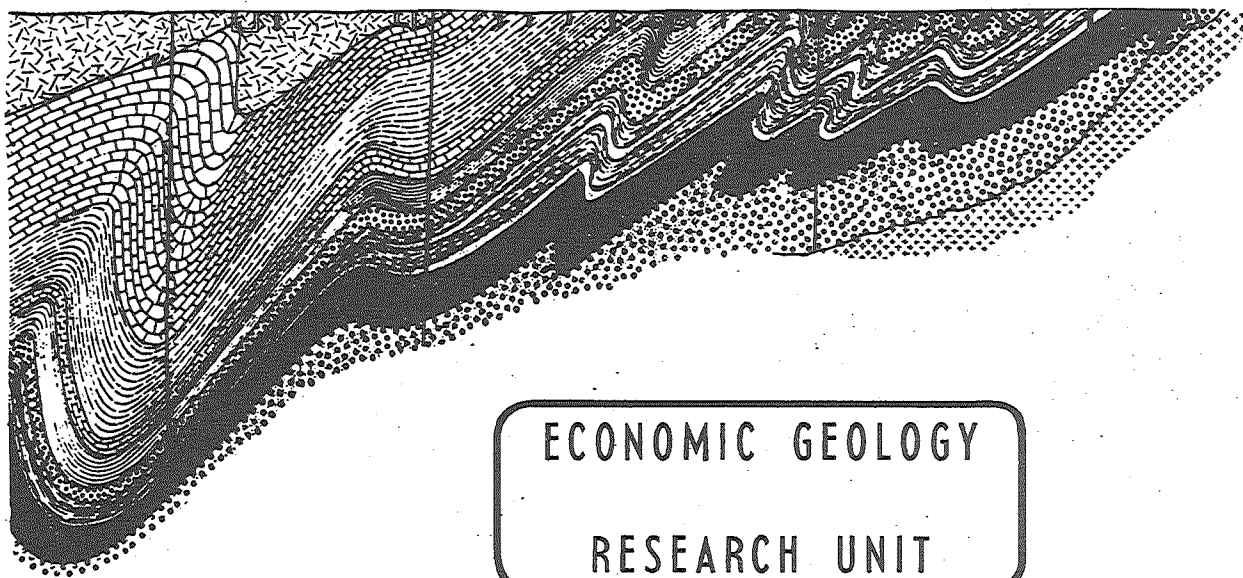




UNIVERSITY OF THE WITWATERSRAND
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RESEARCH UNIT

INFORMATION CIRCULAR No. 42

NEWLY OBSERVED ORE-MINERALS FROM THE
BASAL REEF IN THE ORANGE FREE STATE
GOLDFIELD IN SOUTH AFRICA

R. SAAGER

UNIVERSITY OF THE WITWATERSRAND
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by

R. SAAGER

Visiting Specialist in Mineralogy from Zürich,
Switzerland, in the Economic Geology Research Unit

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ABSTRACT

The occurrence of seven newly observed ore-minerals in the Basal Reef of the Witwatersrand System in the Orange Free State Goldfield is reported and their genetical and textural significances are discussed. It can be shown that some of the ore-minerals are either, detrital components introduced at the time of blanket formation or, they represent recrystallized constituents, mobilized during the metamorphism of the conglomerates. In addition, hydrothermal minerals are also present in the reef. It is further demonstrated that the polygenetic nature of the ores is not only the cause of their complex paragenesis, but appears also, to be the reason for the different and controversial interpretations regarding the origin of the ore which were put forward by its previous investigators.

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INTRODUCTION

The auriferous conglomerates of the Witwatersrand ore-deposit show a considerable variety of different ore-minerals. Notwithstanding the fact that pyrite, chromite, pyrrhotite and uraninite account for almost all the ore-minerals, a large number of trace ore-minerals were already known to early students of the deposit (1, 3, 7, 8, 23, 28). In his description and discussion of the origin of the ore-body, Ramdohr (10) was able to identify more than 20 ore-minerals. In the subsequent ore-microscopical studies of Liebenberg (6), Taylor et al (24), von Rahden (9), Viljoen (27) and Schidlowski (16, 17) further ore-minerals were detected and identified. Up to this stage, the number of known ore-minerals in the Witwatersrand conglomerates exceeded 40 different varieties.

