

of the bulk composition rather than an effect of temperature, as commonly supposed.

The results of the present study indicate that the mechanism for the formation of pyrrhotite proposed by Davidson appears to be more feasible than that suggested by Ramdohr.

Young (1917) remarked on the fact that pyrrhotite was usually accompanied by an abnormal amount of chlorite. In order to see whether any such close relationship existed between the chlorite and pyrrhotite of the V.C.R., the chlorite and pyrrhotite contents (by weight) were plotted graphically (Figure Nos. 20 and 21). The scattered distribution of the points indicates that no obvious quantitative relationship exists between the chlorite and pyrrhotite in the V.C.R. at Venterspost and Libanon.

SPHALERITE.

At least three generations of sphalerite occur in the V.C.R. at Venterspost and Libanon. The oldest generation occurs as tiny rounded grains of sphalerite completely encased inside grains of pyrite, which were obviously derived from an earlier horizon.

More generally, however, the sphalerite occurs as xenomorphic grains which replace earlier sulphides such as pyrrhotite and chalcopyrite. The first, and presumably the older, type displays reddish internal reflections under crossed nicols and occasionally contains oriented inclusions of chalcopyrite and also frequently shows (111) twinning of the larger grains. The second type exhibits honey-coloured internal reflections and does not contain any chalcopyrite. The difference in the colour of the internal reflections shown by the two types indicates that the darker variety is richer in FeS, being formed at a slightly higher temperature. Vokes (1957) has indicated that the iron content of honey-coloured sphalerites is of the order of 6%.

The grains of sphalerite from the V.C.R. were too small to permit the drilling-out of the grains from polished section for X-ray analysis without severe contamination. A sample of sphalerite was, however, obtained from the Bird Reef at Luipaardsvlei. and was examined by means of polished sections, and also chemically analysed for iron. The colour of the internal reflections shown by the Bird Reef specimens of sphalerite appeared to be virtually identical to that of the darker variety of

sphalerite present in the V.C.R. Fuller (1959) has shown, on the basis of unit cell measurements, that samples of sphalerite from the Bird Reef at Luipaardsvlei were most probably formed at about 450 degrees Centigrade.

Chemical analysis of the present sphalerite specimens from the Bird Reef showed an FeS content of 10.60% FeS. This figure, when interpreted in terms of the FeS-ZnS solvus as prepared by Kullerud (1953), suggests a temperature of formation of approximately 400 degrees Centigrade, no allowance being made for the effect of pressure and depth of burial. Barton and Kullerud (1958) further point out that equilibrium assemblages of sphalerite with pyrite will only give a minimum temperature of formation if the temperature is estimated from the solvus for the FeS-ZnS system.

These findings, supported by the fact that exsolved chalcopyrite has been found in sphalerite samples from the V.C.R. (Plate LII), may be taken as an indication that the unmixing of the chalcopyrite from sphalerite occurred in the temperature range of 350-400 degrees Centigrade (Buerger 1934). This therefore represents a minimum temperature to which the V.C.R. must have been raised by the outpouring of the overlying Ventersdorp lavas.

OTHER ORE MINERALS.

Chromite.

The chromite of the V.C.R. was found to occur in two different forms, either as dull black compact octahedra showing signs of rounding, or as brilliant black octahedra showing considerably less rounding and with a saccharoidal habit. These differences in the outward appearance of the two forms of chromite suggested a possible difference in composition. Accordingly, the chromite grains were handpicked and the two different forms were examined by the writer by means of X-ray diffraction using Copper K-alpha radiation.

Due to the high proportion of iron in the samples, the lines of the diffraction pattern showed considerable scattering. Despite this difficulty, the strongest lines, corresponding to d spacings at 2.51, 1.60, 2.08 and 2.95 Angstroms, were clearly visible. These spacings correspond very closely to those listed by Berry and Thompson (1962) for chromite with the composition $(Fe,Mg)Cr_2O_4$. The two diffraction patterns obtained from the two varieties of chromite appeared to be identical. This indicates that, in spite of the differences in their outward appearance, the two forms of chromite occurring in the V.C.R. have the same composition.

Galena.

The galena of the V.C.R. was found to occur in three different generations. The oldest generation occurred as fine anhedral grains and stringers

filling the interstices in fractured grains of uraninite, and must have originated as a result of the radioactive decay of the uraninite (Plate XV).

A second form of galena was found included in apparently ancient pyrite grains (Plate LIII). The third and youngest generation of galena occurred either as isolated anhedral grains embedded in quartz or alternatively, was associated with sulphides such as pyrite, chalcopyrite and pyrrhotite. Where the galena was associated with the sulphides, it either took the form of irregular stringers filling any cracks in fractured sulphide grains, or actually replaced the sulphides.

Chalcopyrite and cubanite (I)

The chalcopyrite of the V.C.R. was usually found to occur as anhedral grains and masses replacing earlier pyrite and pyrrhotite (Plate LIV). A minute inclusion composed of chalcopyrite, pyrrhotite and gold, the three of which jointly formed a single grain with mutual grain boundaries suggesting simultaneous deposition, was found inside a large grain of apparently ancient pyrite. This pyrite showed no obvious signs of healed cracks. This evidence suggests that this minor phase of chalcopyrite must be older than the major phase of chalcopyrite.

A more detailed study of the chalcopyrite was made possible by the use of a stain first suggested by Wachsmajew (1954) for the positive identification of chalcopyrite in sections suspected of containing

pentlandite, chalcopyrite and gold. The stain was prepared by mixing 100 volume strength hydrogen peroxide and concentrated ammonia (specific gravity 0.900) in the ratio of 1:1 by volume.

Unfortunately, no details for the use of the stain were given by Wachromejew. The present writer found that consistent results were only obtainable with this stain when a freshly prepared mixture was used. It was also found that, prior to use, the mixture should be left to stand until it became warm, this stage being accompanied by effervescence. All vestiges of grease should be removed from polished sections before staining. The sections should not be immersed in the staining mixture for longer than 10 seconds at a time. The progress of the staining process should be constantly checked under a microscope.

The staining mixture works relatively slowly at first, and stains the chalcopyrite iridescent in shades of blue and red. At the same time, any features such as twinning or inclusions of exsolved cubanite are rendered clearly visible. Prolonged contact with the staining mixture results in the formation of a dull brownish film on the surface of the chalcopyrite, and renders the section totally unsuitable for micro-photography.

After etching by this method, the chalcopyrite in the present suite of samples was found to show twinning and also to contain numerous anisotropic, creamy-coloured laths of cubanite.

According to Schwartz (1927), the presence of such laths of exsolved cubanite is typical of high temperature deposits which had attained temperatures of at least 450°C. (Plates LV, LVI).

Chalcopyrrhotite or Cubanite (II)

According to Ramdohr (1960), chalcopyrrhotite has a brownish colour not unlike that of pyrrhotite, but with a somewhat brownish tinge, and is weakly anisotropic. Ramdohr further felt that this was the reason why chalcopyrrhotite had often been overlooked, or taken for pyrrhotite, or had been described on occasion as isotropic pyrrhotite or brownish isotropic chalcopryite.

A mineral conforming to the characteristics listed by Ramdohr was found in the present suite of samples from the V.C.R. in intimate contact with undoubted pyrrhotite. After staining with a mixture of hydrogen peroxide and ammonia, the pyrrhotite, as may be seen in the attached photographs (Plates LVII, LVIII), was left completely unattacked, whilst the chalcopyrrhotite, which may be seen to occur as an aureole surrounding the pyrrhotite, was stained a dull brown. (Ramdohr was unable to suggest any specific etch reagent for the identification of chalcopyrrhotite, but felt that, in view of the overall tendency for chalcopyrrhotite to tarnish readily, it could be expected to be sensitive towards etch reagents.)

According to Edwards (1947), pyrrhotite dissolving in chalcopryite at temperatures above 300°C

could be expected to react with the chalcopyrite and to give rise to an aureole of chalcopyrrhotite-chalcopyrite around the residual area of pyrrhotite. Borchert (1934) mentioned that the range of temperatures of solid solution of pyrrhotite and chalcopyrrhotite lay in the region between 350 and 550°C. Ramdohr (1960), however, merely mentioned that in those cases where the minerals were found associated with one another, the temperature of formation of the chalcopyrrhotite must have exceeded 240°C.

Unfortunately, no X-ray diffraction data are available for the positive identification of chalcopyrrhotite, which some authorities do not even accept as a distinct mineral. The optical properties of the mineral described above and the "text-book" aureole which it forms around the pyrrhotite, however, leave little doubt that this mineral is in fact chalcopyrrhotite (cubanite II).

Marcasite.

Only a single grain of marcasite was found during the present study. The grain occurred embedded in the centre of a large pyrite grain. At first inspection the overall colour of the marcasite grain closely resembled that of its pyrite host, but careful study revealed the presence of a slight brownish pleochroism. Under crossed nicols the grain showed intense anisotropism and could readily be distinguished from its pyrite host. Marked anisotropism is the

only reliable method known for distinguishing marcasite from pyrite, other than the use of X-ray diffraction. This latter technique could, however, not be used in the present instance, since the grain was too small to permit drilling out from its pyrite host without severe contamination.

Cobaltite

Cobaltite was found to be far more prevalent in the V.C.R. than was previously thought. It occurred as pinkish-white weakly anisotropic grains, which either had a rounded outline, or occurred as jagged irregular grains showing replacement by gold. (Plates XII, XI). A single pyritohedral crystal of cobaltite was also located. The association of cobaltite with gold, and its origin, has already been referred to under the heading of "Gold".

Leucopyrite and loellingite.

Leucopyrite occurred as anhedral intergrowths with pyrite (Plate LIX). The mineral showed a distinct white colour and extreme hardness, and was strongly anisotropic, with greenish, purple and dark brown polarization colours. These polarization colours differed from those shown by a single grain of loellingite embedded in quartz, which was found to have yellow to deep blue polarization colours (Plate LX).

Both minerals showed the characteristic etch reactions listed for their identification by Short (1948).

The presence of leucopyrite in the V.C.R. at Venterspost has already been mentioned in an earlier

study by Davies (1949), so that little doubt concerning its identity exists.

Pentlandite.

Pentlandite was found to occur only as intergrowths in pyrrhotite in the V.C.R. Its nature and significance has already been discussed under the heading of "Pyrrhotite".

Other minerals present.

Various other minerals were identified in the present suite of samples from the V.C.R. by means of micro-chemical tests and/or optical studies. Unfortunately the identification of these minerals could not be verified by means of X-ray diffraction, as in most cases only minute isolated grains of these minerals were found. In addition, these grains were usually in intimate contact with, or embedded in, other minerals.

The presence of these minerals in the V.C.R. does not help in the elucidation of the mode of mineralization of the horizon. Accordingly, only the salient features of these minerals have been listed below.

Glaucodot.

A few strongly anisotropic small white grains with a faint pinkish tinge were found and identified as glaucodot. The glaucodot grains were embedded in pyrrhotite.

Osmiridium

A single rounded whitish grain showing a high degree of reflectivity and extreme hardness, and which was apparently negative to all etch reagents, was identified as osmiridium.

Skutterudite.

A few small tin-white coloured pyritohedra were found embedded in quartz, well below the plane of the polished section, and were tentatively identified as skutterudite.

Linnaeite.

A single grain conforming to the characteristics listed by Wachromejew (1954) for linnaeite was found. The mineral occurred as an overcapping on an ancient pyrite grain.

Arsenopyrite.

The presence of arsenopyrite in the pyritic and tuff beds of the V.C.R. has already been reported by Davies (1949). In the present suite of samples, only a single strongly-anisotropic diamond-shaped grain of arsenopyrite was found, embedded in a host of pyrite.

Millerite.

A cluster of acicular bronze-yellow crystals arranged in delicate radiating groups, not unlike millerite in appearance, was found embedded below the surface of a large quartz grain. These crystals were tentatively identified as millerite.

Niccolite.

The presence of niccolite in the horizon was established by micro-chemical analysis of a grain obtained from a heavy-mineral concentrate. No grains answering to the description of niccolite were detected in polished section.

Gersdorffite.

Polished section studies revealed the presence of a few white to steel-grey cubo-octahedra and striated pyritohedra embedded in quartz, which were tentatively identified as gersdorffite.

Covellite - Neodigenite - Chalcocite - Bornite.

These four copper minerals were only found as very minute grains in close proximity to, or as inclusions in, chalcopyrite, and were identified solely on the basis of their optical characteristics.

PARAGENETIC SEQUENCE.

The paragenetic sequence of the minerals occurring in the V.C.R. was for the most part determined by the classical criteria suggested by workers such as Bastin and others (1931) and Schwartz (1942).

In those cases where the order of deposition could not be determined with certainty from polished section studies alone, criteria such as exsolution features and geochemical evidence were used as geological thermometers, in the manner suggested by Ingerson (1955) and McKinstry and Kennea, (1957).

The sequence of deposition of the minerals with respect to time shown in the accompanying table indicates only the general trend, and does not reflect minor and obviously localized departures from the overall pattern of mineralization.

PARAGENETIC SEQUENCE OF MINERALS IN THE V.C.R. AT
VENTERSPOST AND LIBANON.

