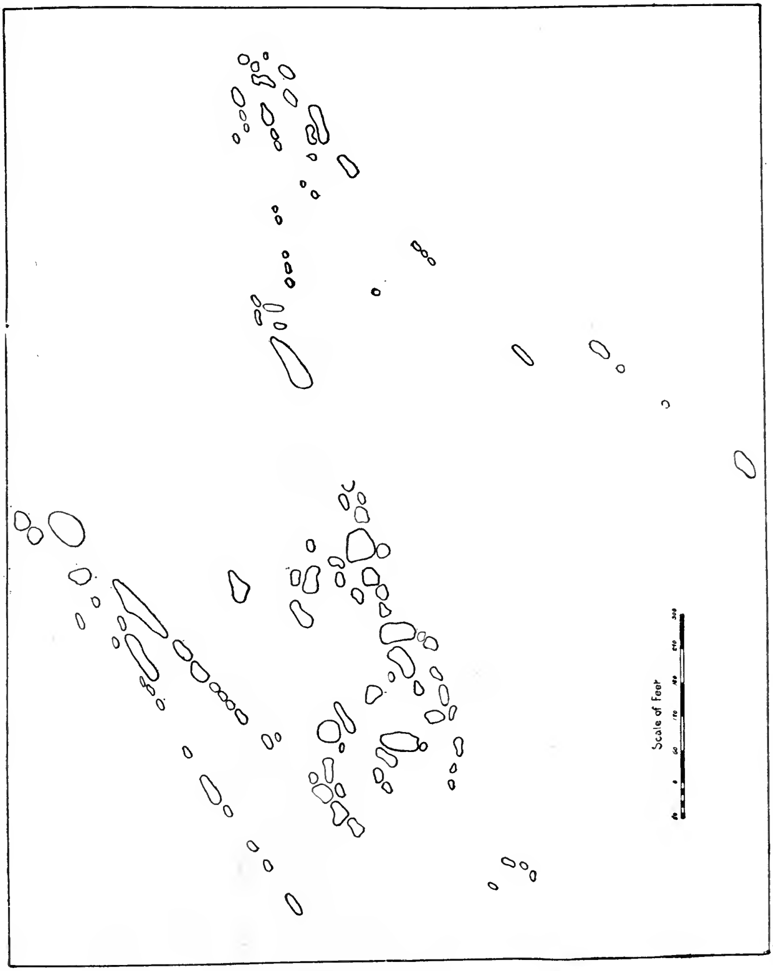

Fig. 5.

Plan of Old Workings at Messina Copper Mine (after Calderwood).

A few are not shown, being hidden by modern dumps.

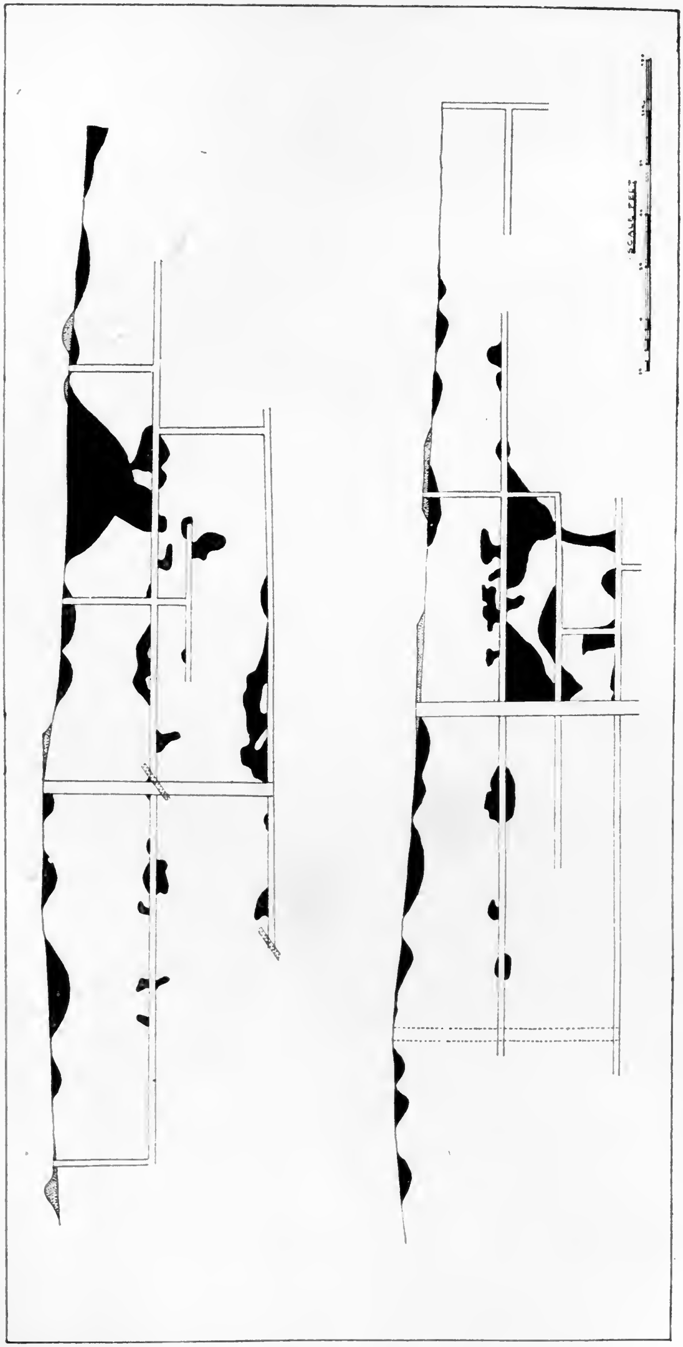

FIG. 6.
Longitudinal sections through North and South Main Lodes, Messina Copper Mine (after Calderwood).

extracted from the old workings. The richer ore contains a few ounces of silver to the ton and traces of gold.

The development has clearly not yet reached the bottom of the zone of secondary sulphide enrichment, which in this case extends practically to the surface.

The following amounts of picked ore containing 61 per cent. copper have been shipped :—In 1906, 585 tons; 1907, 1,242 tons; 1908, January-June inclusive, 370 tons.

SWAKOP-KUISEB (E).

A number of copper occurrences have been located in the schist country between the Swakop and Kuiseb Rivers. The writer has not visited them, but they have been well described in a paper* by Voit, from which the following notes have been extracted :—

The most extensive occurrences are those at the Hope, Gorap, and Matchless mines. All these are situated in close proximity to a belt of schistose amphibolite which strikes through the district in a north-easterly direction and which seems to be connected with the origin of the ore-bodies. Voit's paper is illustrated by plans and sections of these.

At the Gorap mine the copper occurrences are situated within a huge lenticule of mica-schist enclosed by the amphibolite. In this mica-schist is an interbedded string of quartzite lenticules with a length of strike of about three miles. It is in the hanging wall of these quartzite lenticules that the copper impregnations occur.

The ore is chalcopyrite and chalcocite, which give way at the surface to a reddish-brown mixture of cuprite and ironstone mottled here and there with the green and blue copper carbonates. Volborthite also occurs in yellow to green earthy masses.

At the Hope mine the copper occurrence is very similar. There are two parallel quartzite lenticules interbedded with

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* F. W. Voit, Trans. Geol. Soc. S. Africa, VII., p. 77-94 (1904).

the mica-schist. Between these are three zones, having a length of about 260 feet and a width of about one foot, impregnated with copper-ore.

At the Matchless mine, which is about 130 miles away from the Hope, two bands of amphibolite enclose a belt of mica-schist and schistose granite. In these schists is a large lenticule of quartzite on the hanging wall of which the impregnations of copper ore occur. The mineral is chiefly chalcopyrite, which is changed at the surface to green copper carbonate and brown iron-oxide, but solid layers of bornite and chalcocite are also present.

Voit remarks that "the ores occur in compact masses chiefly at the surface and for a short depth down only, whilst at a greater depth, where the bedding was able to offer a greater resistance to the circulation of waters, these ores gradually thin out to narrow seams, and finally pass into finely disseminated impregnations." From which it is clear that the payable ore is a secondary concentration of a low-grade impregnation.