During a detailed microscopical and geochemical investigation of the Basal Reef in the Free State Geduld Mine, near Welkom in the Orange Free State Goldfield, the writer identified 36 ore-minerals (Table 1), seven of which were observed for the first time in the conglomerates, and are described in this paper.

TABLE 1

Ore-Minerals Observed in the Free State Geduld Mine

Pyrite	Mackinawite	Gold
Marcasite	Niccolite	* Dyscrasite
Arsenopyrite	Millerite	Magnetite
Glaucodot	Pentlandite	* Hematite
Pyrrhotite	Cobaltite	Ilmenite
Sphalerite	Linnaeite	Rutile
Galena	Gersdorffite	Chromite
Chalcopyrite	Skutterudite	Uraninite
Cubanite	* Safflorite	Brannerite
Chalcopyrrhotite	* Tennantite	Thucholite
Bravoite	* Stromeayerite	Graphite
* Molybdenite	* Proustite	Leucoxene

* Ore-minerals observed for the first time in
Witwatersrand gold-ores

Thus, with the inclusion of these newly recorded minerals, more than 50 ore-minerals have now been recognized and described in Witwatersrand gold-ores.

Using the traditional subdivision, introduced by Young (29), the ore-constituents were divided into an allogenic group and an authigenic group. The first group embraces all the detrital components introduced during the time of banket

formation, while the second group consists of all the minerals which grew within the blanket, either, as newly formed or, recrystallized grains.

For the purpose of this report, more than 200 polished sections were examined. Most of the hand specimens were collected underground in the mine by the author. Some specimens were, however, drawn from the sample collections of the Free State Geduld Mine and the Head Office of the Anglo American Corporation in Johannesburg. The exact sample localities of most of the specimens are known. The polishing procedure was carried out at the University of the Witwatersrand, Johannesburg, using methods described by Saager (13). Besides the commonly used mineral identification techniques, tests of microhardness and reflectivity determinations were undertaken, while in a few cases, X-ray diffraction and electron-microprobe investigations were also carried out, in order that an accurate and unequivocal identification of the observed ore-minerals might be obtained.

ALLOGENIC ORE-MINERALS

A. MOLYBDENITE

Molybdenite was positively identified in three polished sections. The mineral always appears as idiomorphic inclusions in waterworn pyrite grains. It forms thin, highly elongated flakes, that are usually somewhat bent, and whose maximum lengths are about 70 microns (Plate 1, Figure 1). Under the microscope the molybdenite shows an extremely strong reflection pleochroism. The mineral exhibits the characteristic deep blue intense anisotropism colours when observed under incompletely crossed nicols. Reflectivity measurements, all of which gave values substantially higher than 30 per cent, and the detection of sulphur with the electron-microprobe, confirmed the optical identification of the molybdenite.

The different optical properties and greater abundance of graphite, helped to alleviate any possible confusion between the graphite and the molybdenite. Graphite was also found to form thin, elongated, and in many cases, bent or even broken flakes, but is either associated with carbon or occurs as isolated aggregates. Schidlowski (17), in his paper on graphite, reports an identical appearance of this mineral to that recorded above by the writer. His investigations clearly revealed that graphite was formed in situ from carbon as a result of regional metamorphism.

The occurrence of molybdenite exclusively as inclusions in detrital pyrite grains makes it certain that the molybdenite entered the conglomerate together with the surrounding pyrite, and must, therefore, be an allogenic component of the blanket. The bending of the molybdenite flakes was obviously caused by tectonic movements. Because the surrounding pyrite does not show any evidence of cataclasis, it is suggested that the molybdenite, which is an early crystallizing mineral, must have been exposed to some old tectonic movements in the primary ore-deposit. This deformation took place prior to the crystallization of the mantling pyrite. It is understandable, that cataclastic pyrite could never have survived the rigours of long transport distances which these rounded pyrite grains have undergone. Associations of bent molybdenite flakes in non-cataclastic, enveloping pyrite grains have been reported from Norwegian sulphide ore-bodies by Vokes (26) and by Saager (12). Both these authors came to similar conclusions concerning this somewhat puzzling assemblage. The occurrence of molybdenite in rounded pyrite grains indicates that some of the Witwatersrand ores might have been derived from pegmatitic-pneumatolytic primary ore-deposits. Molybdenite has been reported by Schneiderhöhn (18) in gold-quartz veins, which, without doubt, could represent the