GOLD	-----	-----	-----
URANINITE	-----	-----	-----
OSMIRIDIUM	-----	-----	-----
ZIRCON	-----	-----	-----
CHROMITE	-----	-----	-----
COBALTITE	-----	-----	-----
PYRITE	-----	-----	-----
RUTILE	-----	-----	-----
LINNAEITE	-----	-----	-----
SPHALERITE	-----	-----	-----
GALENA	-----	-----	-----
CARBON	-----	-----	-----
GLAUCODOT	-----	-----	-----
MARCASITE	-----	-----	-----
ARSENOPYRITE	-----	-----	-----
LEUCOPYRITE	-----	-----	-----
LOELLINGITE	-----	-----	-----
GERSDORFFITE	-----	-----	-----
SKUTTERUDITE	-----	-----	-----
NICCOLITE	-----	-----	-----
BROOKITE	-----	-----	-----
ANATASE	-----	-----	-----
LEUCOXENE	-----	-----	-----
BIOTITE	-----	-----	-----
PYRRHOTITE	-----	-----	-----
MILLERITE	-----	-----	-----
PENTLANDITE	-----	-----	-----
CUBANITE	-----	-----	-----
CHALCOPYRITE	-----	-----	-----
CHALCOPYRRHOTITE	-----	-----	-----
CHLORITE	-----	-----	-----
BERICITE	-----	-----	-----
SILVER	-----	-----	-----
BORNITE	-----	-----	-----
CHALCOCITE	-----	-----	-----
COVELLITE	-----	-----	-----
NEO-DIGENITE	-----	-----	-----

Vertical axis: Order of deposition.

Horizontal axis: Time.

ECONOMIC IMPLICATIONS.

The results of the present study suggest that the following factors may be responsible for "tailing losses" (incomplete recovery of the gold) experienced during the extraction of the gold from the V.C.R. at Venterspost and Libanon:

1. Coatings on gold particles a) iron oxides
b) silver
2. Fine size range of the gold
3. Presence of phyllosilicates in the ore

1. Coatings.

a) Iron oxides:

The V.C.R. ore at Venterspost and Libanon contains appreciable amounts of pyrrhotite and an unstable variety of pyrite. Both these minerals oxidize readily, with the concomitant liberation of ferrous iron ions. This ferrous iron then oxidizes further and coats the particles of gold in the ore with ferric oxide, thereby rendering the gold non-amenable to cyanidation. In order to minimize tailing losses, therefore, the V.C.R. ore should not be stockpiled for any length of time.

b) Silver:

The presence of coatings of silver on a few gold grains found during the present study, although probably only of academic interest, may possibly account for the presence of isolated bright particles of gold in the "tails". It is a well-known fact that the rate of dissolution of silver in a cyanide solution is considerably slower than that of gold, and accordingly, where

gold grains are coated with silver, the time normally allowed for the cyanidation of ores would probably only be sufficient to allow for the removal of the silver coating and partial dissolution only of the underlying gold grain.

2. Fine size range of the gold.

As can be seen from Figure No. 1, most of the gold in the V.C.R. was found to be of a very fine nature, with over 80% of the gold grains being smaller than 90 microns in size, whilst 37% of the gold grains were less than 15 microns in size. The grains in the 1-15 micron range were almost all chatted with quartz and phyllosilicates. Such grains would probably not be liberated completely during the crushing process used on the mines, and would therefore possibly not be amenable to cyanidation.

3. Presence of phyllosilicates in the ore.

Further tailing losses may possibly be caused by the presence in the V.C.R. ore of large amounts of phyllosilicates, which have a tendency to clog the pores of the filters used to remove the gold-cyanide complex from the pulp.

Variations in the apparent fineness of gold with the tenor of the ore.

A further factor which should be borne in mind when considering the discrepancy which often exists between "call" and recovery figures of gold, is the variation in the apparent fineness of the gold with the

tenor of the ore. These variations are shown graphically in Figures nos. 7 and 8. These graphs show a progressive increase in the apparent fineness of the gold with increasing gold value of the ore until a critical point is reached, after which the apparent fineness of the gold remains reasonably constant. It is therefore felt that, when estimating "call" figures, the use of one fixed overall value for the silver content of the gold may introduce errors. This is especially the case when some of the ore is of such a grade that it lies below the critical point on the graph, in the region where the apparent fineness of the gold varies rapidly with the tenor of the ore. This question clearly needs further investigation on a scale beyond the scope of the present survey.

CONCLUSIONS.

The origin of the gold in the Witwatersrand Banket has been a subject of discussion and heated controversy ever since gold was first discovered on the Witwatersrand in the latter part of the last century. There are two major schools of thought concerning the origin of the gold: one school envisages a hydrothermal origin for the gold, whilst the other supports a placer origin. The theory apparently receiving the most support at present is a variation of the placer theory known as the "modified placer theory". This hypothesis envisages the recrystallization and/or solution followed by redeposition of previously alluvial gold, with the assumption that these processes took place more or less in situ.

With regard to the origin of the gold in the V.C.R., the results of the present study at Venterspost and Libanon seem, on first inspection, to be somewhat inconclusive. The majority of the gold grains found in the V.C.R. were hackly and irregular in outline, a mode of occurrence which seems to favour a purely hydrothermal origin for the gold, but on the other hand, strong support for an original placer origin of the gold is provided by the small cylindrical grains of gold which were isolated from apparently ancient pyrite. These cylinders appear to be identical to those illustrated by Dunn (1929) for gold of undoubted detrital origin from Australia. They probably owe their preservation in the V.C.R. to their pyrite host, which

presumably prevented the grains from undergoing solution and subsequent redeposition, which appears to have been the fate of the major portion of the gold.

Both of these forms of gold existing in the V.C.R. are, in fact, those which are to be expected in terms of the modified placer theory.

If the modified placer theory is valid, then the source of the gold in the V.C.R. must be some horizon at present underlying the V.C.R. In this context, it is interesting to note that studies carried out on the zircons of the Main Reef and the overlying V.C.R. showed such close similarities as to suggest a common source for the zircons present in both horizons.

Davies (1949), on the other hand, has presented evidence which, in his view, would rule out the Main Reef as a source of the gold in the V.C.R. His argument was based on the following grounds: firstly, that the grains of gold in the V.C.R. were coarser than those in the underlying Main Reef, which was contrary to what would have been expected if attrition and transportation losses had occurred, and secondly, that the fineness values of the gold in the V.C.R. were practically identical to those of the gold in the Main Reef. This similarity in the finenesses is not in accordance with the trend envisaged by Lindgren (1913), who found that the "fineness" of alluvial gold apparently increased downstream from the lode source, and attributed this feature to the preferential leaching of silver relative

to gold by water in a process of erosion and stream transport.

The findings of the present writer are in agreement with those of Davies both with regard to the coarseness of the grains of gold in the V.C.R. relative to those in the Main Reef and with regard to the similarity of the upper apparent fineness values of the two horizons. The writer feels, however, that these facts may have an alternative interpretation, which would not necessarily result in the Main Reef being ruled out as a possible source of the gold in the V.C.R. Firstly, Lindgren's explanation of the reason for the fineness gradient found by him in alluvial gold may not be valid in the present context: experiments carried out by the present writer have clearly shown that even nitric acid is unable to remove silver from alloys of gold and silver whose fineness exceeds 615 parts per thousand. (It should be noted that the major portion of the gold examined from both the V.C.R. and the Main Reef had apparent fineness values well above 615.) Accordingly, Davies' (1949) objection concerning the similarity in the apparent fineness values of the two horizons appears to be irrelevant. Further, it is felt that the fact that the grains of gold in the V.C.R. are coarser than those in the Main Reef may possibly be accounted for if it is assumed that solution of the smaller gold grains derived from the Main Reef took place, followed by their redeposition in the V.C.R. as coarser hackly particles and crystals. Evidence to this effect is afforded by the presence of a few minute

euohedral and subhedral crystals of gold with bright facets showing no signs of attrition, observed in polished section. More detailed polished section studies further revealed the presence of various micro-structures in the gold grains themselves after the grains had been etched. These microstructures and the irregular outline shown by the gold grains (to which reference has already been made) strongly suggest that the gold was apparently recrystallized more or less in situ, and that it has not undergone any significant degree of transportation since its deposition in the V.C.R.

The present writer feels that the basic requirements of the modified placer theory are met by the presence in the V.C.R. of both the cylinders of apparently original detrital gold^{and gold} which has obviously undergone recrystallization and redeposition in situ, as shown by the micro-structures present in the gold. It is also felt that the Main Reef may be considered a probable source of the gold in the V.C.R.

The temperature of mineralization of the V.C.R. is attested to by various geological thermometers, which are briefly listed as follows:

1. Sphalerite host showing blebs of exsolved chalcopyrite. Temperature range 350-400°C (Buerger, 1934).
2. Pyrrhotite with "flames" of pentlandite. 425°C. (Hewitt, 1938).
3. Chalcopyrite with exsolved laths of cubanite. 450°C. (Schwartz, 1927).

These geological thermometers, it is felt, indicate that the temperature of the V.C.R. was not raised to very much more than 450°C as an upper limit as a result of the outpouring of the overlying Ventersdorp Lavas.

BIBLIOGRAPHY.

- ACHUTHARAO, A., 1961, Colour types of zircons from
Archaean Complex of Mysore State: Science and
Culture, v. 27, pp. 98-99.
- AHRENS, L.H., 1954, Quantitative spectrographic analysis
of silicates: Pergamon Press (London).
- ALBEE, A.L., 1962, Relationships between the mineral
association, chemical composition and physical
properties of the chlorite series: Am. Mineralogist,
v. 47, pp. 851-870.
- ARNOLD, R.G., 1954, A preliminary account of the miner-
alogy of the uraniferous conglomerates of Blind
River, Ontario: M.Sc. Thesis (unpublished)
University of Toronto.
- BARTHAUER, G.L., RULFS, C.L. and PEARCE, D.W., 1953,
Investigations of thucholite: Am. Mineralogist,
v. 38, pp. 802-814.
- BARTON, P.B. and KULLERUD, G., 1958, The Fe-Zn-S system:
Ann. Rept. Dir. Geophys. Lab. Washington (1957-1958):
pp. 227-229.
- BASTIN, B.S., GRATON, L.C., LINDGREN, W., NEWHOUSE, W.H.,
SCHWARTZ, G.N. and SHORT, M.N., 1931, Criteria of
age relations of minerals with special reference to
polished sections of ores: Econ. Geology, v. 26,
pp. 561-602.
- BERRY, L.G. and THOMPSON, R.M., 1962 X-ray powder data
for ore minerals: Geol. Soc. America Memoir 85.

- BORCHERT, H., 1934, "Über Entmischung im System Cu-Fe-S und ihre Bedeutung als "geologische" Thermometer: Chem. der Erde, v. 9, pp. 145-172.
- BUERGER, N.W., 1934, The unmixing of chalcopyrite from sphalerite: Am. Mineralogist, v. 19, pp. 525-530.
- CAMERON, E.N., 1961, Ore microscopy: Wiley (New York).
- CARSTENS, C.W., 1941, Über sedimentäre Schwefelkies-vorkommen: Nat. Norsk Videnskabs Selskabs Forh., v. 14, pp. 120-122.
- COETZEE, G.L., 1955, The Cu, Co and Ni content of some S.A. pyrites: M.Sc. Thesis (unpublished) University of the Witwatersrand.
- COHEN, E., 1961, Contribution to discussion of "Fineness of gold in some Southern Rhodesian mines": Trans. Inst. Min. Metall. London, v. 71, pp. 340-345.
- COLEMAN, L.C., 1957, Mineralogy of the Giant Yellowknife gold mine, Yellowknife, N.W.T.: Econ. Geology, v. 52, pp. 400-426.
- DANA, 1909, A system of mineralogy: 6th Edit., Wiley (London). 1946, Dana's system of mineralogy: 7th Edit., v. 1, Wiley (London).
- DAVIDSON, C.F., 1957, On the occurrence of uranium in ancient conglomerates: Econ. Geology, v. 52, pp. 668-693.
- 1960, The present state of the Witwatersrand controversy: Mining Mag. (February-March-April 1960).
- 1961, The Witwatersrand controversy: Mining Mag., v. 105, pp. 88-90.

- and BOWIE, S.H.U., 1951, On thucholite and related hydrocarbon-uraninite complexes: Great Britain Geol. Survey Bull., no. 3, pp. 1-19.
- DAVIES, D.N., 1949, The development and mineralization of the V.C.R. at Venterspost: M.Sc. Thesis (unpublished) University of the Witwatersrand.
- DE ROCK, W.P., 1940, The Ventersdorp Contact Reef. Its nature, mode of occurrence and economic significance. With special reference to the Far West Rand: Geol. Soc. S.A. Trans. and Proc., v. 43, pp. 85-107.
- 1948, The Carbon Leader of the Far West Rand with special reference to the proportion of the gold content of this horizon recovered in drilling: Geol. Soc. S.A. Trans. and Proc. v. 51, pp. 213-238.
- DUNN, E.J., 1929, Geology of gold: Griffin (London).
- DU TOIT, A.L., 1954, The geology of South Africa: 3rd Edit., Oliver and Boyd (London).
- EALLES, H.V., 1961, Fineness of gold in some Southern Rhodesian mines: Trans. Inst. Min. Metall. London, v. 71, part 2, pp. 49-73.
- EDWARDS, A.B., 1947, Textures of the ore minerals and their significance: Australian Inst. Mining and Metall. (Melbourne).
- ELLSWORTH, H.V., 1928, Thucholite, a remarkable primary mineral from Parry Sound: Am. Mineralogist, v. 13, pp. 419-439.
- FERGUSON, R.B., 1950, Red gold from the San Antonio mine, Bissett, Manitoba: Am. Mineralogist, v. 35, pp. 459-460.

