

A HYDROTHERMAL DEPOSIT OF CASSITERITE NEAR ARANDIS  
SOUTH-WEST AFRICA.

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LOCALITY.

The somewhat remarkable occurrence of cassiterite to be described in the following paper is situated approximately 40 miles from the sea and some 23 miles north of Arandis station in the Namib forming the hinterland of Swakopmund.

HISTORICAL.

The deposit exhibits features very distinct from the ordinary tin-occurrences of the Erongo Tinfields, since the cassiterite is not associated with pegmatites.<sup>1</sup> It is not surprising therefore that, although the locality was searched for tin on more than one occasion, this rich occurrence was not discovered until very recently. Evidently no prospector before Mr. W. Stiepelmann, the discoverer and owner of this occurrence, contemplated the possibility of eluvial boulders consisting apparently only of limonite and with which the surface is strewn in great abundance, containing large amounts of cassiterite. Once this fact was ascertained, the locating of the deposits *in situ* presented no difficulties.

GEOLOGY.

The occurrences are situated in a broad band of crystalline limestone striking roughly 20° to 35° E. The latter forms part of the Marble Series of the Schist Formation, a constituent of the Fundamental Complex. An intense folding has brought about a tremendous thickening of the crystalline limestone and, in consequence, a very wide surface outcrop of this rock. The folding is rather complicated and there appear to be a number of pitching anticlines and synclines, into which Old Granites have been intruded on more or less concordant lines.

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<sup>1</sup> Vide: T. W. Gevers and H. F. Frommurze—"The Geology of North-Western Damaraland," *Trans. Geol. Soc., S. Africa*, Vol. XXXII, 1929;  
and: "The Tin-Bearing Pegmatites of the Erongo Area," *ibid* Vol. XXXII, 1929.  
A comprehensive Memoir dealing with the whole of the Erongo Tinfields is to appear in the near future.

These granites include typical porphyritic Salem Granite, non-porphyritic granite of a distinctly more acid nature and intrusive into the former, together with aplitic and pegmatitic granite; in short, most phases of the Main Period of granitic intrusion are represented. The cassiterite therefore also in this locality is no doubt derived from the same ancient granitic magma as that over the rest of the Erongo Tinfields.

The crystalline limestones and schists are traversed by a large number of diabase dykes forming conspicuous dark ridges, characteristic of the landscape in this area.

#### MODE OF OCCURRENCE OF THE CASSITERITE AND MINERALS ASSOCIATED WITH IT.

As already stated, the cassiterite is not associated with pegmatites. Quite a number of barren pegmatites, however, occur in the immediate vicinity of the tin-lodes, but these only carry garnets, some muscovite, occasionally biotite and sporadically black tourmaline, sometimes in great abundance. In a prospect shaft on the mining area Annaberg I the cassiterite-lode actually cuts through a very decomposed pegmatite, containing a little black tourmaline, but entirely barren of tin.

In another prospect shaft what appears to be a highly weathered fine-grained pegmatite is full of flakes of brown mica and also contains some black tourmaline. A small piece of scheelite was found in this shaft and is evidently derived from the pegmatite. The latter does not appear to contain cassiterite.

Only one tin-bearing pegmatite has so far been found in this neighbourhood, and this occurs about 50 yards to the east of the main "tin line." The pegmatite is of the ordinary type, shows very little greisenisation and contains no black iron-tourmaline. The cassiterite is of the ordinary brownish variety and metasomatically replaces feldspar and quartz. It is quite clear that here the mineral belongs to an earlier, pneumatolytic phase of tin-deposition than the main occurrences of cassiterite.

In addition to pegmatites the crystalline limestone is traversed by elongated bodies of pegmatitic quartz, to a large extent rose-quartz. No cassiterite has been found in them.

With the exception of the above pegmatite, the cassiterite occurs together with a glassy vein-quartz, arsenopyrite, pyrrhotite, iron and copper pyrites in irregular lodes and filling elongated drusy cavities in the crystalline limestone. Generally these follow more or less the strike and dip of the latter, and the main occurrences thus exhibit a linear arrangement. Mineral-deposition evidently took place along fissures, probably in the main solution fissures, following bedding planes in the limestone. So far a number of parallel "tin-lines" have been located over a width of several hundred yards and a length of about  $1\frac{1}{2}$  to 2 miles.