sources of the commonly occurring quartz-, pyrite-, and arsenopyrite-pebbles, as well as for the now reconstituted gold. Molybdenite, however, is also known to be present in the much lower temperature deposits of Bou Azzer in North Africa, and Chingolobwe in the Congo. This is in agreement with the appearance of cobaltite, linnaeite, skutterudite, uraninite, etc., in the Witwatersrand conglomerates.

B. HEMATITE

Hematite was recognized only once as a minute inclusion, intergrown with magnetite, in a rounded pyrite grain. The observed blueish-grey colour, the strong pleochroism, and striking anisotropism, as well as the strong red internal reflections and the hardness relations with the adjacent magnetite and pyrite, provided sufficient evidence for a positive identification to be made.

The magnetite-hematite inclusion observed, possibly represents a remnant of a rounded black-sand pebble, pyritized subsequent to its deposition. Replacement relics, particularly of magnetite, have occasionally been found in pyrite pebbles of the Basal Reef (Plate 1, Figure 2). Relics of other black-sand components, i.e. titaniferous magnetite, banded ironstones, and itäberites, are fairly common in most of the reefs and have been described by several authors. It seems clear that pure magnetite and hematite rarely produced relic structures. Consequently pseudomorphism of pyrite after magnetite and hematite can only be recognized where these minerals form replacement relics in pyrite. This explains the apparent scarcity of magnetite, martite, and hematite, among the former black-sand components. In contrast the titaniferous magnetite frequently exhibits extremely striking relic structures, since the present pyrite pebbles show rutile inclusions as remnants of the former ilmenite network in magnetite.

The sulphur which was necessary for the pyritization of the black-sand components was either derived from chemically inorganic, or biological, processes. This means that the sulphur could either be related to the high sulphide content of the original conglomerates, which was partially reconstituted during metamorphism, or it could be related to sulphur producing organisms. In this connection, the occurrence, at times, of a rather high carbon content, as well as the extensive appearance of spherical to subspherical structures (vererzte Bakterien) in the ore, should be mentioned (14, 15, 20). These structures, together with the carbon, may well represent signs of the presence of primitive organic life in the area of sedimentation of the Witwatersrand conglomerates.

C. DYSCRASITE

Dyscrasite was observed in two polished sections. In one, it formed an elongated lancet-shaped inclusion associated with pyrrhotite in a waterworn cobaltite grain. In the other polished section, it occurs as roundish inclusions together with chalcopyrite and pyrrhotite in a compact, detrital pyrite (Plate 1, Figure 3). In both cases the dyscrasite formed true three dimensional inclusions and did not merely represent chance intersections of infiltrations and embayments by the plane of the polished section. Therefore, it can be stated that dyscrasite, together with its waterworn host-sulphides, was introduced at the time of banket formation. Recently, dyscrasite has also been observed by von Rahden (personal communication), associated with pyrrhotite as inclusions in allogenic pyrite grains, originating from the Vaal Reef at the Hartebeestfontein Mine, in the Klerksdorp area. The mode of occurrence is, therefore, identical to that described from the Basal Reef.

The dyscrasite aggregates are, in all cases, very minute, with the largest diameters reaching about 30 microns. The polishing-hardness of the mineral is notably

lower than that of the surrounding pyrite, but only slightly lower than the hardness of pyrrhotite and chalcopyrite. In oil immersion, a weak reflection pleochroism in white and creamish-white colours could be recognized. The anisotropism is very distinct and is completely different from the anisotropism shown by native arsenic and bismuth, both of which were studied by way of comparison. The reflectivity of the dyscrasite is essentially higher than that of pyrite, and a value of 62.2 per cent, using a wavelength of 590 nm was obtained. All these observations were clearly diagnostic of dyscrasite. Exsolution textures, reported by Ramdohr (11) in dyscrasite from Canada, were not encountered in the Witwatersrand material.