FISHER, M.S., 1935, The origin and composition of alluvial gold with special reference to the Morobe goldfield, New Guinea: Trans. Inst. Min. Metall. London, v. 44, pp. 337-421 and 559-564.

1939, Notes on the gold, pyrite and carbon in the Rand banket: Bull. Inst. Min. Metall. London, v. 48, pp. 495-560.

FISHER, N.H., 1945, The fineness of gold with special reference to the Morobe goldfield, New Guinea: Econ. Geology, v. 40, pp. 449-495.

FOSTER, W.R., 1948, Useful aspects of the fluorescence of zircon: Am. Mineralogist, v. 33, pp. 724-735.

FRONDEL, C., 1958, Systematic mineralogy of uranium and thorium: U.S. Geol. Survey Bull., no. 1064.

FRYKLUND, V.C. and HARNER, R.S., 1955, Comments on minor elements in pyrrhotite: Econ. Geology, v. 50, pp. 339-345.

FULLER, A.O., 1958, A contribution to the petrology of the Witwatersrand System: Geol. Soc. S.A. Trans. and Proc., v. 61, pp. 19-51.

FULLER, A.O., 1958, Temperatures of formation of sphalerites from the Bird Reef group: Geol. Soc. S.A. Trans. and Proc., v. 61, pp. 97-103.

GEORGE, D.R., 1949, Mineralogy of uranium and thorium-bearing minerals: U.S. Atom. Energy Comm., R.M.O. 563 revised.

GOLDSCHMIDT, V.M., 1954, Geochemistry: Clarendon Press (Oxford).

- MALLIMOND, A.F., 1954, Polishing mineral specimens:
Mining Mag., v. 91, pp. 208-
- HARGRAVES, R.B., 1961, Silver content of gold in Witwatersrand conglomerates: Econ. Geology Research Unit, University of the Witwatersrand, Information Circ. No. 3.
- HAWLEY, J.E., 1952, Spectrographic studies of pyrite in some eastern Canadian gold mines: Econ. Geology, v. 47, pp. 260-304.
- and NICHOL, J., 1961, Trace elements in pyrite, pyrrhotite and chalcopyrite of different ores: Econ. Geology, v. 56, pp. 467-487.
- HEGEMANN, F., 1943, Die gemischte Bedeutung von Kobalt und Nickel im Pyrit: Zeitschr. angew. Mineral., v. 4, pp. 122-239.
- HEWITT, R.L., 1938, Experiments bearing on the relation of pyrrhotite to other sulphides: Econ. Geology, v. 23, pp. 305-338.
- HEY, M.H., 1954, A new review of the chlorites: Mineralog. Mag., v. 30, pp. 277-292.
- HOEKSTRA, H.R. and FUCHS, L.H., 1960, The origin of thucholite: Econ. Geology, v. 55, pp. 1716-1738.
- HOPPE, G., 1962, Petrogenetisch auswertbare morphologische Erscheinungen an akzessorischen Zirkonen: N.Jb. Miner. Abh., v. 98, pp. 35-50.
- HORNE, J.E.T., 1951, Notes on the photoluminescence of minerals: Great Britain Geol. Survey Bull., no. 3, pp. 20-43.

- HUNT, J.M., STEWART, F. and DICKEY, P.A., 1954, Origin of hydrocarbons of Uinta Basin: Am. Assoc. Petroleum Geologists Bull., v. 38, pp. 1671-1738.
- INGERSON, E., 1955, Methods and problems of geologic thermometry: Econ. Geology, 50th Ann. Vol., 1905-1955, pp. 341-410.
- JAEGER, J.C., 1957, The temperature in the neighbourhood of a cooling intrusive sheet: Am. Jour. Sci., v. 255, pp. 306-318.
- JORALEMON, P., 1951, The occurrence of gold at the Getchell mine, Nevada: Econ. Geology, v. 46, pp. 267-310.
- KEEP, F.E., 1939, Contribution to discussion of FISHER, M.S., 1939, Notes on the gold, pyrite and carbon in the Rand banket: Bull. Inst. Min. Metall. London, v. 48, pp. 542-543.
- KERR, P.R., 1945, Cattierite and vaesite: new Co-Ni minerals from the Belgian Congo: Am. Mineralogist, v. 30, pp. 483-497.
- MIJKYRAS, D., 1950, Untersuchungen der magnetischen Eigenschaften des Magnetkieses bei verschiedenen Temperaturen in besonderem Hinblick auf seine Entstehung: Neues Jb. Min. Beil.-Bd. (Abhandl.) v. 80A, pp. 297-342.
- KOEN, G.M., 1961, The genetic significance of the size distribution of uraninite in Witwatersrand bankets: Geol. Soc. S.A. Trans. and Proc., v. 64, pp. 23-54.

- KOEN, G.M., 1962, Note on chlorite pseudomorphs after detrital amphibole in Witwatersrand Banket: Geol. Soc. S.A. Trans. and Proc., (in print).
- KOSTERIN, A.V., ZUEV, V.N. and SHEVALEEVASKII, I.D., 1958, Zr/Hf ratio in zircons in some igneous rocks of northern Kirgizia: Geochemistry (English Edit.), no. 1, pp. 116-119.
- KRUMBEIN, W.C., 1935, Thin section mechanical analysis of indurated sediments: Jour. Geology, v. 43,
- KULLERUD, G., 1953, The FeS-Zns system. A geological thermometer: Norsk. geol. tidsskr., v. 32, pp. 61-147.
- and YODER, H.S., 1959, Pyrite stability relations in the Fe-S system: Econ. Geology, v. 54, pp. 533-572.
- LABUNTZOV, A.N., 1927, Mineralogy of northern Karelia: Izvestiya Akad. Nauk., pp. 609-
- LAWN, J.G., 1924, Presidential address on the subject of silver in Witwatersrand ores: Geol. Soc. S.A. Trans. and Proc., v. 27, pp. 29-31.
- LAWN, J.G., 1935, Contribution to discussion of article by FISHER, M.S., 1935, The origin and composition of alluvial gold with special reference to the Morobe goldfield, New Guinea: Trans. Inst. Min. and Metall. London, v. 44, pp. 391-392.
- LIEBENBERG, W.R., 1955, The occurrence and origin of gold and radioactive minerals in the Witwatersrand System, the Dominion Reef, the Ventersdorp Contact Reef and the Black Reef: Geol. Soc. S.A. Trans. and Proc., v. 58, pp. 101-255.

- LINDGREN, W., 1933, Mineral deposits: McGraw Hill (New York).
- MACADAM, P., 1931, The distribution of gold and carbon in the Witwatersrand bankets: Geol. Soc. S.A. Trans. and Proc., v. 34, pp. 81-89.
- MACDONALD, G.A., 1954, Activity of Hawaiian volcanoes during the years 1940-1950: Bull. Volcanology, 2nd series, v. 15, pp. 119-179.
- MATHIAS, M., 1962, A disharmonious granite; the Spitskop granite, S.W.A.: Geol. Soc. S.A. Trans. and Proc., Vol. 55, pp. 281-293.
- MCKINSTRY, H.B. and KENNEDY, G.C. 1957, Some suggestions concerning the sequence of certain ore minerals: Econ. Geology, v. 52, pp. 379-390.
- MENDELSSOHN, B., 1932, Notes on a vein containing cobaltite, gold and apatite on the Far East Rand: Geol. Soc. S.A. Trans. and Proc., v. 25, pp. 191-193.
- NISANYAN, G.B., 1959, Rutile and anatase in the Upper Devonian deposits of the Argichi River Basin: Zap. Armysansk. Otd. Vses. Mineralog. Obshchestva, no. 1, pp. 153-158. (Abstract in Chemical Abstracts, v. 57, no. 10, column 12128, 1961.)
- PABST, A., 1962, Personal communication (University of California.)
- PACERMAN, G.H., 1955, Volume, weight and number frequency analysis of sediments from thin section data: Jour. Geology, v. 63, pp. 50-58.

- PATCHETT, J.E., and NUFFIELD, E.W., 1960, Studies of radioactive compounds. The synthesis and crystallography of brannerite: Canadian Mineralogist, v. 6, pp. 483-490.
- PELLETIER, R.A., 1940, Pyrrhotite as an enriching factor in Rand ores: Chem. Metall. Mining Soc. S.A. Jour., v. 40, pp. 353-
- PETTIJOHN, F.J., 1948, Sedimentary rocks: Harper (New York).
- POLDERVAART, A. and ECKELMANN, F.D., 1955, Growth phenomena in zircon of autochthonous granites: Geol. Soc. America Bull., v. 66, pp. 947-948.
- TRENTICE, T.K., 1939-1940, Precious metal constituents of Witwatersrand ores: Assoc. Sci. and Tech. Soc. S.A. Ann. Proc., pp. 17-41.
- RAMDOW, P., 1958, New observations on the ores of the Witwatersrand in South Africa and their genetic significance: Akademie Verlag (Berlin). Annexure to v. 61, Geol. Soc. S.A. Trans. and Proc.
- 1960, Die Erzminerale und ihre Verwachsungen: Akademie Verlag (Berlin).
- RICE, R., 1958, Quoted by ROBERTSON, D.S. and STEENLAND, N.C., 1960, On the Blind River uranium ores and their origin: Econ. Geology, v. 55, pp. 659-694.
- ROBERTSON, D.S. and STEENLAND, N.C., 1960, On the Blind River uranium ores and their origin: Econ. Geology, v. 55, pp. 659-694.
- ROSSOUW, P.J., 1934, Unpublished company report on Borehole 11, Venterspost.

- SAMPSON, E., 1956, A procedure for polishing ore sections with diamond abrasives: Econ. Geology, v. 51, pp. 482-484.
- SCHWARTZ, G.M., 1927, Intergrowths of chalcopyrite and cubanite: Econ. Geology, v. 22, pp. 44-61.
- 1942, Progress in the study of exsolution in ore minerals: Econ. Geology, v. 37, pp. 345-364.
- SHARPE, J.W.N., 1950, The economic auriferous Bankets of the Upper Witwatersrand and their relationship to sedimentation features: Geol. Soc. S.A. Trans. and Proc., v. 52, pp. 265-301.
- SHARPE, J.W.N., 1955, Contribution to discussion of article by LIEBENBERG, W.R., 1955, The occurrence and origin of gold and radioactive minerals in the Witwatersrand System, the Dominion Reef, the Ventersdorp Contact Reef and the Black Reef: Geol. Soc. S.A. Trans. and Proc., v. 58, pp. 101-255.
- SHORT, M.N., 1948, Microscopic determination of the ore minerals: U.S. Geol. Survey Bull., no. 914.
- SIDEROV, G.P. and RAFEL'SKII, R.P., 1958, Hydrothermal synthesis of uraninite: Geology of uranium, Chapman (London).
- SMITH, E.A., 1913, The sampling and assay of precious metals: Griffin (London).
- SMITH, F.G., 1942, Variations in the properties of pyrite: Am. Mineralogist, v. 27, pp. 1-19.
- 1947, The pyrite geo-thermometer: Econ. Geology, v. 42, pp. 515-523.

- SPENCE, H.S., 1930, A remarkable occurrence of thucolite and oil in a pegmatite dyke: Am. Mineralogist, v. 15, pp. 499-520.
- STANTON, R.L., 1957, Studies of polished surfaces of pyrite and some implications: Canadian Mineralogist, v. 6, part 1, pp. 87-118.
- STRINGHAM, B., 1952, Fields of formation of some common hydrothermal alteration minerals: Econ. Geology, v. 47, pp. 661-664.
- TRAILL, R.J., 1954, A preliminary account of the mineralogy of radioactive conglomerates in the Blind River region, Ontario: Canadian Mining Jour., v. 75, pp. 63-68.
- TYLER, S.A. and MARSDEN, R.W., 1937, A discussion of some errors introduced in accessory mineral separations: Nat. Research Council Ann. Rept., pp. 3-9.
- VOKES, F.M., 1957, The copper deposits of the Birtavarre district, Troms, Northern Norway: Norges Geol. Undersökelse, v. 199, pp. 1-239.
- VON AUDEL, R., 1939, Sur l'importance dans les minerais d'or du calibre particules: Annales des Mines, 13e serie, v. 16, pp. 155-161.
- VON KNORRING, O. and HORNUNG, G., 1961, Hafnian zircons: Nature, no. 4781, pp. 1098-1099.
- WACHROMEJEV, S.A., 1954, Erzmikroskopie: VEB Verlag Technik (Berlin).
- WAGER, L.R., VINCENT, E.A., SMALES, A.A. and BARTHOLOMEW, P., 1957, Sulphides in the Skaergaard Intrusions, East Greenland: Econ. Geology, v. 52, pp. 835-903.