EDMUNDIAN (F).

The Edmundian mine is situated about 190 miles by rail from Beira, about seven miles west of Macequece, and about ten miles east of Umtali. It lies near the top of a low range of mountains rising up from the north side of the Beira-Mashonaland railway, with which it is connected by a good wagon road of about two miles in length, with a steady downward grade. The mode of occurrence of the ore has been well described* by Brackenbury. It consists of lenticular bodies of chalcopyrite, with a little pyrrhotite, and, in the upper portion of the mine, their oxidation products, distributed in the form of vertical shoots throughout a zone of fracture in amphi-

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* C. Brackenbury, Trans. Institution of Mining and Metallurgy, XV., p. 633-642 (1906).

bolic and chloritic schists. The rich shoots often attain a thickness of over three feet of solid sulphide, narrowing down laterally to veins a few inches wide, which in turn split up into little stringers and finally into disseminations along the course of the lode.

UMKONDO (C).

This is a promising proposition situated some 115 miles east of Victoria by wagon road, about ten miles west of the Sabi River, and some 130 miles south and slightly west of Umtali.

Its site was indicated by the presence of numerous old workings, which extend over a length of about 1.500 feet, and are in places over 300 feet wide. The old workers not only made large open-cast excavations, as much as 60 feet in depth, but also sank small shafts, and in places stoped out the ore right down to the water level.

The copper occurs in a sedimentary formation, consisting of much altered shales and sandstones overlying granite, apparently unconformably, and intersected by numerous gabbrodiorite dykes.

Brackenbury, who gives a very able and detailed description of this occurrence, concludes that the copper has been subsequently introduced into these beds along zones of fracture, and that although the ore in some cases occurs as a bedded deposit, it is not likely to be found in this form at any great distances from these zones of disturbance. He also connects the ore-bodies with the gabbrodiorite intrusions.

The present water level has been found to be less than one hundred feet below the surface, but the sulphides do not appear until some distance below this.

In the zone of oxidation the ore is mainly green and blue carbonate in the form of incrustations and little seams in the bedding planes of the shales and in the fractures in the quartzite, but also occurs as an impure grey oxide in the shape of hard nodules in the shale up to several inches in diameter.

ALASKA (B).

This is a promising prospect, situated some 90 miles north-west of Salisbury, about thirty miles west of the Ayrshire mine and only some thirteen miles from the Eldorado mine.

It is remarkable for the great size of its old workings, which are perhaps the largest in the country between the Limpopo and Zambesi Rivers. They extend in an almost unbroken line for about 1,700 feet, with an extreme width of 660 feet, and they have been proved to go down in some places to a depth of at least 70 feet.

The occurrence has been well described by Brackenbury in the paper already cited. The copper so far exposed is mainly in the form of the green carbonate, malachite, the sulphide zone not yet having been reached. It is disseminated throughout siliceous and calcareous schists.

PALABORA (B).

The Palabora kopjes are situated some forty miles east of Leydsdorp and are celebrated as the source from which the Kafirs of the surrounding districts formerly obtained their iron and copper ores. I visited the locality in 1907, and since then a detailed account of the old workings has been published by Mellor.* The kopjes, with one exception, to which the name Lulu has been given, are of granite, and stand out conspicuously from the surrounding flat or slightly undulating bush-country. Lulu kop is composed of a white metamorphosed limestone or marble, and it is in this that the ore-bodies and old workings are mostly situated.

Magnetite is distributed almost everywhere throughout the

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* E. T. Mellor, Report Geological Survey, Pretoria. p. 44-49 (1907).

limestone, occurring in grains, crystals and masses, up to six feet or more in diameter. It is especially abundant along certain bands in the limestone.

Chalcopyrite is found in places disseminated in small quantity throughout the limestone while its alteration products, malachite and azurite, are more abundant, though only constituting a very small proportion of the rock.

The old workings extend over the whole area of the kop and are mostly shallow pits which have been sunk on pockets of ore.

Nothing of a payable nature is exposed, but indications of copper are so abundant, not only in the limestone, but in the adjacent granite, that the locality must be regarded as worthy of a more complete examination than it has yet received.

WILLOWS (G).

The Willows occurrence is situated east of Pretoria. It consists of a series of parallel lodes—true fissure-fillings—outcropping in clay-slates.

The ore consists of chalcopyrite, pyrite, and tetrahedrite in a gangue of siderite. In the oxidized zone where the ore contained a big percentage of silver, malachite and azurite largely replaced the sulphides.

A great deal of work was done on this occurrence in the early days when it was regarded as a silver mine, and it is said that something like a quarter of a million's worth of ore was shipped from it.

Development work has lately been restarted after a long period of idleness.

VALLEY (G).

The Valley mine is located 85 miles south-east of Bulawayo and is primarily a gold proposition, but produces copper as a bye-product.

It is on a quartz reef situated near the junction of the granite and schists, and is heavily charged with pyrite, pyrrhotite and chalcopyrite.

In the middle of 1906 a smelter was erected to treat the sulphide concentrates, the resulting matte being shipped. The following outputs have been declared, the quantities referring to the amount of copper in the matte :—1906, 76 tons, value £5,765; 1907, 115 tons, value £9,625; 1908, January to June inclusive, 40 tons, value £2,327.

SUBENI (G).

Running through the farms Nonpareil, Goudhoek, and Fairview, about a day's journey south-east of Vryheid, is a large prominently outcropping quartz reef, situated near, and running parallel to, the junction of granite and schists.

The Subeni prospect is located on Goudhoek and consists of a metalliferous shoot in the quartz reef. The minerals consist of chalcopyrite and bornite with a very little chalcocite.

Shafts have also been put down in this reef on Nonpareil and Fairview, but nothing of a promising nature has been discovered at those places.

OTAVI (H).

The Otavi Mountains are situated in northern Damaraland. The writer has not seen the copper and lead deposits there, the following account being extracted from a paper* by Kuntz. The mountains are composed entirely of limestone.

"As in all limestone formations, so also here a great number of caves exist as a consequence of the action of water. Some of them are empty, some filled with water, and others filled with a sandstone-like mass, which contains the copper ore in small and large pieces of different shapes.

"The enormous copper deposits at Otavi, Guchab, Tschumeb, etc., are simply fillings of such caves.

* J. Kuntz, Trans. Geol. Soc. S. Africa, VII., p. 75-76 (1904).

"At Gross-Otavi, dark and light grey limestone can be seen cropping out in layers, striking east and west, and dipping steeply to the south. This rock is spangled with large and small pockets of copper ore of irregular shape, and from the size of a pea to that of a cubic yard. The pockets again are connected with each other by a network of irregular running veins, as the accompanying sketch shows. The extent of this cavernous zone is about 80 by 200 yards, the ore consisting chiefly of chalcocite, seldom bornite and chalcopyrite. There is also a great quantity of galenite.

"The occurrences at Klein-Otavi and Guchab are of the same nature, but show more compact bodies of ore.

"What Gross-Otavi is on a small scale, Tschumeb is on a much larger scale. The extent of the outcrop is about 200 yards in the direction of the east and west strike, and 40 yards vertically. The dip is steeply to the south, and the ore-deposit seems to have the same dip, as proved by the prospecting shafts, following, apparently, an easier decomposable bed within the limestone.

"The most northerly part of this body is, to a great extent, replaced by copper and lead ore, whilst in the southern part the ore occurs breccia-like, as at Gross-Otavi, showing that the character and origin of the deposits are the same in both places.

"As in the footwall, so in the hanging-wall beds of limestone, numerous small clefts and cracks are filled with copper ore.

"On the eastern part of the outcrop the ore consists chiefly of galenite, the copper ore being in the minority. Towards the west the galenite diminishes, but does not disappear entirely, while the chalcocite is the chief ore there. Bornite and chalcopyrite exist only in small quantities."

The genesis of these ore-bodies seems uncertain, though it is clear they are secondary enrichments.

During the financial year 1907-8 (April to March inclusive) there were shipped from Tschumeb 15,000 tons of ore with an average content of 0·035 per cent. silver, 19 per cent. copper, and 23 per cent. lead. Also 1,000 tons of matte containing 0·040 per cent. of silver, 38 per cent. of copper, and 19 per cent. of lead, and 700 tons of 95 per cent. lead containing 0·090 per cent. of silver.