The genetical significance of the occurrence of dyscrasite in the ore is somewhat obscure. It is clear that dyscrasite is an extremely rare allogenic constituent in the deposit. The mineral occurs as inclusions in detrital sulphides and is apparently favourably associated with pyrrhotite. Dyscrasite is a fairly common constituent in the ore-deposit of Cobalt, Ontario (25). This fact can be reconciled with the occurrence of Co-Ni-minerals in the Witwatersrand conglomerates where in particular, the appearance of a dyscrasite inclusion in a cobaltite pebble, suggests a primary source, which might have been of a similar nature to the above-mentioned deposit of Cobalt, Ontario.

AUTHIGENIC ORE-MINERALS

A. SILVER-SULPHOSALTS (Stromeyerite and Proustite)

Stromeyerite and proustite were observed in one polished section from a sample obtained near the contact of a dyke which cuts across the Basal Reef at a rather obtuse angle. Both these silver minerals are closely associated with galena which, together with sphalerite and chalcopyrite, gives rise to specimens highly enriched in these sulphides, at this dyke contact.

Proustite was observed twice in the polished section. In the first case, it forms an irregular, small inclusion in the galena, while in the second, it occurs together with quartz in the same galena aggregate. In contrast with the galena, proustite is slightly softer, and has a whitish-blue colour and a notably lower reflectivity. In oil immersion, its colour is a distinct blue. Reflection pleochroism, together with strong anisotropism, and light-red internal reflections were also observed. The optical distinction between proustite and pyrargyrite could not be determined due to the extremely small grain-size. However, the almost total absence of antimony in the Basal Reef, the occurrence of tennantite in the galena enrichment, the strong pleochroism, and the distinct blue colour observed in oil immersion, provided a satisfactory identification (Plate 2, Figure 5).

Stromeyerite occurred in the same polished section as the proustite and is also closely associated with galena. Both these minerals, galena and stromeyerite, replace cubic-shaped pyrite (Plate 1, Figure 4). Compared with galena, stromeyerite is softer, and has a slightly lower reflectivity. Reflection measurements gave unsatisfactory results due to the relatively fast light-etching of the stromeyerite. In oil immersion, a weak pleochroism, in delicate violet-purple to creamy greenish-white colours, was observed. This, together with the characteristic anisotropism, enabled a positive identification of stromeyerite to be made. Extended exposure of the mineral to the unfiltered illumination, used in the ore-microscope, produced the typical intergrowth pattern reported by Stephens (22) for light-etched stromeyerite.

The weakly occurring "oleanderblatt structures" are a sign that the stromeyerite was exposed to temperatures higher than 93°C . Studies of Schwartz (19) and Ramdohr (11) indicated that above this temperature the rhombic stromeyerite attains a cubic form, but reverts back to its rhombic structure when cooled below 93°C . This transformation is the cause of the formation of the peculiar, lancet-shaped lamellae (oleanderblatt structure) observed in the stromeyerite aggregates that were studied. Such a heating of stromeyerite, above 93°C , which clearly is not the result of cementative processes, is in good agreement with its present position in the banket, namely, adjacent to a dyke contact.

The presence of the two silver minerals was unexpected, since, with the exception of native silver (9), silver-bearing minerals have never been reported from the Witwatersrand conglomerates. This implies that almost the entire silver production of the mines is derived from the gold, which usually carries about 10 per cent silver. During the last few years the fineness of the Witwatersrand gold has been the subject of many investigations and controversial discussions. Lawn (5) noted large variations of the silver contents of bullions in every mine he had investigated. This he ascribed entirely, to the variation of the fineness of the gold, as he made no allowance for the presence of any silver mineral. It is understandable, that the possible silver content of the sulphides, which are present in the Witwatersrand conglomerates, might cause the difference in the Ag/Au-ratio of ore-samples. Von Rahden (9) defined as "apparent fineness", the fineness of the gold produced from an ore-sample, which not only contains gold-silver alloys but one which also contains other argentiferous minerals. However, Hargraves (4) and von Rahden (9) demonstrated that the different base metal sulphides occurring in the Witwatersrand conglomerates carry negligible amounts of silver, and are therefore, not the reason for the variation of the Ag/Au-ratio in ore-samples.