The outcrop of the tin-lodes is indicated by dark eluvial boulders consisting mainly of limonite, quartz and, as indicated by their weight, cassiterite. In addition, in some places a large number of crystals or irregular lumps of cassiterite, frequently coated by a film of iron-oxide, are found strewn over the surface. On account of the arid climatic conditions, the latter and limonite-boulders have not been moved to any appreciable distance from their outcrops, and the latter are therefore easy to locate. Prospecting here consists of the simple process of picking up all brownish and rusty-looking boulders and rock-fragments and testing their weight. There exist, however, a large number of barren limonite and quartz-limonite veins and bodies. Limonite-boulders without any appreciable quartz content very rarely contain cassiterite.

The weathering responsible for the production of the limonite is apparently very superficial. In the prospect shaft on Annaberg I it barely extends to a depth of 10 to 12 feet. Down to this depth (Fig. 1) the ore contains large amounts of reddish and yellowish iron oxides, particularly abundant where it fills irregular cavities in the limestone. The limestone forming the walls of the lode is generally also very weathered and stained reddish or yellow down to this depth.

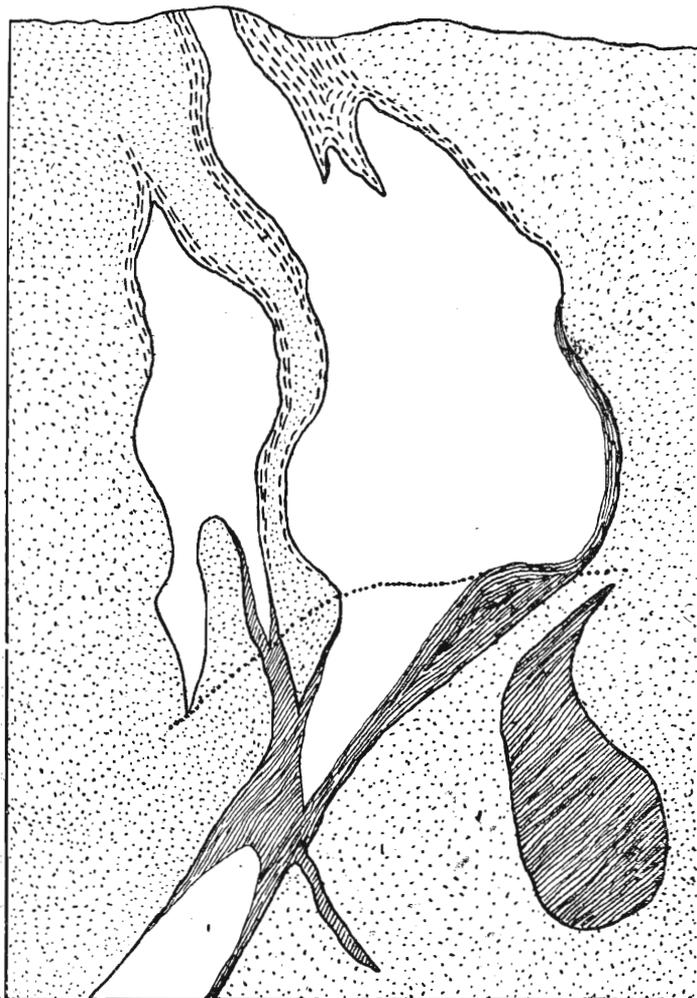
The limonite is partly of the fibrous type and often shows beautiful reniform surfaces where cavities occur. In places it passes over into haematite. In addition, masses of limonite often contain drusy cavities partly filled with agate, chalcedony or secondary quartz. The iron-oxides are no doubt derived from the decomposition of iron-sulphides (mainly pyrrhotite) and possibly also carbonates deposited with or after the cassiterite from hydrothermal solutions. Cubes of limonite, pseudomorphs after iron pyrites, are still preserved. Solution processes in the limestone along these fissures and the decomposition of iron- (and probably also manganese-) carbonates contained in it, may have also contributed a slight share.

Cassiterite.—The ore-lodes, consisting mainly of cassiterite and quartz, vary from mere fissure fillings, only a few inches across, to large drusy cavities in the limestone, 5-6 feet wide (Fig. 1). In addition, the cassiterite is to a large extent remarkably pure and massive. Blocks of almost pure cassiterite, weighing over 250 lbs., have been taken from quite shallow pits. Generally such massive cassiterite is full of drusy cavities, studded with well-formed crystals. Where fresh undecomposed contacts of cassiterite with the crystalline limestone were observed, it was partly found metasomatically to replace the calcite.

It is interesting to note, that in contradistinction to the cassiterite found in the pegmatite dyke previously described, which is of the ordinary brownish-red variety, that associated with vein-quartz and sulphides in the main occurrences is of the whitish-grey variety. Microscopic sections reveal the crystalline habit of the former (brown) variety to be mainly bipyramidal, the pyramid faces being well

FIG. 1.