From Guchab 1,800 tons of ore containing 33 per cent. of copper and 0·040 per cent. of silver were shipped.

During the first quarter of the current financial year (April to June, 1908) about 6,500 tons of ore, 900 tons of matte and 800 tons of lead were shipped.

CHAPTER V.

COBALT.

KRUISRIVIER AND EENZAMHEID (E AND D).

THE well-known Kruisrivier cobalt lode in the Selons Valley has often been described* and was visited by the writer in 1907. The mineral is smaltite, which occurs, as shown in the accompanying section (fig. 7), as an impregnation at or near the junction of a series of felspathic quartzites with a gabbrodiorite intrusion.

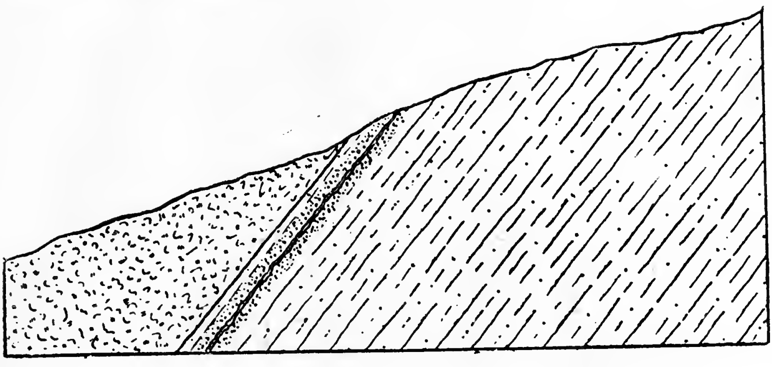

FIG. 7.

Section through Kruisrivier Cobalt Lode (after Mellor).

In the best exposure, about two feet from and parallel to the junction, there is a thin interbedded vein of smaltite crystals on either side of which the quartzite is impregnated with

* E. J. Dunn, Quarterly Journal Geological Society of London, XXXIII., p 883 (1877).
R. Oehmichen, Zeitschrift fur Practische Geologie, p. 271-274 (1899).
R. Beck, Trans Geol Soc. S. Africa, X., p. 10 (1907).
E. T. Mellor, Report Geol. Survey, Pretoria, p. 70-71 (1907).

the same mineral. The quartzite in this zone contains numerous cherty patches and has a generally altered and indurated appearance.

On the adjoining farm, Laatstedrift, there is a further occurrence of the smaltite, the impregnated rock there being the gabbrodiorite.

At the surface the smaltite is changed into the peach-red and black oxidation products, erythrite and transvaalite. Both contain a notable quantity of gold, up to four ounces per ton.

On Eenzamheid, about a mile south of Balmoral station, on the Pretoria-Delagoa Bay railway, there is an analogous occurrence of cobalt ore, which, however, the writer has not seen. It has been described by several observers.* The smaltite, together with a little quartz and molybdenite, occurs as an impregnation in a series of parallel basic dykes that penetrate a highly indurated shale and are probably offshoots from a big neighbouring gabbrodiorite intrusion. A small proportion of nickel is present in the smaltite.

* D. Dorffel, Trans. Geol. Soc. S Africa, VI (1903).
C. B. Horwood, Trans. Geol. Soc. S. Africa, VII. (1904)

CHAPTER VI.

TIN.

ROOI BERG (B, C AND F).

THE Rooi Berg, which give their name to this field, are a group of hills rising out of the flat or gently undulating country about 40 miles due west of the village of Warmbaths. The ore occurrences are situated mainly on the northern slopes of the Rooi Berg and their western extension, on the farms Haartebeestpoort, Blauwbank, Haartebeestfontein, Olievenbosch, and Onverwacht, and have been well described by Recknagel.*

The whole of the area is covered with a sedimentary formation consisting of felspathic quartzites, shales and thin conglomerates, surrounded by, and resting on, granite, which is intrusive into it.

Over the whole north-western half of this area, the formation is practically undisturbed, and strikes from north-west to south-east, with a dip of 5 to 10 degrees to the north-east. Over the eastern portion of this area, that is, on the northern slopes of the Rooi Berg, the formation is equally free from dislocations, but strikes mainly east and west, with a southerly dip of about 30 degrees. The thickness of this sedimentary formation is very considerable, amounting to several thousand feet.

Overlying the sedimentary formation are a series of felspar-porphyry flows, which constitute the main mass of the Rooi Berg.

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* R. Recknagel, Trans Geol. Soc. S. Africa, XI. (1908).

Throughout the whole area the felspathic quartzites contain impregnations of tourmaline. The impregnations vary from very small isolated irregular patches to belts which follow the same stratum uninterruptedly for long distances. With the tourmaline which is predominant are associated the following other secondary minerals, in decreasing order of abundance, quartz, felspar (orthoclase), and sidero-calcite. Cassiterite is usually present, but only in very small quantities. Pyrite is abundant, but chalcopyrite is rare.

The main tin occurrence is situated on Haartebeestfontein and Olievenbosch, and differs somewhat from the prevalent type. It may be described as a gigantic stockwork, in which the tiny cracks, veinlets and impregnations of the stockwork proper are represented by fissures and lodes accompanied by impregnations of corresponding magnitude. It owes its rediscovery to the existence over the whole of its outcrop—some 70 acres—of very extensive old workings.

These lodes strike in all directions, but at least two parallel systems can be distinguished among them, one containing lodes with an approximately north-south strike, and the other whose lodes strike west-north-west.

It is very difficult to describe in a few words the various types of lodes encountered, as there is scarcely any type unrepresented. There are fissures of small width, mere cracks with no vein filling except some clay; there are similar fissures with irregular pockets of vein minerals attached; there are lodes with one well-defined wall, showing brecciated structure and enclosing vughs of large dimensions; and there are lodes which show both walls well defined over long distances. The task of conveying a proper idea of the various types is made even more difficult by the fact that in most of the lodes various types are represented.

The filling of the lodes consists in part of decomposed country rock and clay, but mainly of the following gangue minerals (in order of decreasing abundance), tourmaline, quartz, sidero-calcite, and orthoclase. As an accessory gangue mineral found in small quantity only fluorite may be mentioned. These gangue minerals enclose, besides cassiterite as the main metallic mineral, smaller quantities of pyrite, specularite, chalcopyrite, galenite, sphalerite, and, as a rarity, gold. The most frequent gangue mineral, and, in many places, the only one, is tourmaline; it occurs mostly in a fibrous state, and very often forms spherulitic aggregates which, in places, are the only filling of wide veins. In some of the lodes the tourmaline crystals form, with quartz or sidero-calcite, a dense felt-like mixture which, only under the microscope, reveals its true nature. Orthoclase, mostly pink in colour, forms the gangue mineral in several lodes, at least in part, and usually appears quite fresh to the unaided eye, but in places can be seen changing into yellowish-green sericite.

The cassiterite occurs either by itself, forming crystalline masses of smaller extent within the lodes, or associated with either of the gangue minerals, forming coarse to fine-grained mixtures, or as impregnations in the country rock.

It is established that most of the fissures and lodes must have been originally mere cracks, and that open fissures were the exception. The present apparent filling of gangue minerals is merely a replacement of the sides of these cracks. It is further established that a rerupturing of many fissures has taken place afterwards, as the brecciated lodes include fragments of pre-existing "filling." These cracks were the main channels through which the impregnating agents operated. The secondary minerals introduced completely replaced the rock immediately adjoining the cracks, but, further away, were merely disseminated throughout it, and finally ceased to penetrate at all. It is interesting to note that where these impregnations followed the bedding planes a banded arrangement of the secondary minerals is often met with.

As to the forces that produced the original cracks, no satisfactory explanation has yet been offered. It is certainly most uncommon to find an area of sedimentary formation, practically free from dislocation, fissured to such a degree. The only dislocation of any extent is that which separates eastern and western are as above described, and which strikes north-east through Blauwbank, but this is three miles away from the fissured area. In looking for possible causes of the fissuring, the theory of torsional movement suggests itself as a feasible explanation.