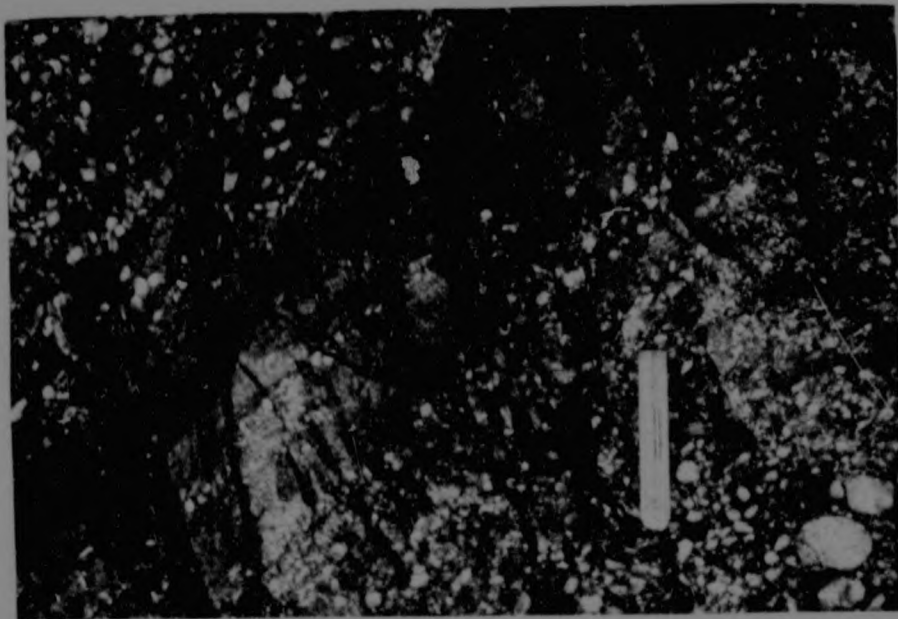
- WEISS, H., 1925, The application of X-rays to the study of alloys: Royal Soc. (London) Proc., Series A, v. 108, pp. 643-654.
- WALCOTT, A.J., 1926, Some factors influencing crystal habit: Am. Mineralogist, v. 11, pp. 221-258.
- WILLEMSE, J., 1962, Contribution to discussion of article by KOEN, G.M., 1962, Note on chlorite pseudomorphs after detrital amphibole in Witwatersrand Banket: Geol. Soc. S.A. Trans. and Proc. (In press).
- WYATT, M., 1954, Zircons as provenance indicators: Am. Mineralogist, v. 39, pp. 983-990.
- YOUNG, R.B., 1917, The banket of South African gold fields: Gurney and Jackson (London).
- ZIES, E.G., 1941, Temperatures of volcanoes, fumaroles and hot springs: in, Temperature, its measurement and control in science and industry, (Am. Physics Inst.) Reinhold (New York), pp. 372-380.

ABBREVIATIONS USED IN MICROGRAPHS.

CARBON	_____	C.
CHALCOPYRITE	_____	CPY.
CHALCOPYRRHOTITE	_____	CPYRR.
COBALTITE	_____	CO.
GALENA	_____	G.
GOLD	_____	AU.
LEUCOPYRITE	_____	LEUPY.
LEUCOXENE	_____	LEU.
PYRITE.	_____	PY.
PYRRHOTITE	_____	PYRR.
QUARTZ	_____	QTZ.
SILVER	_____	AG.
SPHALERITE	_____	ZN.
URANINITE	_____	U.

Plate I

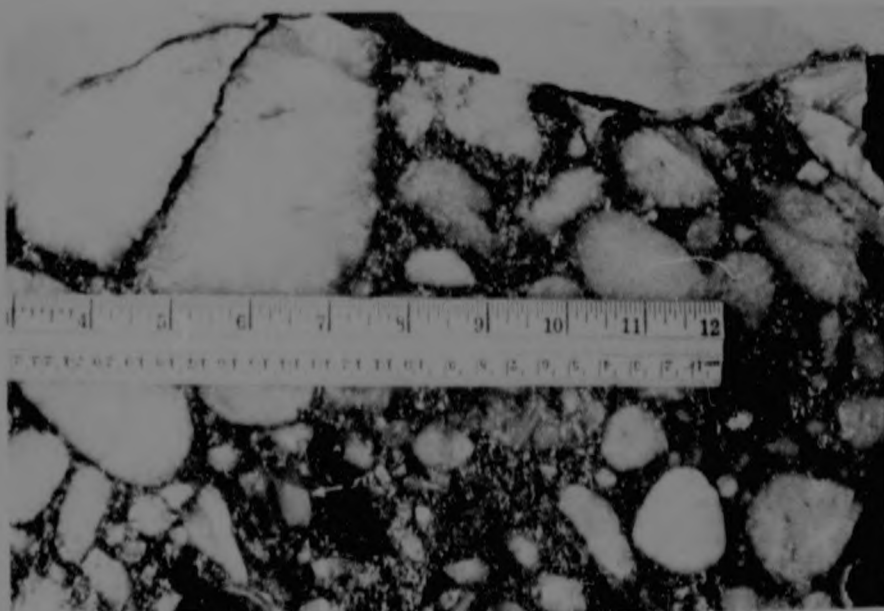
Scale 9" rule



Steeply dipping V.C.R. with central band of glassy quartzite. Note the wide variation in the size of the pebbles and cobbles.

Plate II

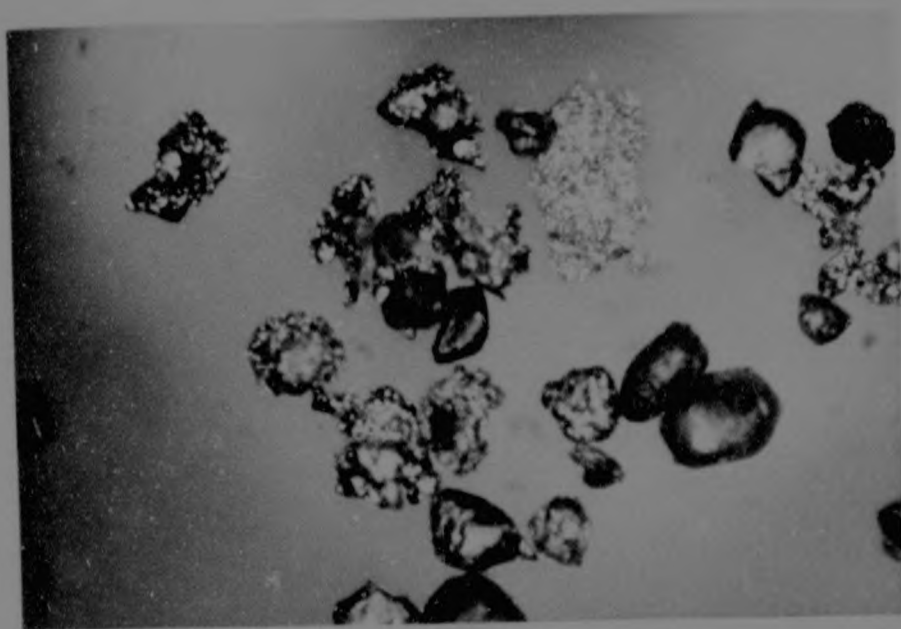
Scale 12" rule



V.C.R. ore containing an angular fragment of banded chert. Note the dark chlorite matrix and the replacement by chlorite on the periphery of the quartz pebbles.

Plate III

50 X



Hackly grains of gold and rounded zircon grains

Plate IV

50 X



Cylindrical and hackly grains of gold.

Plate V

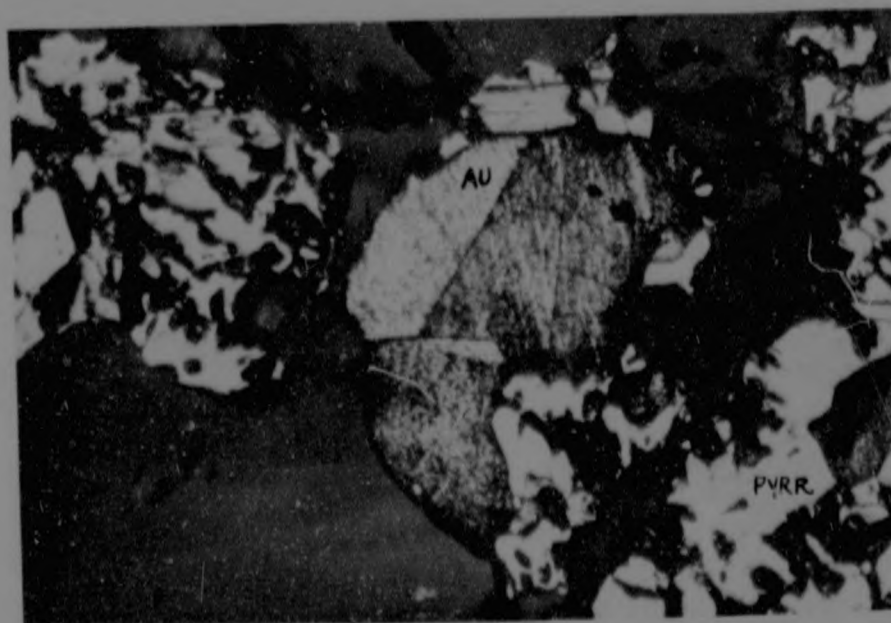
105 X



Etched gold grains apparently showing twinning.

Plate VI

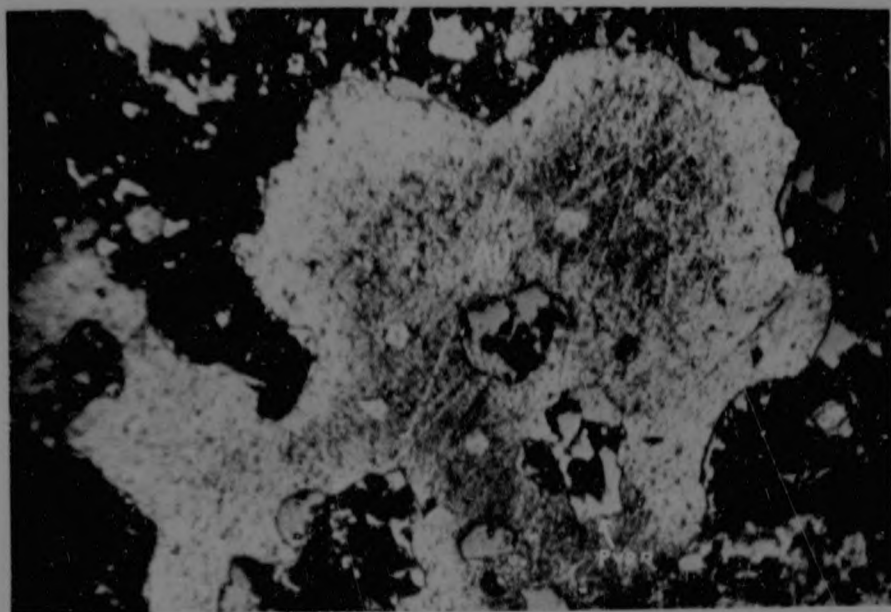
105 X



Etched grain of gold. Note the sharp boundaries of the segments.

Plate VII

105 X



Etched grain of gold showing minute crystals of included gold and "islands" of pyrrhotite.

Plate VIII

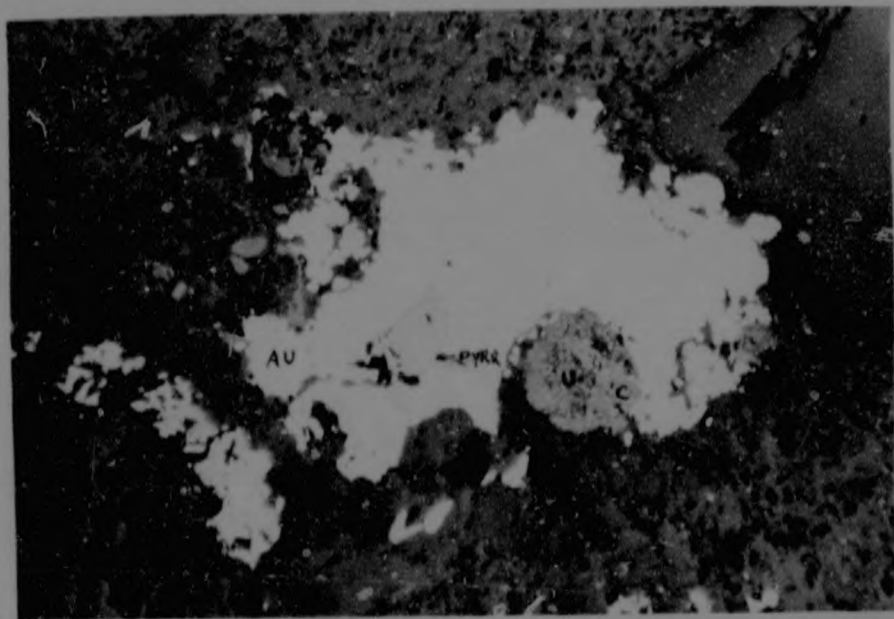
(Oil immersion) 700 X



Adjacent portions of an etched grain of gold showing differences in orientation, with suggestion of cubic structure.