Fisher (3) indicated that he had never found naturally occurring gold with a fineness below 450. With this finding in mind, von Rahden put forward the hypothesis that all ore-samples which produced gold possessing a fineness lower than 450 must carry silver minerals. Later in a sample obtained from the Ventersdorp Contact Reef at Ventersdorp, he noted the occurrence of native silver. The silver minerals observed in the Basal Reef help to underline the hypothesis put forward by von Rahden. It seems possible, that at least locally, the Ag/Au-ratio of ore-samples is affected by the presence of silver minerals. The variation in the Ag/Au-ratio of ore-samples is, therefore, not necessarily related to a change in the fineness of the gold present in these samples.

The clearly authigenic nature of the two silver minerals associated with the galena enrichment, together with the fact that they were found only along the contact of an intrusive dyke, suggests that the formation of these minerals is somehow related to the dyke intrusion. One possible explanation is that they formed by mobilization phenomena induced by the dyke intrusion. The silver minerals, in this instance, would have been formed during the reconstitution of the ore-minerals by concentration from the finely dispersed silver originally present in the galena. A second possible mode of formation was by hydrothermal mineralization associated with the intrusion of the dyke. The author considers the latter explanation to be the more likely, for the following reasons. No decrease in the galena content of the normal Basal Reef could be observed in the immediate vicinity from where the specimen, highly enriched in galena, was obtained. Thus, it is difficult to explain the formation of the galena enrichments by mobilization. The galena, however, is commonly distributed in an extremely fine state in the Basal Reef. A decrease of the galena content can, therefore, very easily be overlooked. The chalcopyrite and sphalerite enrichments which were also found alongside the dyke-contact are even more difficult to explain by mobilization phenomena, since chalcopyrite only occurs in very minute amounts in the Basal Reef, while sphalerite has only been observed two or three times, forming extremely small inclusions in pyrite.

B. TENNANTITE

A mineral of the tetrahedrite-group has been recognized by Ramdohr (11) "... and reliably determined in very few grains only in two sections both from the Main Reef". Because Ramdohr does not give any further description of the occurrence of this mineral, and because a mineral of the tetrahedrite-group was found several times in the material studied during this investigation, brief mention of the mineral will be made here.

Occurring in two distinctly different associations (Plate 2, Figures 5 and 6), the mineral of the tetrahedrite-group was recognized as the arsenic-rich member, tennantite. It forms roundish to irregular inclusions of less than 50 microns diameter in the earlier described galena enrichments, which also carry proustite and stromeyerite. The higher polishing-hardness of tennantite and its distinct greenish tinge against the background of the surrounding galena, as well as its isotropism and reflectivity (approximately 29 per cent), allowed a positive identification to be made (2). Undoubtedly, the tennantite inclusions in the galena were formed in situ and a similar mode of formation as for the proustite and stromeyerite is suggested.

Together with galena, tennantite is much more abundant as inclusions in porous buckshot pyrite. Also in these cases, tennantite and galena must be regarded as authigenic constituents which were mobilized during regional metamorphism and which were introduced into the porous pyrite grains. This mobilization resulted, in many instances, in typical hydrothermal textures. Such pseudo-hydrothermal phenomena are, in fact, also known to occur abundantly in the conglomerates among other ore-minerals. Ramdohr (10) considered that the transport of material had been effective over only very short distances, measurable in fractions of an inch, rather than over hundreds of feet. There is thus, no relation between the two types of occurrence of tennantite, since tennantite infiltrations into pyrite have been recognized over the entire area where the reef was studied, and not only close to the dyke-intrusion.

C. SAFFLORITE

Safflorite was seen in one polished section completely surrounding a cobaltite pebble, while in a few other sections it occurred as peripheral inclusions in porous buckshot pyrite, or intergrown with gold (Plate 2, Figures 7 and 8). In oil immersion, the mineral exhibits strong anisotropism and a distinct reflection pleochroism, with blueish to greyish colours. The reflectivity is almost the same as for pyrite, which in many cases, has hampered the distinction between the pyrite and the safflorite inclusions. An excellent expedient, where such difficulties occurred, has proved to be the difference in the polishing-hardness of the two minerals. The initial recognition of safflorite, where it surrounds the cobaltite pebble, was extremely difficult, and a positive identification could only be obtained by making use of X-ray diffraction. Generally, it proved difficult to distinguish between safflorite, gersdorffite, skutterudite and linnaeite, not only because they all reveal similar optical properties, but also because they all form mobilized, irregular aggregates. X-ray diffraction as well as the electron-microprobe was used in many cases to distinguish these four minerals. It is, therefore, probable that safflorite occurs more abundantly and might have been overlooked in the past, especially when it is associated with one of the three above-mentioned Ni-Co-minerals.