WEYNEK.

The Weynek tin lodes are situated on the farm of that name about four miles from the great Rooi Berg stockwork already described. They are in the same felspathic quartzites but the mode of occurrence of the ore is very different. They, also, owe their rediscovery to the presence of old workings on them.

There are two main parallel lodes. Their mean dip is, approximately, at right angles to that of the felspathic quartzites, but their course here and there follows the bedding planes for short distances.

The filling of these lodes is a clayey substance of uncertain nature. The cassiterite, with which is associated the oxidation products of chalcopyrite, is disseminated throughout this filling. No tourmaline is present.

The genesis of the ore occurrence is, no doubt, the same as that of the Rooi Berg, and the lode stuff was probably originally very similar, but has subsequently suffered decomposition owing to local causes.

DOORNHOEK (B AND F).

The farm Doornhoek* is situated north-east of Nylstroom. The tin-ore occurs partly as an irregular impregnation in the granite, but chiefly as an impregnation along fissures in the overlying felspar-porphyry flows.

* J. P. Johnson, South African Mining Journal, VI., p. 571 (1908).

The main ore-body, which has been traced for a distance of several hundred yards, is coincident with a fissure crossing the felspar-porphyry and consists of an impregnation of the crushed rock forming the walls. Five main prospecting shafts have been sunk on this to an average depth of about fifty feet, the distance between the two extreme end shafts, measuring along the lode, being 1,250 feet. The average width of this lode is about eighteen inches, and the values go as high as 30 per cent. tin, and average 10. It is intersected in various directions by numerous small cassiterite-bearing veins.

This lode is the centre of a highly stanniferous area of the nature of a stockwork. Numerous parallel veins intersect the surrounding rock in all directions.

The cassiterite and associated secondary minerals (tourmaline, quartz, sericite and fluorite), while megascopic in the granite, are in a very fine state of division in the lodes, being there rarely distinguishable to the naked eye.

POTGIETERSRUST (B).

The Potgietersrust tin-field* is located in the mountainous country between the Magalakwin River and its tributary the Sterk. The country rock is granite. Throughout the whole of this area irregular impregnations of cassiterite and associated secondary minerals are met with, but the payable occurrences so far dicovered are confined to a zone of fissuring running through the farms Solomonstempel, Sterkwater, Groenfontein, Roodepoort, and Zaaiplaats.

Running north and south through Groenfontein and extending into Roodepoort on the one hand and Sterkwater on the other, is a pegmatitic quartz-vein, dipping at a low angle to the west, and containing massive fluorite and sericite, together with much coarsely crystalline cassiterite.

The granite adjoining this quartz-vein on the east is

* J. P. Johnson, Trans. Geol. Soc. S. Africa, X., p. 115-119 (1907).

sparsely impregnated with small crystals of cassiterite for a width of about forty yards. Megascopically this impregnated granite shows little evidence of alteration. Apart from the cassiterite, specks of yellow to green sericite and an occasional crystal of violet-blue fluorite, alone differentiate it from the adjoining rock.

East of this belt of impregnated granite and arranged in a line roughly parallel to it, are small patches of similarly impregnated granite and groups of peculiar cylindrical pipes. These extend into Zaaiplaats on the north and Solomonstempel on the south.

The cylindrical pipes, as a rule, consist of a core of altered granite thickly studded with crystals of cassiterite, usually, but not always, surrounded by a sharply defined ring consisting of spherulites (about a centimetre in diameter) of black tourmaline closely packed in a white quartz matrix. Outside this is a halo of granite characterized by specks of yellowish green sericite which gradually merges into the unaltered rock.

The extent to which the granite is altered in these pipes is very variable in one and the same pipe. As a rule the greater part of the rock still retains its granitic texture, and to the naked eye seems to have suffered little alteration beyond the replacement of some of the constituents by sericite, fluorite and cassiterite. Much, in some cases the major portion, has, on the other hand, suffered such complete alteration as to be megascopically nothing more than a friable dirty green (sericitic) rock speckled with cassiterite. Between these two extremes every gradation can be observed. Under the microscope the sericite is seen to be an alteration product of the felspars.

Accessory secondary minerals occurring in the pipes are molybdenite, pyrite, chalcopyrite (and hence malachite), arsenopyrite, and galenite. Grains of copper were also found in one of the pipes on Zaaiplaats embedded in the tourmaline spherulites at a depth of 130 feet.

The pipes are found to take an irregularly inclined course in depth and sometimes join together. They mostly dip to the west.

The payable tin-ore is practically confined to these chimneys. According to Merensky* about 250 tons of ore yielding an average of 30 per cent. of tin were recovered from one pipe alone.

The output of ore and concentrates from this field has been as follows:—1906, 61 tons, value £3,928; 1907, 1,296 tons, value £36,435; 1908, January to June inclusive, 712 tons, value £43,754.

WELBELOOND.

This is an interesting prospect situated on the farm Welbeloond on the eastern flank of the Tyger Berg. The ore-occurrence, which I have not seen, and for a description of which I am indebted to Mr. Mills-Davies, consists of small quartz veins carrying coarse cassiterite, which traverse a long low kopje of slates and quartzites not far from an intrusive granite contact.

EMBABAAN (I).

The detrital accumulations of cassiterite in the Embabaan valley have been regularly worked since 1892, but it is only from 1905 that records of the output have been kept.

The cassiterite is derived from irregular impregnations in the surrounding granite. Associated with the cassiterite in small quantities and having the same source are the rare and interesting minerals, aeschynite, euxenite, and monazite.

The following outputs of concentrates have been registered:—Year ending 30th June, 1906, 229 tons; 1907, 270 tons; 1908, 512 tons.

* H. Merensky, Trans. Geol. Soc. S. Africa, XI., p. 35-39 (1908).

LANGVERWACHT (I).

Detrital accumulations of cassiterite were worked in the creek on the farm Langverwacht, about twelve miles from Cape Town, during 1906 and 1907, when about 300 tons of concentrates were shipped. The cassiterite is derived from irregular impregnations in the surrounding granite.

CHAPTER VII.

MOLYBDENUM.

APPINGADAM (B).

THE molybdenum occurrence* on Appingadam is situated at the foot of the north end of the kopjes on the left bank of the Sterk River and occupies an irregularly shaped area. The country rock around this area is granite plentifully sprinkled with spherulites of tourmaline, though, so far as can be detected by the unaided eye, otherwise unaltered. Within this area the granite shows additional alteration of varying intensity. The first manifestations are the increase in the number of tourmaline spherulites and the addition of sericite and fluorite. Then molybdenite and cassiterite (which however is here rare) appear. With the increase in quantity of these secondary minerals the granite gradually loses its original character. Finally, in certain centres of intense alteration peculiar types of rock have been produced which bear no resemblance to the original. Their constituent minerals occur both in evenly granular aggregates and as irregular mixtures. They comprise tourmaline-quartz rock, sericite-quartz rock, sericite-molybdenite rock, molybdenite-arsenopyrite-quartz rock, and arsenopyrite-fluorite rock. Sphalerite also occurs in irregular masses. These rock types, of course, pass one into the other, and it is possible to get hand specimens containing all the minerals mentioned together.

Molybdenite in the form of scales, often hexagonal, is the dominant metallic mineral. The yellow oxidation product, molybdite, also occurs.

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* J. P. Johnson, Trans. Geol. Soc. S. Africa, X., p. 115-119 (1907).

An interesting feature of this altered area is the presence of groups of giant spherulites of tourmaline, some as much as four decimetres in diameter, in which the slender needles of the ordinary sized spherulite are replaced by stout columns. Tourmaline also occurs as short, thick crystals associated with quartz in small irregular bodies.

To find a market molybdenum-ore must contain not less than 45 per cent. of the metal, and must be free from other metallic minerals, especially copper. Picked sulphide, practically free from gangue, will command from 16 to 19 shillings per unit per cent. of molybdenum per ton.

HOUTENBEK (B).

On the farm Houtenbek, north-east of Pretoria, there are two interesting occurrences* which, although not of economic importance, are deserving of mention here. The country rock is granite.