Plate IX

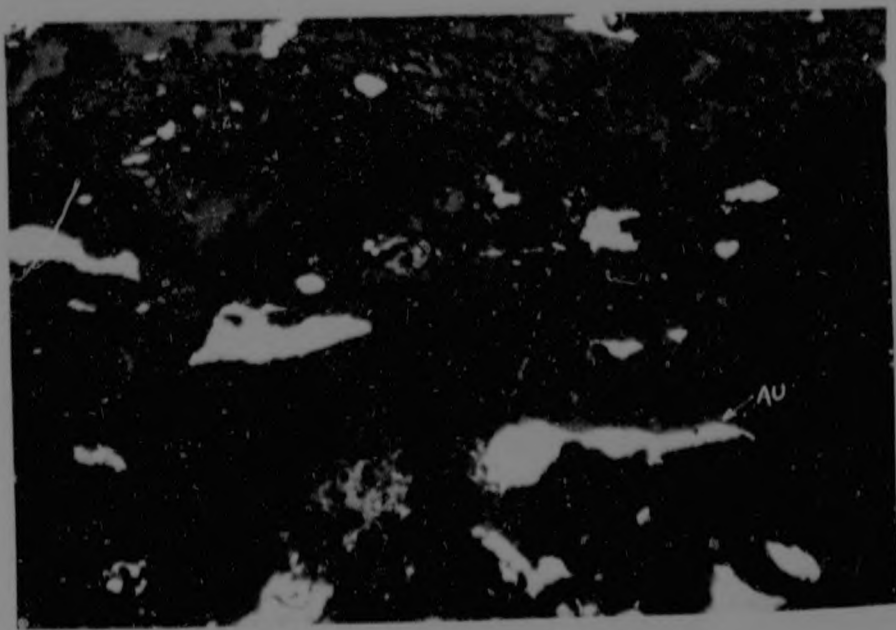
48 X



Gold replacing pyrrhotite.

Plate X

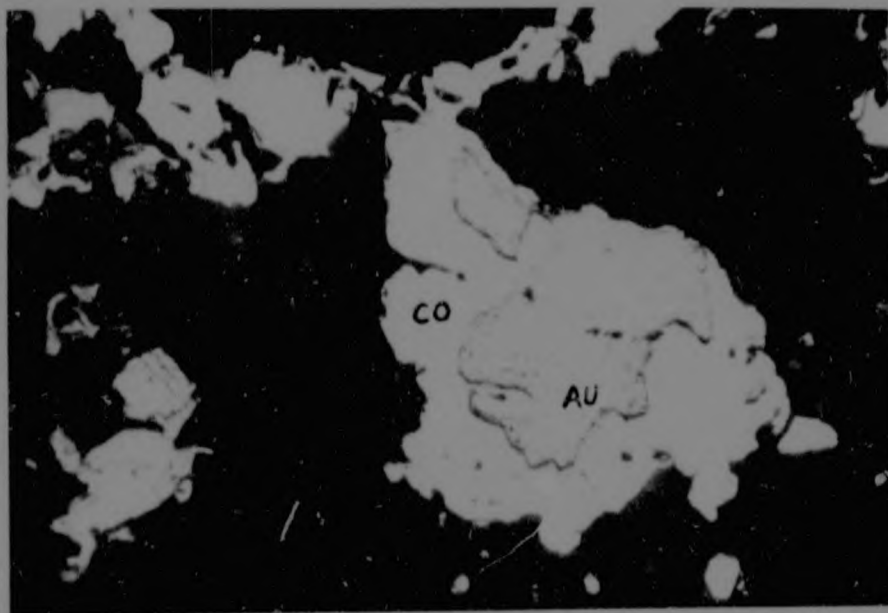
48 X



Anhedronal stringer-like grains of gold in a quartz and chlorite matrix.

Plate XI

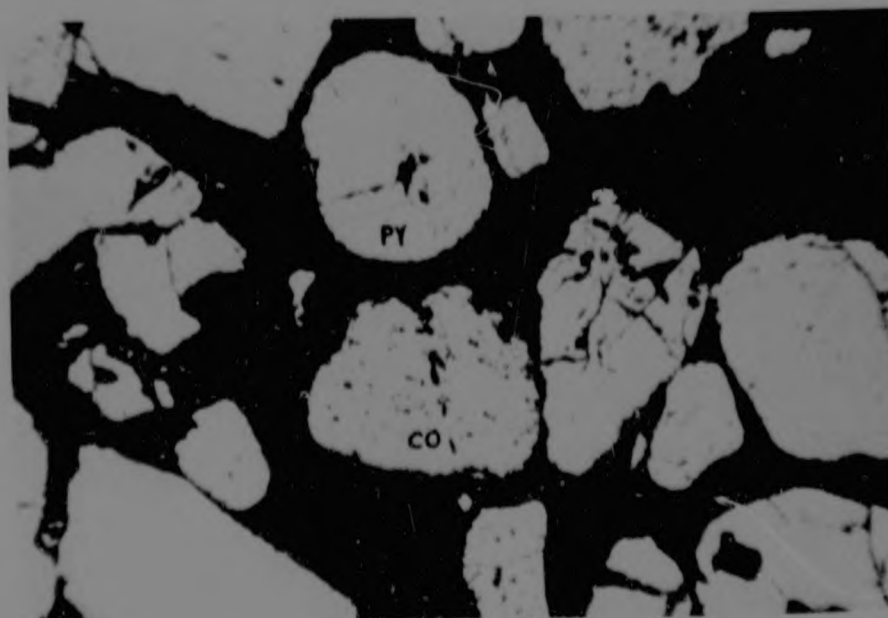
150 X



Gold replacing irregular grain of cobaltite.

Plate XII

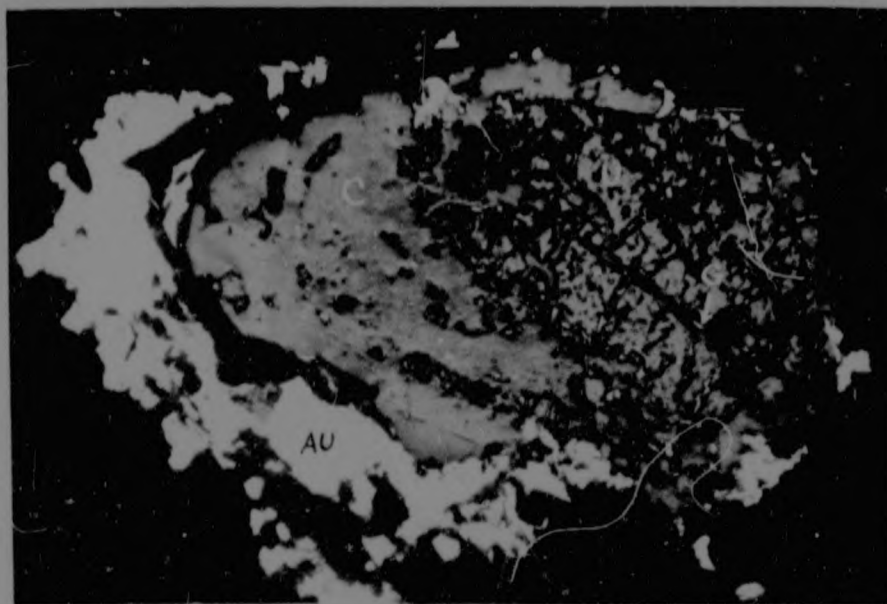
48 X



Abraded grains of cobaltite and pyrite.

Plate XIII

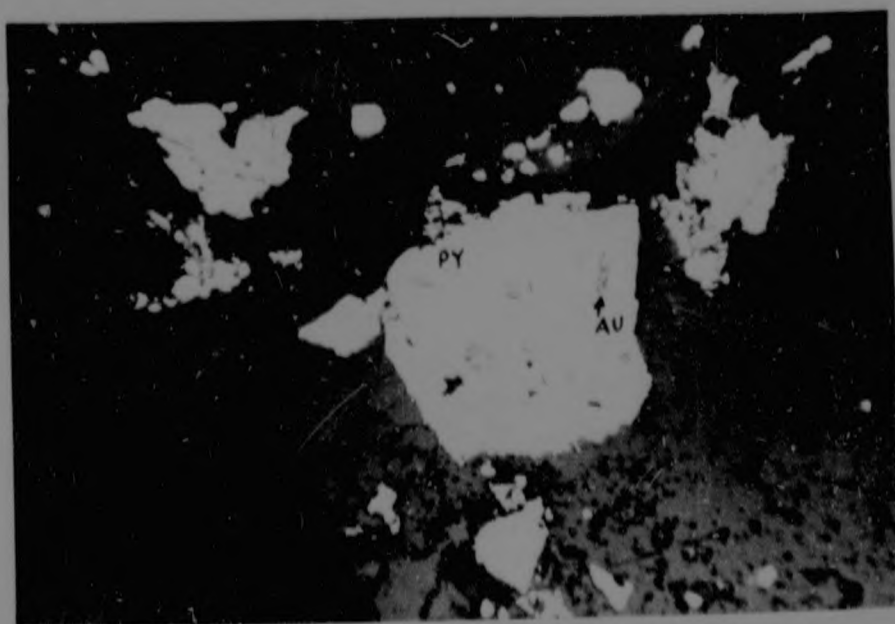
150 X



Gold clearly filling cracks in uraninite and "carbon" host. Note also the presence of galena grains in the cracks in the uraninite.

Plate XIV

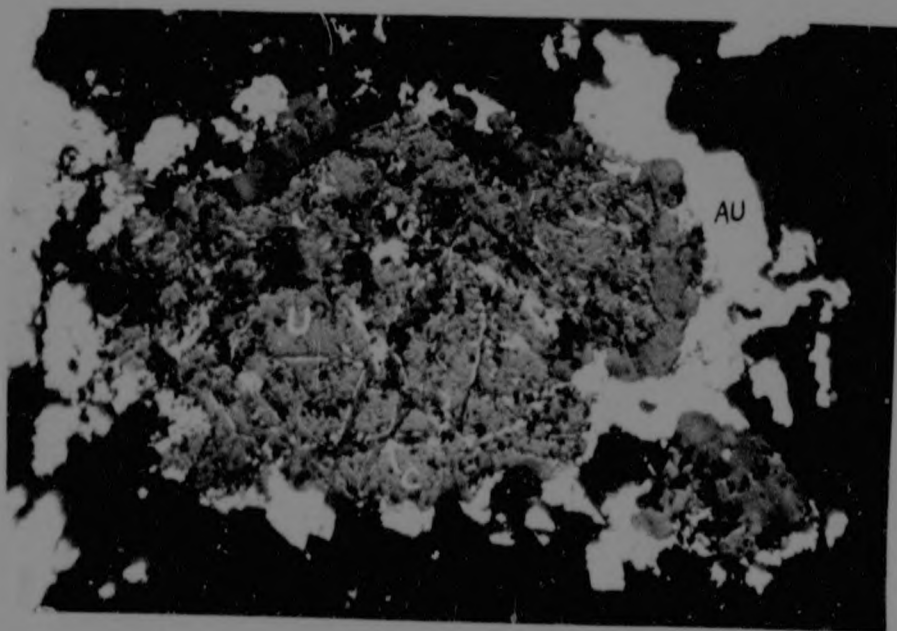
48 X



Pyrite grain showing rounded and cylindrical inclusions of gold. Dark spots are inclusions of quartz.

Plate XV

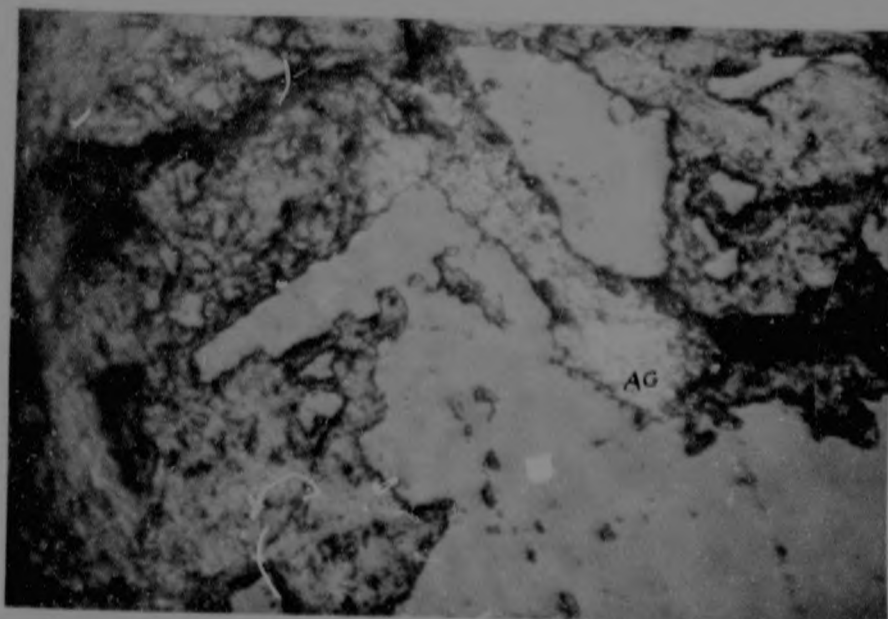
150 X



Gold replacing uraninite. Note the presence of fine stringers of "carbon" cementing the uraninite grain, and fine specks of included galena.