Safflorite, skutterudite, gersdorffite, and linnaeite are all remobilized minerals and are commonly closely associated with similarly reconstituted gold. They surround the gold or occur as infiltrations and fracture-healings in allogenic ore pebbles. This remarkable affinity between gold and Co-Ni-minerals has interested many students of the

Witwatersrand ores. Clearly the remobilized Ni-Co-minerals have, subsequent to their deposition, acted as favourable precipitation and enrichment agents for the gold which was also remobilized. The strongly marked association of gold and cobaltite reported by Liebenberg (6), von Rahden (9) and Sharpe (21) was not observed in the samples investigated from the Basal Reef. On the contrary, the cobaltite appears to deviate from all other Co-Ni-minerals and occurs as distinctly waterworn detrital grains. Of the more than 1000 cobaltite aggregates investigated by the author this mineral has been found to occur in only two or three instances as irregular in situ formations. Intimate contemporaneous intergrowths, mineral encirclements and fracture-healings of cobaltite and gold do, therefore, not appear. On the other hand, cobaltite pebbles containing some rounded gold inclusions, very similar to the gold inclusions in the allogenetic pyrite pebbles, have been observed. These assemblages clearly represent mineral intergrowths originating from the primary ore-deposits. The detrital nature of such pebbles was clearly demonstrated with the discovery of a rounded cobaltite grain, carrying myrmekitic gold and pyrrhotite, and irregular inclusions of galena. A more detailed study of this unusual cobaltite pebble is in preparation by the author.

It is clear that the cobaltite in the Basal Reef of the Free State Goldfield did not act as a collector for the metamorphic remobilized gold, as was suggested by Liebenberg (6), who regarded this as a common feature in all Witwatersrand ore-horizons. Contrary to his statement, the more rare gold-cobaltite assemblages must be accepted to be of primary origin. The writer considers that such a difference between the Basal Reef and the other reefs is very unlikely, particularly when considering the otherwise almost identical mineralogy. It is suggested that Liebenberg may probably have confused cobaltite with safflorite, gersdorffite, skutterudite, and linnaeite. It is therefore proposed, that for reasons as yet unknown, only the secondarily mobilized Ni-Co-minerals and not the detrital cobaltite, acted as a collector for the gold which was reconstituted during the metamorphism of the banket.

From the genetical point of view the appearance of safflorite is not surprising. It points, as do the other Ni-Co-minerals, to primary ore-deposits of the Chingolobwe and Bou Azzer type as one of the possible sources of certain ore-minerals. It is, furthermore, plausible to accept that either linnaeite, gersdorffite, skutterudite or safflorite have been formed during the metamorphism, according to the availability of sulphur and arsenic. However, the almost exclusive occurrence of cobaltite as waterworn pebbles still forms a puzzling and as yet unsolved problem.

CONCLUSIONS

It has been shown in this paper that with careful microscopic study and modern mineral determination methods, further ore-minerals could be identified in the Witwatersrand gold-ores. The writer believes that continued detailed mineralogical studies of the reefs in other gold mines will reveal additional minerals, as yet undescribed in the Witwatersrand conglomerates.

The extremely complicated ore paragenesis of the conglomerates can only be explained by a polygenetic origin of the different ore components. This statement is emphasized by the genetical interpretations of the newly observed ore-minerals discussed in this paper.

Molybdenite and dyscrasite are doubtless allogenetic minerals, which have been introduced into the conglomerates as extremely rare and small inclusions in detrital minerals. Hematite, together with magnetite, occurs as replacement remnants of black-sand components

which were pyritized subsequent to their deposition. Safflorite, and part of the mineral tennantite, are newly formed minerals derived from material which was reconstituted by metamorphism. These minerals now exhibit pseudo-hydrothermal textures. Proustite and stromeyerite are considered to be hydrothermal minerals, formed at the time of, and as a result of, dyke intrusions.