Section through south-wall of prospect-shaft on Annaberg I.  
 Scale: 1 inch = 3½ feet.



-  Coarse crystalline limestone.
-  Decomposed yellowish limestone.
-  Mainly pyrrhotite arsenopyrite and quartz,
-  Massive cassiterite, quartz, pyrrhotite, arsenopyrite, iron- and copper-pyrites, bornite, with limonite in great abundance above dotted line, which marks approximate lower depth of weathering and above which the ore body contains numerous cavities filled with brown earthy matter.

developed, the prism faces very poorly or hardly at all. Twinning is very frequent and gives rise to characteristic re-entrant angles. In addition, this variety in the Erongo Tinfields is invariably a product of pneumatolytic replacement of feldspar and quartz.

The other variety (whitish-grey), however, apart from the different conditions of its deposition, *i.e.*, from hydrothermal solutions, shows a marked tendency towards the prismatic habit. In drusy cavities long and slender columnar crystals have been found with the prism faces perfectly developed and terminated by a very low pyramid.

Although by far the most abundant, cassiterite is not the only tin-mineral found in this interesting deposit. In one of the southern workings there occurs directly associated with cassiterite, quartz and the sulphides, an interesting bright green mineral containing tin, which has been named "Arandisite." (*Vide* F. Partridge: A new Tin-mineral from South-West Africa; *Trans. Geol. Soc. S.A.*, Vol. XXXII, 1929.)

*Sulphides*.—Another interesting feature of this occurrence is the presence of abundant sulphides directly associated with the cassiterite-quartz lodes. In the upper horizon exposed, *arsenopyrite* is the most abundant of these. This occurs not only irregularly disseminated throughout the ore-mass, but also as massive veins and irregular bodies in the adjoining calcite. In a prospect shaft on Annaberg I, it occurs together with pyrrhotite mainly as a selvage of varying width along the foot of the ore-body and as an irregular body of considerable width in the adjoining limestone (Fig. 1). Its weathering has given rise to films of white arsenic oxide.

Where observable, the arsenical pyrites is generally moulded on crystals of cassiterite, and therefore appears to be somewhat later than the latter.

*Pyrrhotite*.—Below the zone of weathering (limonite), particularly in the lowest depths so far attained, pyrrhotite is the most abundant sulphide present and frequently occurs in large masses.

*Iron-pyrites* is also fairly abundant and sometimes occurs in large cubes or rectangular blocks, frequently altered to limonite in the upper weathered zone. Probably at least part of the iron-pyrites has resulted from the alteration of the pyrrhotite.

*Copper-pyrites* is generally also irregularly distributed in fair abundance in the ore-body. It gives rise to stains and films of malachite along its margins and other fissures.

*Bornite* is also present, sometimes in fair abundance, in the lower horizons exposed.

Both iron- and copper-sulphides, and to a lesser extent also arsenopyrite, also occur as specks in the adjoining limestone away from the ore-body, where they metasomatically replace the calcite.

*Native Bismuth*.—A few pieces of native bismuth were found in one of the prospect shafts, but not *in situ*.

## HYDROTHERMAL NATURE OF THE DEPOSIT.

While nearly all the occurrences of cassiterite in the Erongo Tin-fields are pneumatolytic in nature (associated with pegmatites, the cassiterite replacing felspar, quartz and occasionally iron-tourmaline or impregnating fissures in the immediate vicinity of pegmatites) (*loc. cit.*), there exist a few isolated occurrences showing transitions from pneumatolytic to hydrothermal conditions. Typical pneumatolytic minerals gradually recede, till the cassiterite is no longer associated with them. At the same time quartz (non-pegmatitic) and pronounced hydrothermal minerals increase and finally entirely replace the former. This occurrence near Arandis is the largest and most important of the last type so far discovered.

The evidence in support of this may be briefly stated as follows:—

- (1) Entire absence of felspar or any remnants of a pegmatitic base.
- (2) Absence of typical pneumatolytic minerals.
- (3) Association of cassiterite with non-pegmatitic quartz, pyrrhotite, arsenopyrite, Fe- and Cu-pyrites, bornite and bismuth ore.
- (4) The fact that the cassiterite-quartz lode was found to cut a pegmatite of a type similar to that which in the neighbourhood carries pneumatolytic cassiterite.
- (5) The nature of the contours of the ore-bodies suggests the deposition of the minerals in solution-fissures in crystalline limestones.
- (6) The very pronounced difference in physical features, such as colour and crystalline habit, of the two types of cassiterite.
- (4) The massive and continuous nature of the cassiterite to form veins and large, drusy masses.

*Total output* from September, 1928, to September, 1929: 14·52 metric tons.