Plate XVI

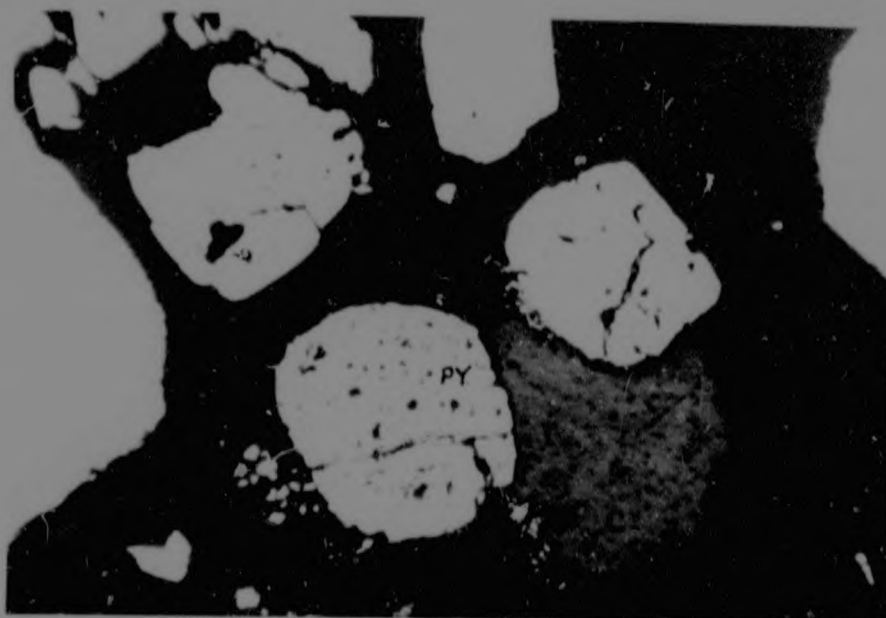
60 X



Poorly polished grain of native silver (?) embedded in eroded phyllosilicate matrix.

Plate XVII

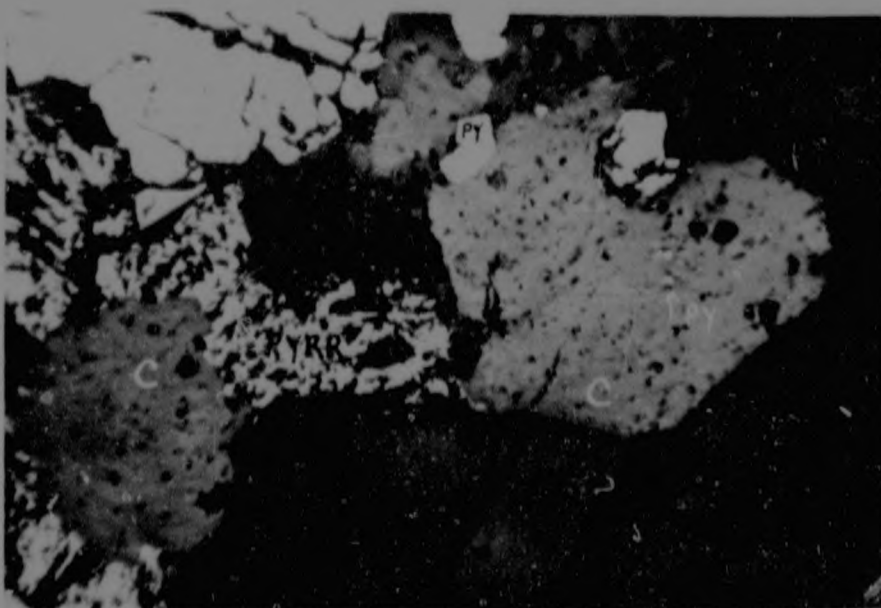
48 X



Irregular grain of apparently once plastic "carbon" wedged between rounded pyrite grains.

Plate XVIII

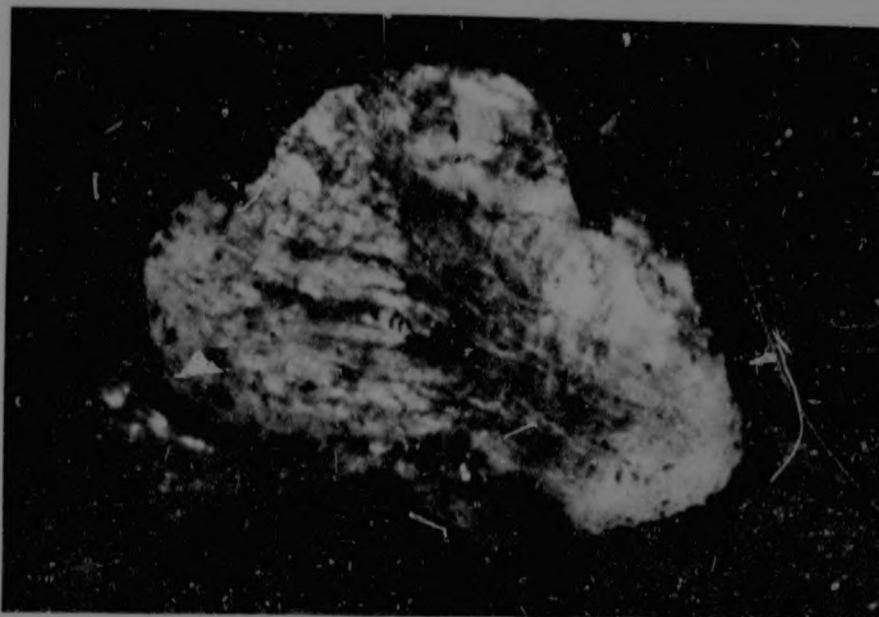
48 X



Irregular grains of "carbon" moulded about, and containing inclusion of, pyrite, and also showing replacement by pyrrhotite.

Plate XIX

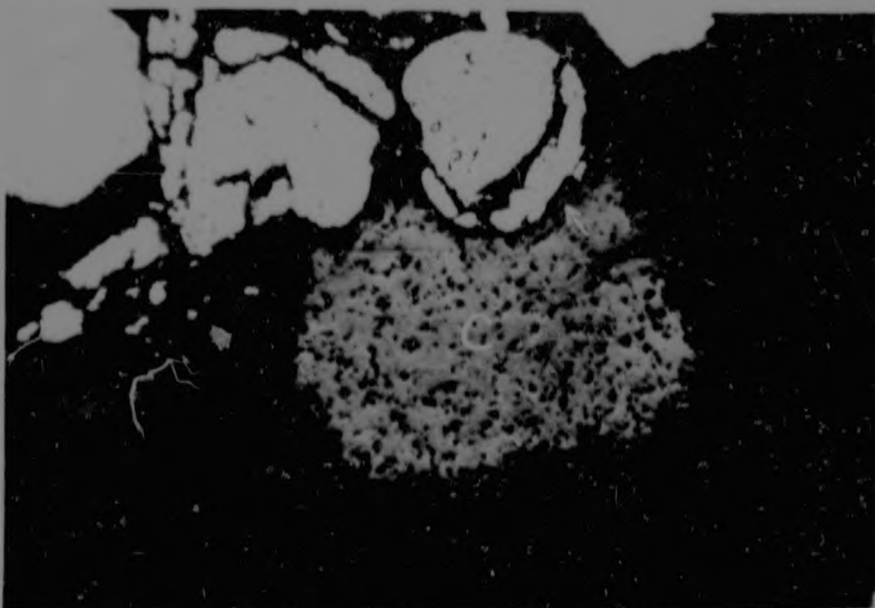
(X nicols) 80 X



Irregular "carbon" grain showing fibrous habit.
Note the haphazard orientation of the fibres.

Plate XX

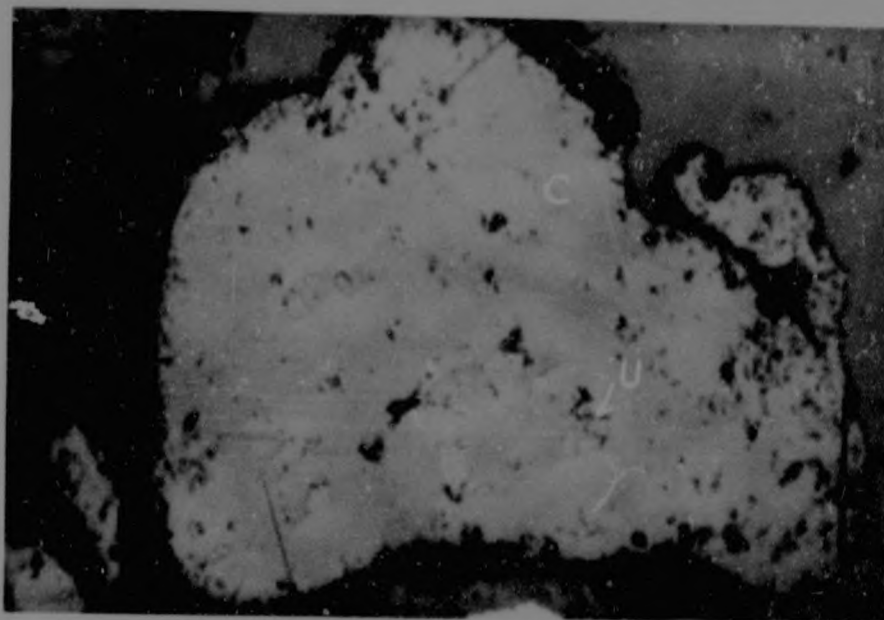
48 X



"Carbon" moulded around pyrite. Note the darkening
of the "carbon" where in contact with the pyrite.

Plate XXI

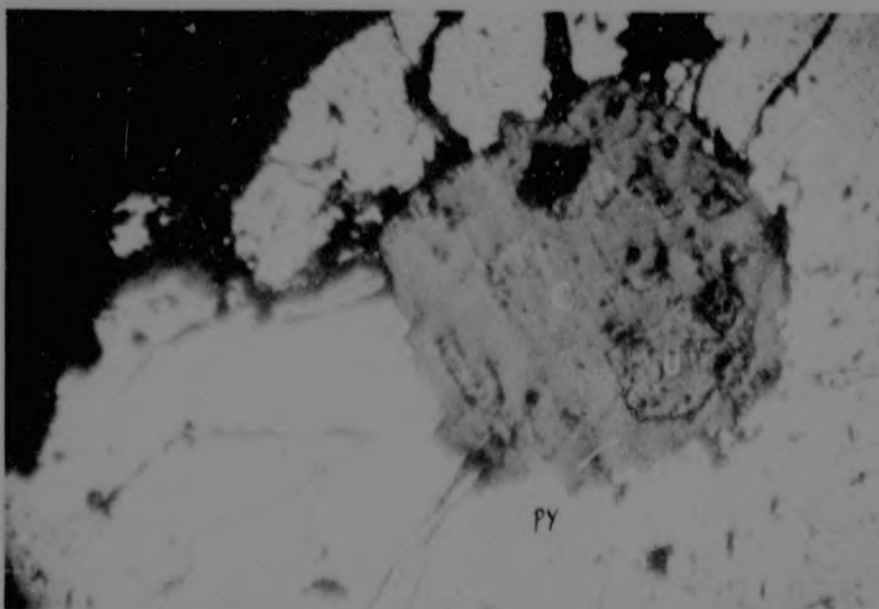
200 X



"Carbon" with inclusions of shattered subhedral uraninite.

Plate XXII

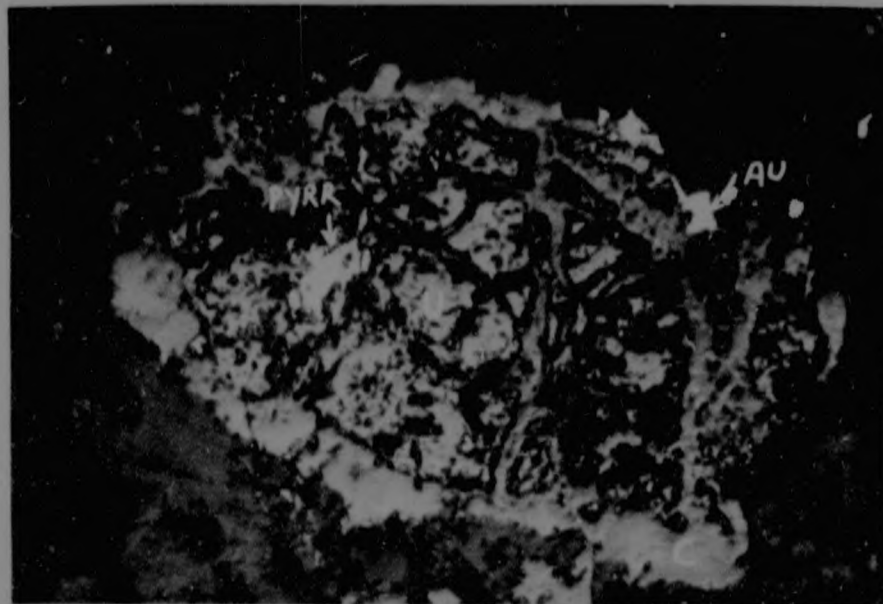
60 X



Fragments of euhedral uraninite in "carbon" surrounded by shattered pyrite.