One is a band, two feet in width, consisting of almost pure arsenopyrite, some fluorite, and large leaves of molybdenite.

The other is a similar band showing arsenopyrite, fluorite, and large crystals of monazite, all closely intergrown. The monazite is greenish-grey to dark red in colour. Some of the ore was reported to have an average yield of 5 per cent. of thorium.

* H. Merensky, Trans. Geol. Soc. S. Africa, XI., p. 31 (1908).

CHAPTER VIII.

Tungsten.

RICHARDSON (B).

The Richardson mine is situated at Essexvale, near Bulawayo.

The mineral is wolframite with a little scheelite, and occurs together with chlorite, quartz, tourmaline, fluorite and topaz, as an impregnation in fine-grained granite.

In 1906 17 tons, and in 1907 12 tons, of picked ore were produced. The figures of output for the first six months of this year are not available.

SCHEELITE-KING (G).

The Scheelite-King mine is situated near the Umswege River, on the Gatuma side of the Hartley district.

The mineral is scheelite, and occurs in a quartz reef in schistose granite, which is much epidotized in the vicinity.

During 1907 38 tons of picked ore were produced. Mining is being continued there, but no declaration of output has yet been made for this year.

I am indebted to Mr. Mennell for the information relating to the above occurrences which I have not seen.

CHAPTER IX.

Lead.

DWARSFONTEIN (G).

The Dwarsfontein occurrence is situated about forty miles south-east of Pretoria. It is a vertical lode outcropping in clay-slates.

The ore consists of galenite, with subordinate chalcopyrite, pyrite, and tetrahedrite, in a gangue of siderite. In the oxidized zone where the ore contained a big percentage of silver, cerussite and malachite largely replaced the sulphides.

As a rarity, trauslucent red crystals of the lead chromate, crocoite, are met with.

A great deal of work was done on this occurrence in the early days when it was regarded as a silver mine. From 1891 to 1893 inclusive, £50,000 was realized from the sale of ore, concentrates, and metal.

Work has lately been restarted. A small amount of galenite was contributed to the Pretoria district output (given under Edendale) for the first six months of this year.

ROODEKRANZ (G).

The Roodekranz occurrence is situated sixteen miles south-west of Pretoria. It is a lode in the dolomite formation containing galenite and quartz.

It made small contributions to the Pretoria district output during 1906 and 1907.

PENHALONGA (G).

The Penhalonga mine is located on the slopes of the range of hills of the same name, some 10½ miles north of Umtali. It is primarily a gold proposition, but produces lead as a bye-product. A short description of it has been published by Townsend.*.

The ore occurrence is a vertical quartz reef heavily charged with argentiferous galenite, running in and parallel to a series of schists, and has been traced for a distance of 14,000 feet. There are numerous old workings on it.

At present some 3,500 feet of the lode is being exploited. This portion is divided into two sections by a longitudinal fault. The western section is 1,500 feet in length and the eastern section is 2,000 feet in length, a barren stretch of 700 feet separating the two. The lowest drive is some 900 feet below the outcrop.

The ore-body consists of quartz lenticules intercalated with small bands of schist. Its width varies from 25 to 50 feet, of which 8 to 20 have proved to be worth working. The quartz contains in addition to the galenite a small amount of zinc, iron and copper sulphide. The oxidized zone is characterized by a considerable quantity of the chromate of lead, crocoite.

In the eastern section there is a parallel band of quartz lenticules lying 150 feet to the south, which, however, has not been found in the western section.

Galenite concentrates have been shipped for several years. From January to June, 1908, inclusive, concentrates containing 510 tons of lead valued at £6,292 were produced.

UITLOOP-RIETFONTEIN (F).

This occurrence† is situated in the granite ridge which forms the boundary between the farms Uitloop and Rietfontein, north of Potgietersrust, and although not of economic importance is of special interest in that it presents the unusual

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* H. P. Townsend, Journal S. African Assoc. Engineers, XIII., p. 132-140 (1908).

† J. P. Johnson, Trans. Geol. Soc. S. Africa, X., p. 115-119 (1907).

feature of being genetically similar to the tin, molybdenum and tungsten impregnations already described.

The main occurrence is in a narrow but sharply defined belt of altered granite which strikes approximately north and south and dips at a big angle to the west. This is traceable for some distance.

The section is as follows :—

(*a*) Hanging Wall.

(*b*) *Mottled Red and Yellowish-green Rock.* Altered granite. Granitic structure mostly retained but partly obscure. 1 ft.

(*c*) *Bluish-white Chert-like Rock.* Traversed by a network of fluorite veinlets containing galenite. Altered granite. Traces of granitic structure retained in places. Specks of red felspar throughout. 2 ft.

(*d*) Foot Wall.

A short distance to the west of this a similar occurrence runs parallel and has been exposed in a pit, but at the time of my visit had not been traced far. It is not so sharply demarcated from the enclosing rock as in the main occurrence. It shows veinlets of chert and galenite-bearing fluorite traversing a narrow belt of the granite which is not megascopically much altered.

A microscopical examination shows the ore-body to be a line of crush in the granite, along which the galenite and associated secondary minerals have been deposited by vapours at the expense of the felspars.

EDENDALE (G).

The Edendale lead and zinc mines are located on the farm of the same name, some seventeen miles north-east of Pretoria. Both are situated on a lode in quartzites and shales.

This lode consists of a belt of fissuring of very variable width. It has been traced for a distance of about 2,000 yards and opened up at one point to a depth of 700 feet. It dips against the strata at an angle of about 75 degrees.

The metalliferous minerals consist of galenite and sphalerite with very subordinate chalcopyrite, and occurs in the form of lenticular bodies and disseminations throughout the lode. The galenite contains about 14 ounces of silver to the ton, and constitutes about ten per cent. of the ore. The sphalerite is less abundant. The two minerals are seldom mixed.

At the surface the sulphides are largely replaced by the oxidation products cerussite and smithsonite. In smaller quantity also occur the red oxide of lead, minium, in opaque earthy crusts, and translucent yellowish-white crystals of the lead sulphate, anglesite.

These mines have been responsible for nearly the whole of the lead-ore output from the Pretoria district, which is as follows :—1904, 389 tons, value £2,863; 1905, 768 tons, value £3,756; 1906, 1,103 tons, value £14,473; 1907, 1,014 tons, value £12,513; 1908, January to June, inclusive, 682 tons, value £6,328. During 1906 and 1907, Roodekranz and, during 1908, Dwarsfontein, contributed to the above amounts.

In 1907, 40 tons of zinc ore, valued at £365, were also sold.

There is a similar but smaller occurrence on the adjoining farms Leuwkloof and Broederstroom, some 28 miles south-west of Pretoria. A small quantity of galenite included in the above figures was mined from there in 1907 and during the first six months of 1908.

OTTOSHOOP (H).

The Ottoshoop lead and zinc occurrences are analogous to the Otavi copper-lead deposits, being fillings of irregular cavities in dolomite.

The ore consists of galenite and sphalerite in a gangue of calcite, fluorite and quartz. A little chalcopyrite is sometimes associated with the sphalerite. The immediately adjoining rock is charged with tremolite.

Pockets have been located on the farms, Zendelingspost, Buffelshoek, Witkop, Naauwpoort, Strydfontein, Kuilfontein, Rhenosterhoek, and Doornhoek.

The main occurrence at Witkop well illustrates these deposits. There a horizontal section of a characteristic chamber of ore is exposed at the surface. It is approximately circular in outline, and has a diameter of about fifty yards. Within this area the solid dolomite is replaced by angular blocks embedded in a matrix of calcite, fluorite, and quartz containing masses and disseminations of galenite and sphalerite. The galenite is argentiferous. The immediately surrounding dolomite and the included blocks of same, are charged with tremolite.

At the surface the sulphides are often changed to cerussite, smithsonite, and hemimorphite. Minium and anglesite are also present in subordinate quantity. More rarely greenockite occurs in greenish yellow crusts.

The output of ore from this district has been :—1907*, 334 tons of lead ore, value £3,930, and 318 tons of zinc ore, value £2,851; 1908, January to June inclusive, 723 tons of lead ore, value £5,173, and 249 tons of zinc ore, value £1,715.