It could also be shown that the primary deposits, which contributed towards the total mineral composition of the conglomerates, consisted of several different types. These are, for example : (a) pegmatitic-pneumatolytic deposits (tourmaline bearing gold-quartz veins, etc.); (b) hydrothermal deposits (type: Mother Lode, Chingolobwe, Dobschau etc.); and (c) sedimentary deposits (type: itaberites, banded ironstones etc.), after the classification of Schneiderhöhn (18).

A large number of genetical processes, which were involved in the formation of the Witwatersrand deposits, not only explain their complex mineralogy, but also account for the enormous difficulties which have to be overcome in providing a satisfactory interpretation of the ore formation. With certain reservations, it is possible to obtain specimens from the Witwatersrand ores which exhibit classic hydrothermal, placeristic or even sedimentary syngenetic characteristics. This means, therefore, that "proof" can be obtained for any genetical interpretation one wishes to construe on the origin of the Witwatersrand conglomerate ores.

The present investigation led the author to the conclusion that by far the largest amount of the ore components were doubtlessly derived from distant primary deposits and were carried into the basin of deposition either as pebbles, sand, or as fine material in suspension. A further considerable proportion of the ore-minerals is considered to have formed during, or just after, the formation of the banket, and is related partially to biogenetically precipitated material. The increase in pressure and temperature which took place as a result of the superposition of a thick succession of sediments and lavas, caused mobilization and reconstitution of the ore-minerals. These processes hardly altered the bulk chemical composition of the deposit but had a tremendous influence on the textural appearance of the ore. Lastly a very minor amount of the ore-minerals consist of hydrothermal mineralization which formed locally as a result of dyke intrusions.

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Key to Plates

Plate 1

- Figure 1 : Bent molybdenite flake (grey) together with gangue (black) forming an inclusion in a rounded pyrite grain (white). Free State Geduld Mine, Basal Reef. Oil-immersion, x360.
- Figure 2 : Magnetite inclusion (dark grey) in a waterworn pyrite grain (white). The magnetite is a replacement relic of a now pyritized black-sand pebble. Free State Geduld Mine, Basal Reef. Oil-immersion, x360.
- Figure 3 : Dyscrasite (bright white) together with chalcopyrite (grey) and pyrrhotite (dark grey) forming inclusions in a compact pyrite pebble (light grey). Free State Geduld Mine, Basal Reef. Oil-immersion, x520.

- Figure 4 : Galena (light grey) and slightly light-etched stromeyerite (somewhat darker and softer than galena) replacing idiomorphic pyrite (white). Free State Geduld Mine, Basal Reef. Oil-immersion, x360.

Plate 2

- Figure 5 : Galena (whitish grey, scratched) with irregular inclusions of tennantite (grey and harder than galena, lower centre) and of proustite (dark grey and softer than galena, centre). Gangue (black). Free State Geduld Mine, Basal Reef. Oil-immersion, x650.
- Figure 6 : Infiltration of tennantite (dark grey) and galena (grey) into the porous rim of a rounded pyrite grain (white). Gangue (black). Free State Geduld Mine, Basal Reef. Oil-immersion, x360.
- Figure 7 : Inclusions of galena (grey and with distinct relief) and of safflorite (slightly darker than galena and much harder) in an idiomorphic pyrite grain (white). Free State Geduld Mine, Basal Reef. Oil-immersion, x360.
- Figure 8 : Xenomorphic gold aggregate (white and scratched) surrounded by safflorite (grey and distinctly harder than gold). On the left side of the photograph part of a rounded pyrite grain can be seen (slightly brighter than safflorite). Gangue (black). Free State Geduld Mine, Basal Reef. Oil-immersion, x450.