Plate XXIII

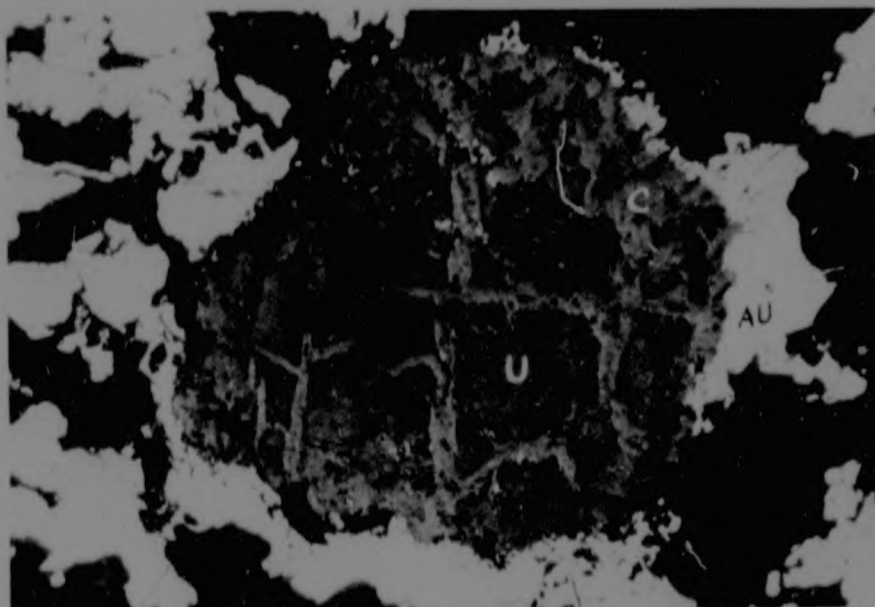
200 X



Uraninite with thin shell of "carbon" transected by veinlets of "carbon". Note the pyrrhotite inclusion and grain of gold on the periphery.

Plate XXIV

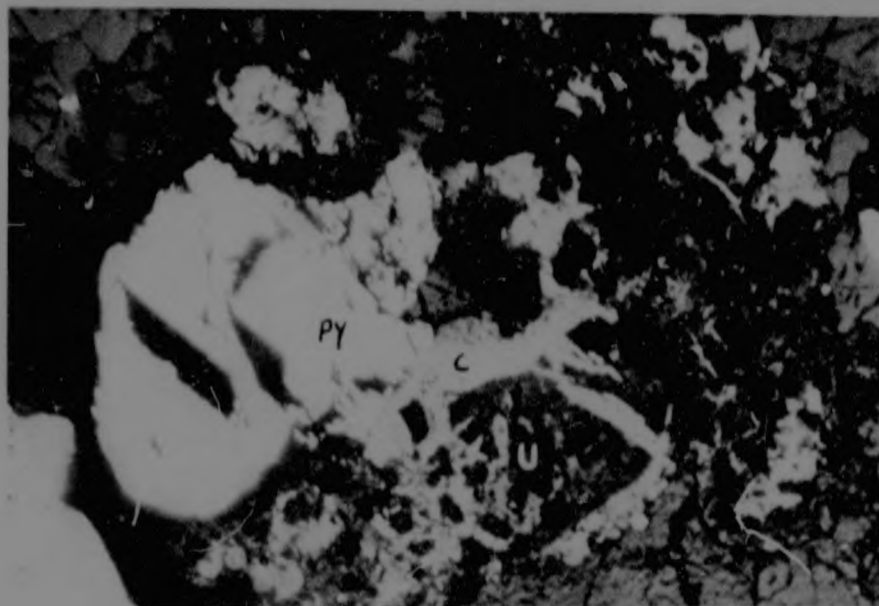
132 X



Uraninite (black) stained with HF apparently showing (111) cleavages, with fractures filled by "carbon". Note the degree of replacement by gold on the periphery.

Plate XXV

80 X



Subhedral uraninite (black) after staining with HF,
cemented by fine grey veinlets of "carbon".

Plate XXVI

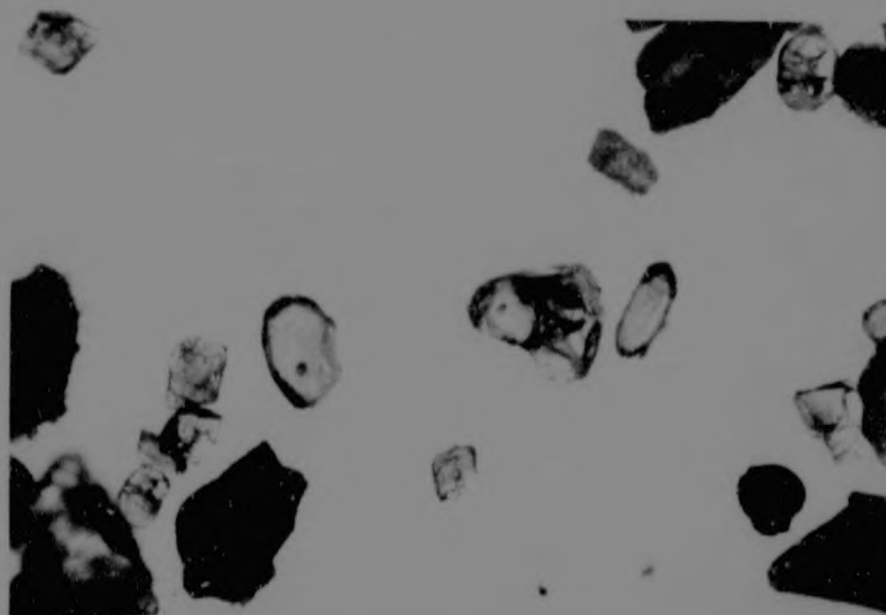
38 X



Zircons showing varying degrees of rounding.

Plate XXVII

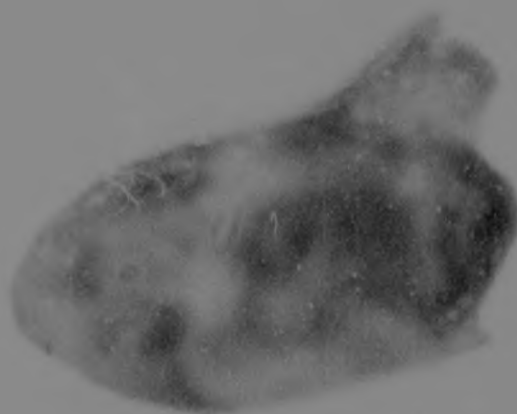
38 X



Geniculate zircon grain.

Plate XXVIII

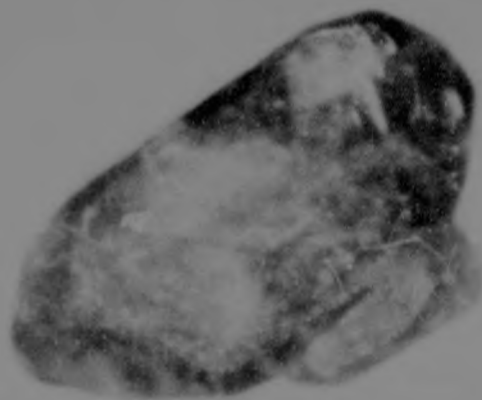
400 X



Zircon grain showing outgrowth.

Plate XXIX

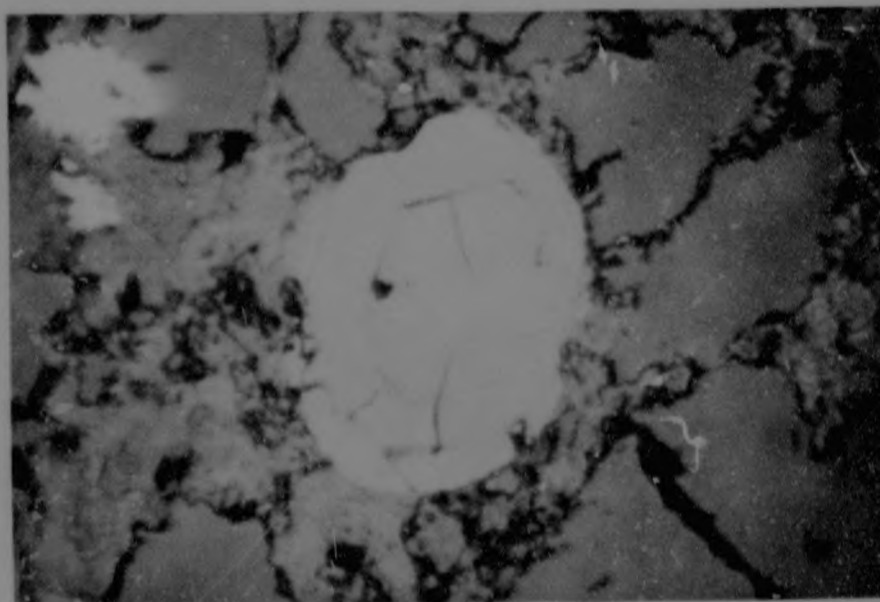
400 X



Zircon grain showing overgrowth.

Plate XXX

60 X



Zonal zircon with a euhedral core.

Plate XXXI

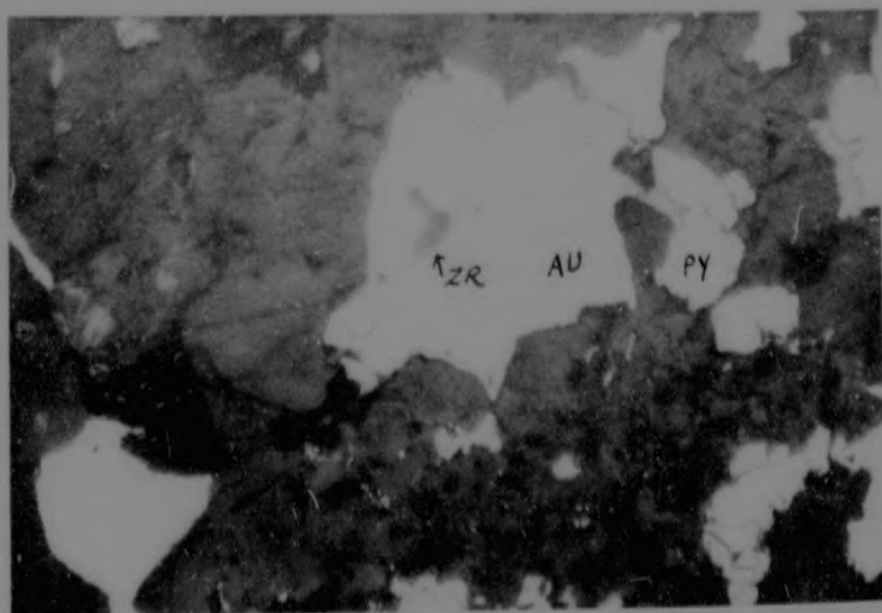
300 X



Zircon with randomly oriented rounded and rod-like inclusions.

Plate XXXII

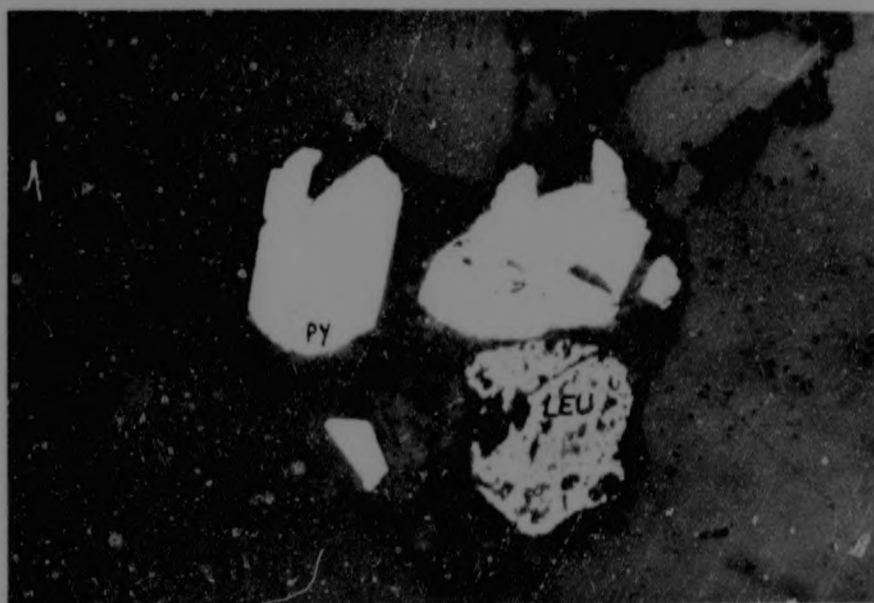
135 X



Geniculate zircon inclusion in gold.

Plate XXXIII

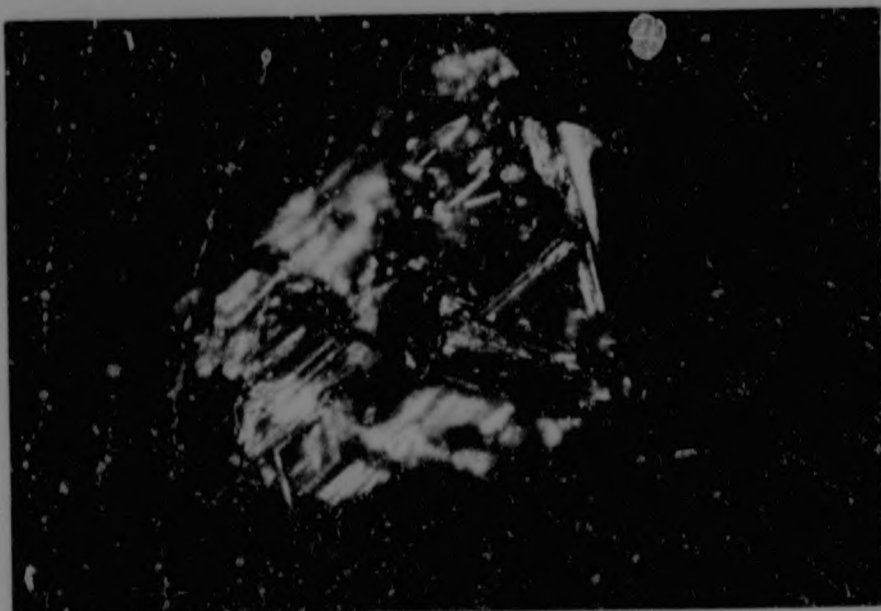
48 X



Grain of leucoxene and pyrite grains.