* Previous records unobtainable. Some ore was mined at Rhenosterhoek in the early days.

CHAPTER X.

Mercury.

LOUW'S CREEK (F).

This occurrence is about ten miles south of Malelane Station, on the Pretoria-Delagoa Bay Railway, and on the further side of the range of hills between the railway and Louw's Creek, which it overlooks.

The writer has not seen the ore-body and is indebted to Mr. Draper for the information contained in this note.

The mineral is cinnabar. It occurs disseminated throughout a belt of crushed quartzite from four to five feet wide and about 400 yards long. The mercury content over this width and length is from 2 to 3 per cent.

Numerous prospecting shafts have been put down on it, but an adit driven lower down the hill-side to intersect the deposit in depth, failed to locate it.

CHAPTER XI.

Antimony.

MURCHISON RANGE (C).

The Murchison Range* is made up of picturesque lines of kopjes lying between the Selati and Groot-Letaba Rivers. It affords a pleasing contrast to the monotonously flat or slightly undulating bush-country with which it is flanked. Geologically it consists of a narrow belt of schists, bounded on either side by granite.

These schists in common with their representatives in other parts of the country contain numerous auriferous quartz-veins, fahlbands and general impregnations of a lenticular nature, which conform both in strike and dip with the adjacent beds. Sawyer has published an account of them in his book on "The Murchison Range" (1892), while Wilson-Moore†, and, more recently, Merensky‡, have also made contributions to our knowledge of them.

The antimony deposits occur in the string of kopjes which extend in a north-easterly direction from north of Leydsdorp for a distance of about thirty miles. These kopjes are constituted of a definite horizon in the schists, and are made up of much altered and compressed chloritic quartzites and quartz and clay slates, which dip at a big angle to the north. The antimony occurs as the sulphide, stibnite, in lenticular veins which can be traced at intervals throughout the whole length of these kopjes and which seem to occupy the same minor stratigraphical position.

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* J. P. Johnson, The Antimony Deposits of the Murchison Range (1907).

† Wilson-Moore, Trans. Geol. Soc. S. Africa, I., p. 51-62 (1895).

‡ H. Merensky, Trans. Geol. Soc. S. Africa, VIII., p. 42-46 (1905).

The richest sections of the antimony reef which I saw are at the Gravelotte and Caledonian properties, but very little work has been done on them, and that only in the oxidized zone. There, large lenticules of pure mineral are a prominent feature, while gangue is absent unless an occasional small quartz vein can be considered as such.

Only at the Free-State mine has the antimony reef been opened up in depth. There the stibnite occurs disseminated throughout a calcareous gangue, which, under the microscope, is seen to be mainly made up of calcite and dolomite with a little green sericite and some secondary quartz.

It seems not unlikely, therefore, that these antimony deposits are impregnations of a bed of metamorphosed limestone.*

At the Castle kopjes there is a large quartz vein which was exceedingly rich in visible gold in places and which sometimes contains a little stibnite.

At the surface the stibnite is altered into a yellow oxide, probably cervantite, and the hydroxide, stibiconite.

The antimony reef contains a notable quantity of gold and silver.

The individual kopjes of the antimony line are separated from one another by transverse faults, the beds trending sharply round to the south at the east end of each kopje, and to the north at the western end.

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* Mellor in a later account (Report Geol. Survey, Pretoria, 1907) regards the antimony reef as a true lode.

CHAPTER XII.

IRON (I).

The prominent part played by the peculiar banded silica-iron oxide rocks and magnetite-hematite-quartz slates, among the older sedimentary formations of South Africa make it probable that many valuable ore-bodies will be found where the conditions have been favourable to the growth of secondary enrichments. The iron was probably originally deposited in the form of hydrate at the time of the laying down of the beds, and though, strictly speaking, largely of the nature of a chemical precipitate, may, for convenience, be regarded as a member of the class of Detrital Accumulations.

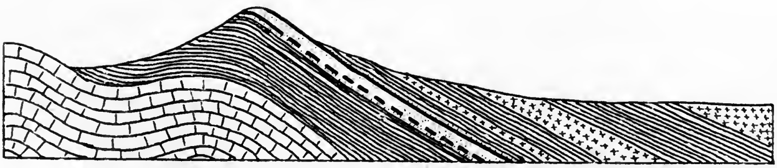

FIG. 8.

Section through the Timeball Range, near Pretoria, showing the Magnetite Beds (after Hall & Steart).

In the quartzite of the Timeball Range, near Pretoria, there are two beds (fig. 8) highly charged with magnetite, in one of which the magnetite is considerably in excess of the quartz and constitutes a good iron ore.

The iron content of the different sedimentary ores, when theoretically pure, a condition, however, which, in nature, is never attained in bulk, are :—Magnetite ($Fe_3 O_4$) 72 per cent., hematite, and its variety specularite ($Fe_2 O_3$), 70 per cent., limonite ($2Fe_2 O_3 . 3H_2 O$), 60 per cent., and siderite ($Fe CO_3$) 48 per cent. The most serious impurities usually met with are sulphur and phosphorus, which are present in the form of pyrite and apatite, and must not exceed certain minute proportions.

CHAPTER XIII.

HINTS TO PROSPECTORS.

South Africa affords a fine field for prospectors. The number of competent prospectors in the country could probably be counted on the fingers of one hand, a circumstance, however, which one can only expect. A combination of mining experience and geological knowledge are the essential qualifications of competent prospectors, and those possessing them are seldom inclined to expend their talents in a direction where reward is so uncertain. For all that there are prospectors.

There are also many mining men possessing the necessary grounding, who now and then can, and are prepared to, spend a little time and money in trying their luck. To these amateur prospectors a few hints will be useful.

The use of the pan in detecting the presence of gold or other heavy minerals occurring in a finely divided state will already be familiar to them. In searching for coarse, heavy minerals in loose debris, such as detrital cassiterite, a sieve will be found more useful. By placing some of the debris inside and jigging it in water, the heavier minerals will be made to sink to the bottom, while on sharply inverting on the ground the contents will be spread out with the heavy minerals on top. These can then be readily examined.

They should also make themselves thoroughly acquainted with the blowpipe methods of determining minerals and with the use of the more readily applicable reagents. These methods are described in all text-books on minerals, and cannot be detailed here. Proficiency in the laboratory is essential before their aid is employed in the field, as many of them are not so easy in practice as they seem to be on paper. By experimenting with mixtures of minerals they will be put on their guard against the weaknesses of these methods under certain conditions. For instance, small percentages of a mineral yielding a very strong coloration may obscure the presence of large percentages of one giving only a feeble coloration.

Amateur prospectors as defined by the writer will already be familiar with the commoner rock-forming minerals. The economically valuable metalliferous minerals, with the exception of certain iron compounds, however, do not come under that heading. The writer has, therefore, prepared the following comparative description of their more obvious features. This is not intended to supersede the use of a text-book on minerals, but merely to narrow down the range of enquiry. It must be remembered that numerous other minerals will answer to many of the descriptions given here, though they are less likely to occur in any abundance, and it must be remembered that the most precious minerals are worthless unless present in sufficient quantity. Having located the mineral in the following scheme they should, unless a decisive result such as the production of a recognisable metallic bead shall have been obtained, turn to their text-book and put it through the remaining tests, which will either confirm the preliminary identification, or else prove it to be merely a similar but worthless mineral.

ANTIMONY.

Stibnite.—Sulphide (Sb_2 S_3). A brittle metallic grey mineral. Distinguishable from galenite by its fusibility in an ordinary flame.

Antimony is used in the manufacture of certain bearing and type alloys. Its property of imparting expansion in changing from the liquid to the solid state and hence of producing a sharp cast, makes it specially useful for the latter purpose. The demand, however, is limited.

ARSENIC.

Arsenopyrite (Mispickel).—Sulpharsenide of Iron (Fe As S). A heavy whitish metallic grey mineral. Resembles smaltite-chloantite. It is the main source of arsenic which, however, is also obtained as a bye-product in the treatment of the cobalt-nickel arsenides. In common with these last minerals it readily yields the characteristic arsenical (garlic-like) odour on roasting on charcoal.