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PLATE 1

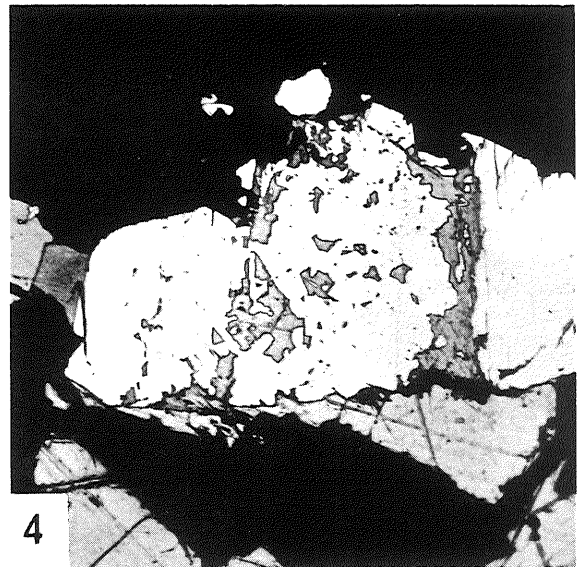
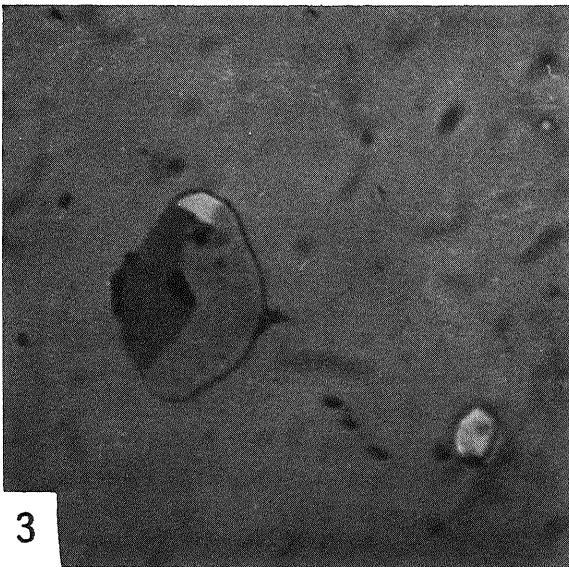
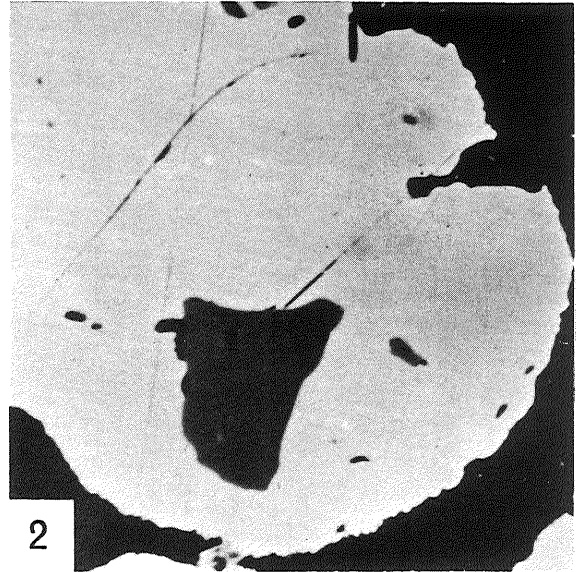
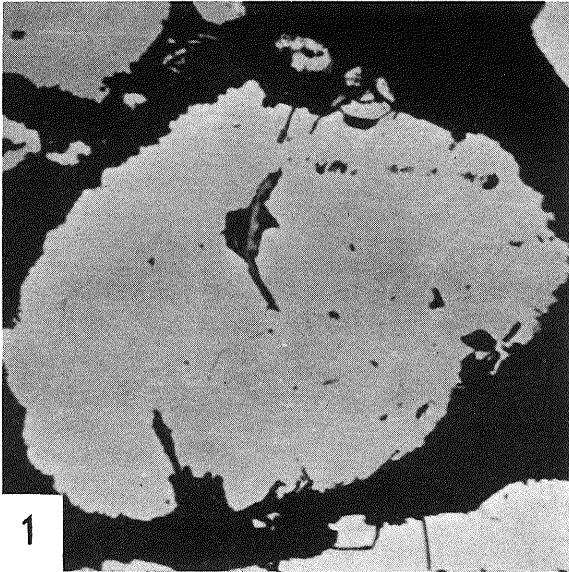


PLATE 2