CADMIUM.

Greenockite.—Sulphide (Cd S). A yellow translucent mineral. It is a common associate of the sulphide of zinc, sphalerite, but has not hitherto been known to occur in sufficient quantity to constitute an ore. The cadmium, however, is recoverable as a bye-product in the production of zinc.

Cadmium is mainly employed in the manufacture of solder alloys. Its possession of the quality of lowering the melting point of the metals with which it combines, makes it specially useful for that purpose. The demand, however, is limited.

CHROMIUM.

Chromite.—Oxide of chromium and iron ($Fe\ Cr_2\ O_4$). An opaque black, sometimes brownish, mineral. Distinguishable from magnetite by not being attracted by the hand magnet, by its brown (as opposed to black) streak and by the test for chromium. Fuse the mineral with salt of phosphorus when any chromium present will impart a dirty green colour which changes on cooling to a clear glass.

The principal uses of chromium at present are the preparation of chromium salts, employed in tanning and textile works, the manufacture of chrome-brick for basic furnace linings, and of ferro-chrome alloys for use in the manufacture of certain steels.

COBALT AND NICKEL.

Smaltite-Chloantite.—Arsenides of cobalt and nickel [(Co Ni) As_2] respectively, the one grading into the other. A heavy whitish metallic grey mineral. Distinguishable from arsenopyrite* by the test for cobalt or nickel. By fusing with borax, after first roasting, any cobalt present will impart a deep blue colour to it. Nickel will give, when using the oxidizing portion of the flame, a violet colour which changes to reddish-brown on cooling.

Cobaltite and Gersdorffite.—Sulpharsenides of cobalt (Co As S) and nickel (Ni As S) respectively, are exactly similar to the above in external characters.

Niccolite.—Arsenide (Ni As). A heavy reddish metallic yellow mineral, much resembling pyrrhotite, which, however, will attract a compass needle, and bornite, which may be distinguished by the test for copper. It usually contains a little cobalt and sometimes sulphur or antimony in place of some of the arsenic.

Garnierite.—Hydrous silicate of magnesium and nickel. An earthy apple-green mineral of very variable composition. Not known in South Africa, but may be looked for in serpentine areas. Very large bodies occur in that rock near Noumea, New Caledonia, where it is mixed extensively.

COPPER.

Chalcocite.—Sulphide (Cu_2 S). A heavy, brittle, blackish metallic grey mineral. Contains 80 per cent. copper.

Bornite.—Sulphide (Cu_3 Fe S_3). A yellowish to reddish metallic brown mineral. Contains from 50 to 70 per cent. copper. Occupies an intermediate position between chalcocite and chalcopyrite, and is usually intimately mixed with varying proportions of these minerals, hence its variable cop-

* Arsenopyrite itself, however, sometimes contains small quantities of hese metals, as also does pyrrhotite, pyrite and chalcopyrite in certain occurrences See under Nickel-ore occurrences.

per content in mass. Distinguishable from both these, when isolated, by the colour on a fresh fracture. Readily tarnishes to metallic red and blue tints.

Chalcopyrite.—Sulphide ($Cu\ Fe\ S_2$). A metallic yellow mineral. Contains 35 per cent. copper.

Tetrahedrite.—Sulphantimonide ($Cu_8\ Sb_2\ S_7$). A brittle blackish metallic grey mineral. Often argentiferous. Has some resemblance to chalcocite, but may be distinguished by the emission of dense white inodorous antimonial fumes on roasting on charcoal. The tetrahedral crystals of this mineral afford a ready basis for identification.

Malachite and Azurite.—The green and blue carbonates, respectively, resulting from the alteration of the sulphides. Sometimes occur in translucent crystals, but more often as an opaque earth. They form important ore-deposits.

All the copper minerals will yield a metallic globule under the blowpipe on charcoal—the sulphides with soda after roasting and the carbonates without.

LEAD.

Galenite (Galena).—Sulphide (PbS). A heavy brittle metallic grey mineral. Resembles stibnite and argentite. Usually contains a varying quantity of silver.

Cerussite.—Carbonate ($Pb\ C\ O_3$). A heavy translucent white mineral, often tinted brown, blue or green. An important ore of lead resulting from alteration of galenite.

Both minerals yield a lead globule under the blowpipe on charcoal.

MANGANESE.

Pyrolusite.—Oxide ($Mn\ O_2$). A blackish metallic grey mineral.

Psilomelane and Wad.—Hydrous alteration products of pyrolusite which often form important ore-deposits. Range from a hard greyish-black to a soft brownish-black mineral.

These minerals may be distinguished from most similar ones by the test for manganese. Fuse with soda when any manganese present will impart a green colour to it. Wolframite and tantalite will yield the same manganese reaction, but are much heavier.

MERCURY.

Cinnabar.—Sulphide (HgS). A very heavy translucent red mineral. Heated in a glass tube it gives off sulphurous fumes and mercury which, with careful manipulation, can be made to condense on the sides.

MOLYBDENUM.

Molybdenite.—Sulphide (MoS_2). A flexible metallic grey mineral. Distinguishable from graphite by dissolving in nitric acid with the formation of a whitish grey residue (MoO_3). Also readily gives off SO_2 under blowpipe.

Molybdenum is mainly employed in the manufacture of certain steels, to which it imparts desirable properties.

TANTALUM.

Tantalite.—Tantalate of iron and manganese [$(Fe, Mn) Ta_2 O_4$]. A heavy opaque blackish-grey mineral. Resembles cassiterite. Distinguishable from wolframite by infusibility under blowpipe alone. Not known to occur in South Africa, but may be looked for with tin-ore occurrences.

Tantalum is used for the filaments of certain electric lamps. The demand is very limited.

THORIUM.

Monazite.—Phosphate of the Rare Metals (Ce, La, Di, Y, Er and Th). Thorium contents very variable. A translucent yellowish-brown to hyacinth-red mineral.

Moistened with sulphuric acid and ignited on a platinum wire, it affords the reaction for phosphoric acid—a bluish-green flame coloration.

Thorium is used for the manufacture of gas mantles. The demand is very limited.

TIN.

Cassiterite.—Oxide (SnO). A heavy opaque black, sometimes translucent brown, mineral. Resembles some varieties of wolframite, rutile, sphalerite, tourmaline and garnet. Distinguishable from wolframite by infusibility under blowpipe alone. From the others by its high specific gravity. From all by yielding a bead of tin when fused with soda on charcoal.*

TUNGSTEN.

Wolframite.—Tungstate of Iron and Manganese [(Fe, Mn) W O_4]. A heavy opaque greyish-black or brownish-black mineral. Resembles cassiterite and tantalite.

Scheelite.—Tungstate of Calcium (Ca W O_4). A heavy translucent white and yellow mineral, often brownish, greenish and reddish.

Tungsten is used in the manufacture of certain steels, to which it imparts desirable properties.

URANIUM.

Uraninite (Pitchblende).—A very heavy opaque greyish, greenish, and brownish-black substance of variable composition, probably including two or three different mineral species. Interesting as the chief source from which radium is obtained.

Uranium has been used experimentally in the manufacture of certain steels to which it imparts desirable qualities, but it is at present too costly for that purpose.

* This, however, is not readily obtained When megascopic by wrapping in a piece of zinc foil and dropping into hydrochloric acid. cassiterite can be reduced externally to metal which will reveal its characteristic colour on rubbing.

VANADIUM.

Vanadinite.—A chloro-vanadate of lead ($3Pb_3 V_2 O_8 . Pb Cl_2$). A heavy translucent red mineral. Yields a globule of lead under the blowpipe on charcoal. Distinguishable from crocoite and minium (which are also a different tint of red) by the chlorine test. Heat in salt of phosphorus bead with copper oxide, when, if chlorine is present, it is immediately surrounded by a purple flame.

Vanadium is mostly used in the manufacture of certain steels to which it imparts desirable properties. Vanadinite is a frequently occurring accessory mineral in lead ores and was formerly concentrated from lead ores carrying 4 to 5 per cent. in the Iberian peninsula. The discovery of a large occurrence of rich vanadium sulphide (patronite) in South America, has, however, for the time being, deprived that source of commercial value.

ZINC.

Sphalerite (or Zincblende).—Sulphide (ZnS). A brittle translucent yellowish to blackish-brown mineral.

Smithsonite.—Carbonate ($ZnCo_3$). A brittle translucent white, often greyish, greenish and brownish, sometimes green, blue and brown, mineral.

Hemimorphite (Calamine).—Hydrous silicate ($H_2 Zn Si O_5$). A brittle translucent white mineral sometimes with a bluish or greenish tint, also yellow to brown.

Smithsonite and Hemimorphite are alteration products of sphalerite, but often form important ore-deposits. Under the blowpipe on charcoal, they give an incrustation which is yellow while hot and white when cold, and which, when heated again, after moistening with cobalt solution, becomes a fine green. Smithsonite may be distinguished from the others by the carbonate reaction.*

* Effervescence in acids.

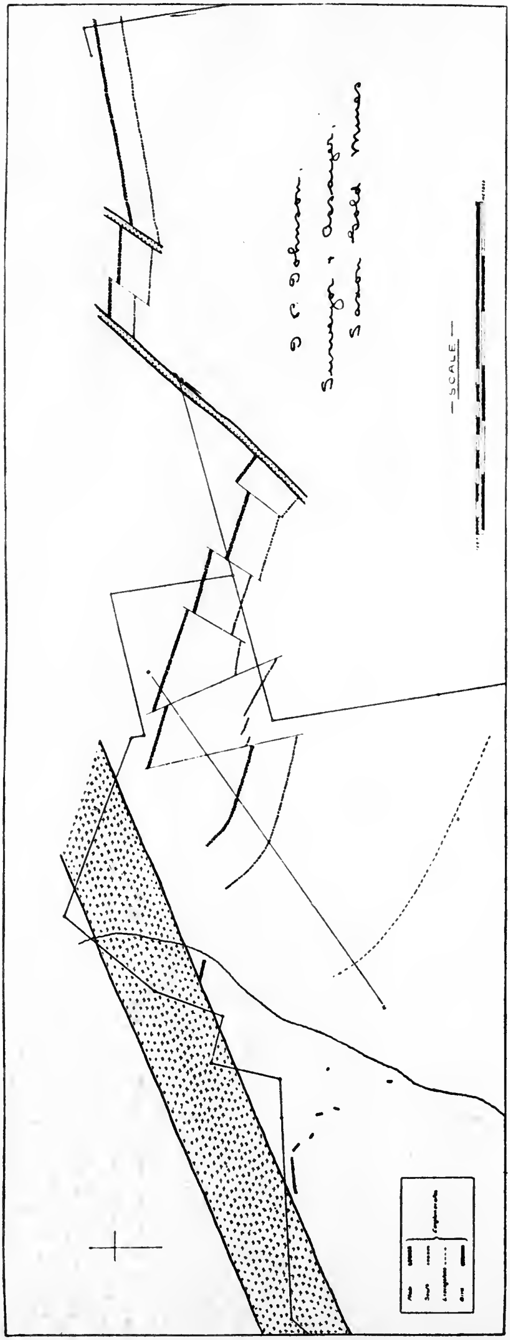

Fig. 9.

Plan of Auriferous Conglomerates at the Saxon and Princess Mines, Witwatersrand, illustrating the Effects of Faults and Dykes.

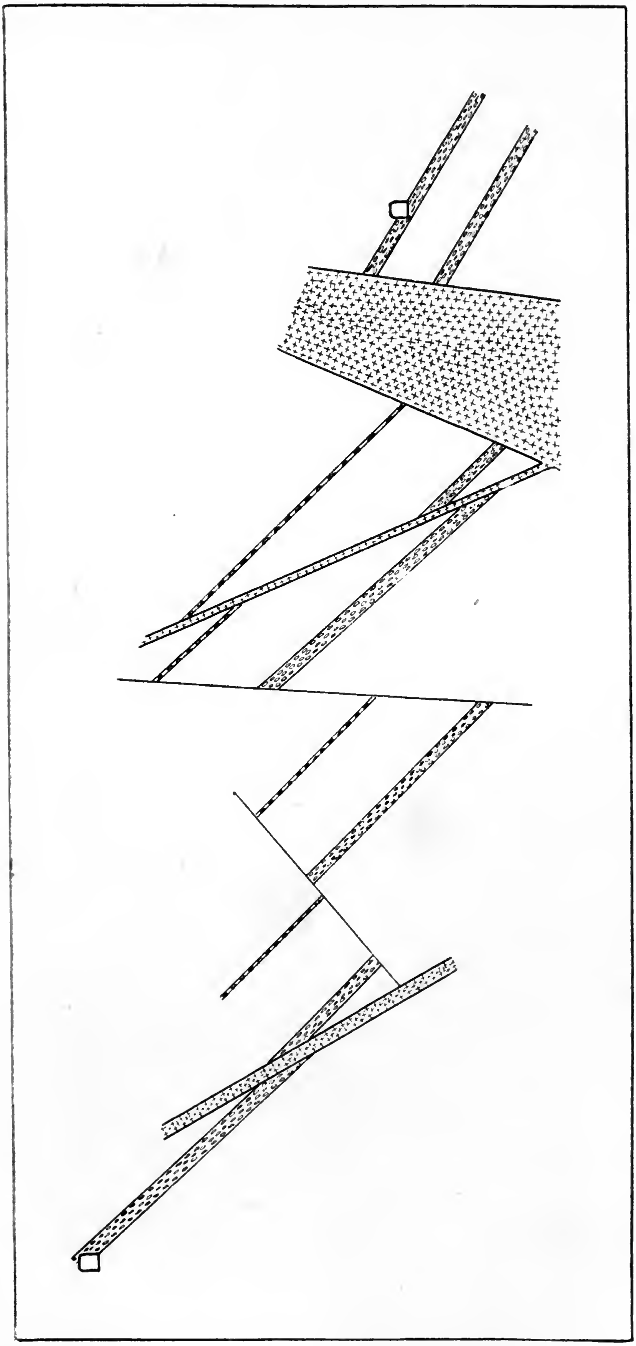

Fig. 10.

Section through Auriferous Conglomerates between the 15th and 16th (1,080 feet) levels, Luipaardsvlei Mine, Witwatersrand, illustrating the Effects of Faults and Dykes.

It is hardly necessary to remind the reader that most minerals exhibit a wide range of variation in regard to their colour. Only that most frequently met with is mentioned in the above comparative descriptions. Also that minerals that are usually translucent may often be transparent or opaque.

When prospecting for the insoluble minerals search should always first be made among the detrital accumulations in the bottom of creeks or in the natural riffles of river beds. On finding any there, they may be traced to their source by panning or sieving at intervals in the direction from which they have apparently drifted. In prospecting for the more readily decomposable minerals, stains of the colour of the oxidation products of the various metalliferous minerals should be looked for, especially along gossan-like (rusty) outcrops.

Worthless but more abundant and more noticeable minerals often serve as indications of the presence of valuable minerals. Tourmaline, for instance, nearly always points to the presence of cassiterite. The commoner associates of the valuable minerals recorded in the preceding pages, should be specially noted.

Any old workings that may be discovered should be examined, though it should be borne in mind that the Kafirs very often excavated small patches of ore that would not pay a European to exploit.

Further, having located a reef, they must not be discouraged if, after tracing it for a little distance, they find its continuation shifted by a dyke or fault. The dislocation produced by them is seldom of serious extent. A little perseverance will usually pick up the reef again on the other side.

Finally, it may be observed (1) that occurrences of tin and its genetically allied metals should be looked for in the vicinity of intrusive granite contacts, (2) that gold deposits are mostly found among the schistose rocks, and (3) that the neighbourhood of big gabbrodiorite intrusions is frequently prolific in other metalliferous minerals.

If would-be prospectors will ponder over this last statement for a little while, and at the same time call to mind the various types of ore occurrences described in the preceding pages, and the working hypothesis by which they are coordinated, they will soon realize the importance to them of an understanding of the principles outlined in the introduction.

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