Plate XXXIV

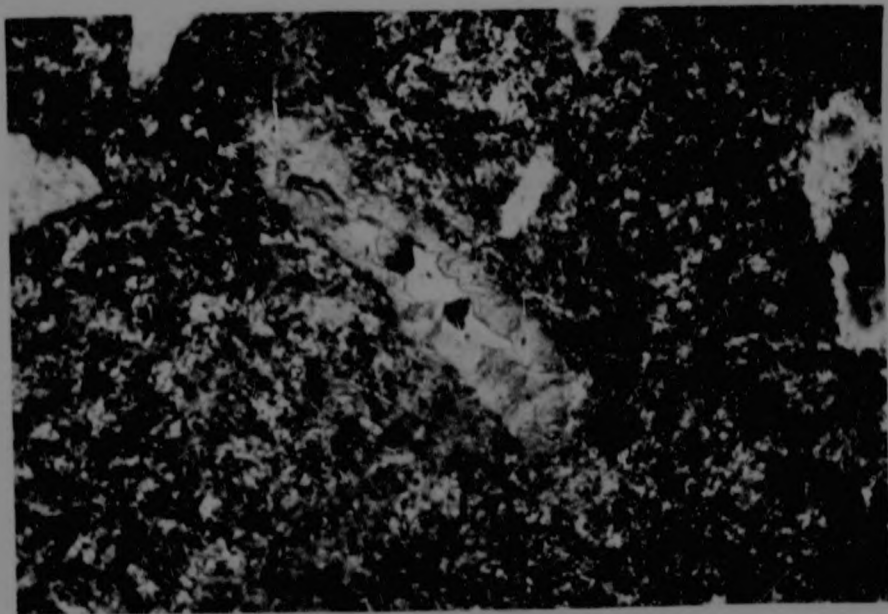
90 X



Cluster of subhedral rutile.

Plate XXXV

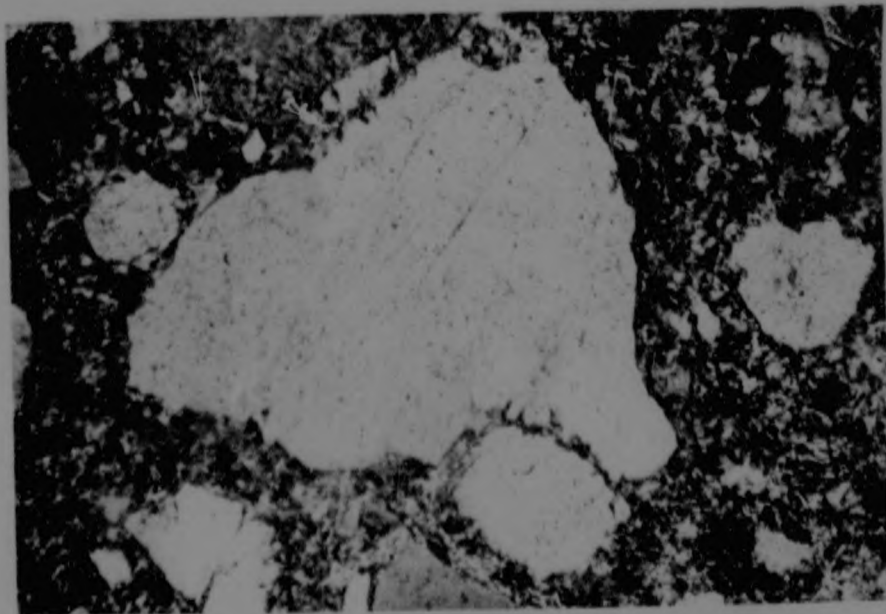
(X nicols) 27 X



Scaly mixture of chlorite and sericite.

Plate XXXVI

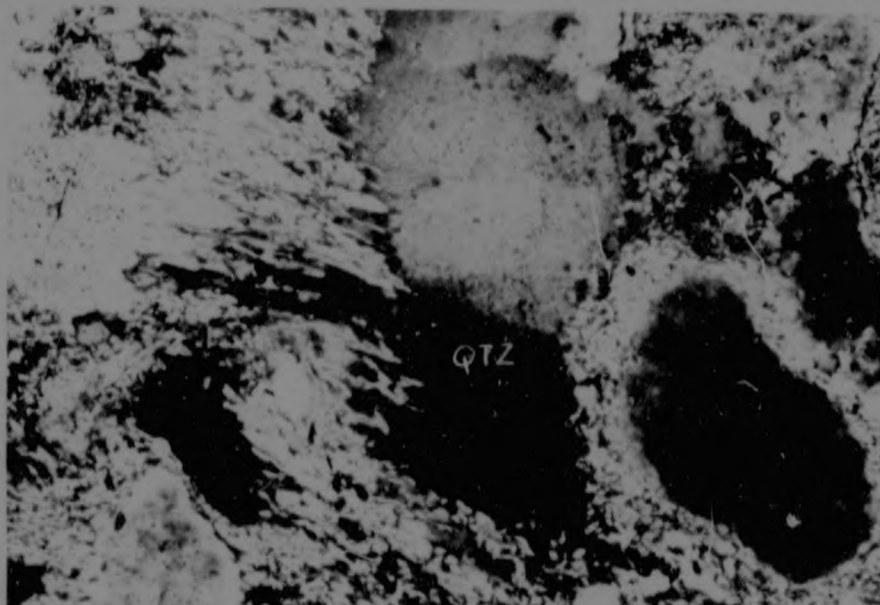
(X nicols) 27 X



Scaly mixture of chlorite and sericite replacing quartz.

Plate XXXVII

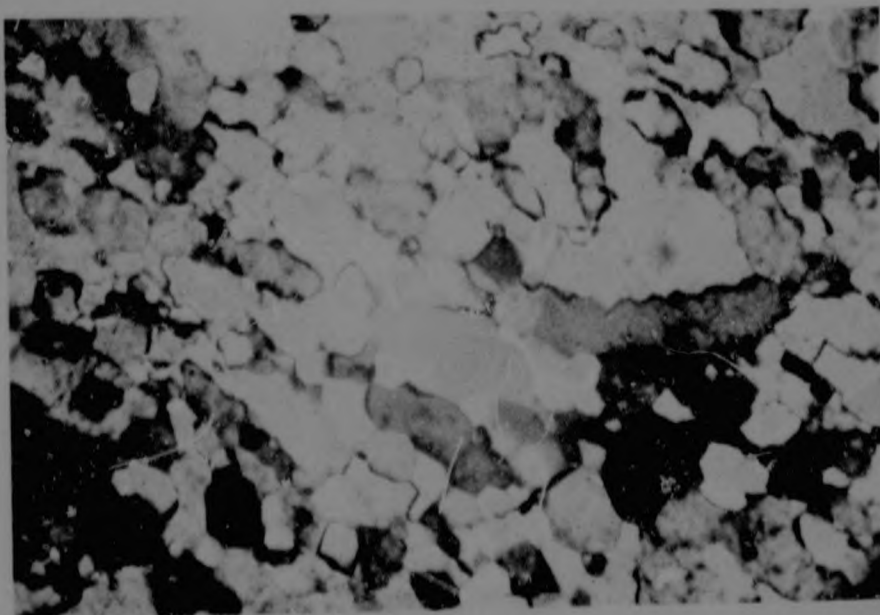
(X nicols) 27 X



Fine sharas of sericite replacing quartz.

Plate XXXVIII

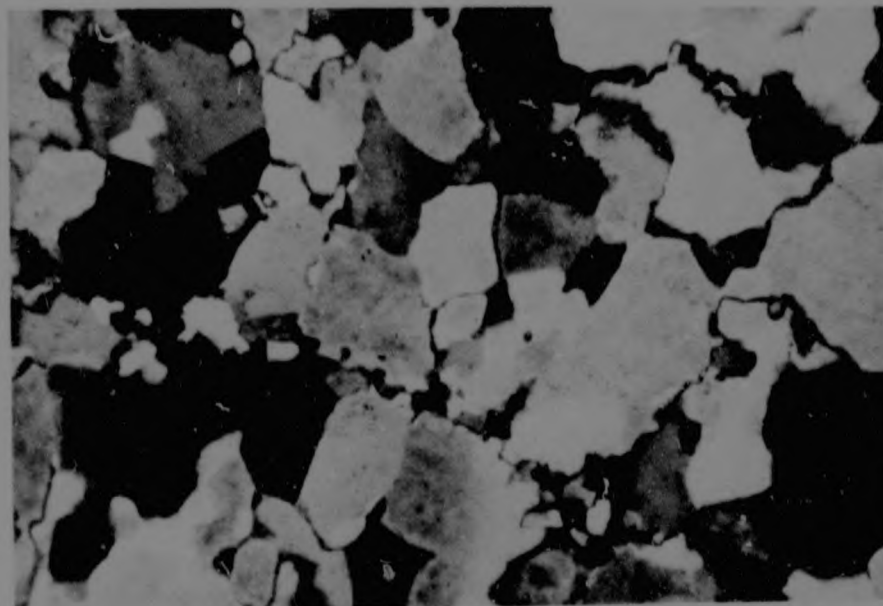
(X nicols) 27 X



Quartz. Note the fine black inclusions of "dust".

Plate XXXIX

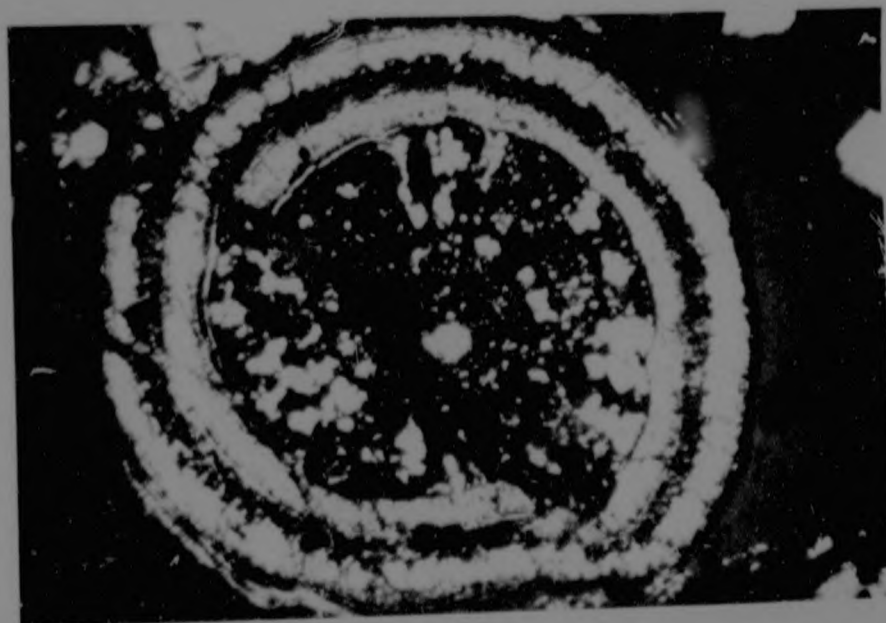
(X nicols) 27 X



Quartz grains showing strain.

Plate XL

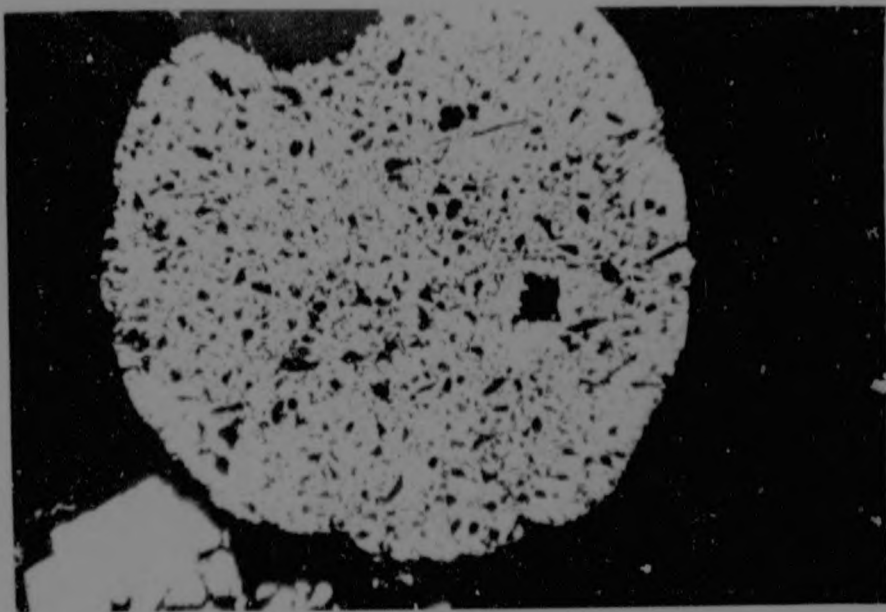
6 X



Radial pyrite.

Plate XLI

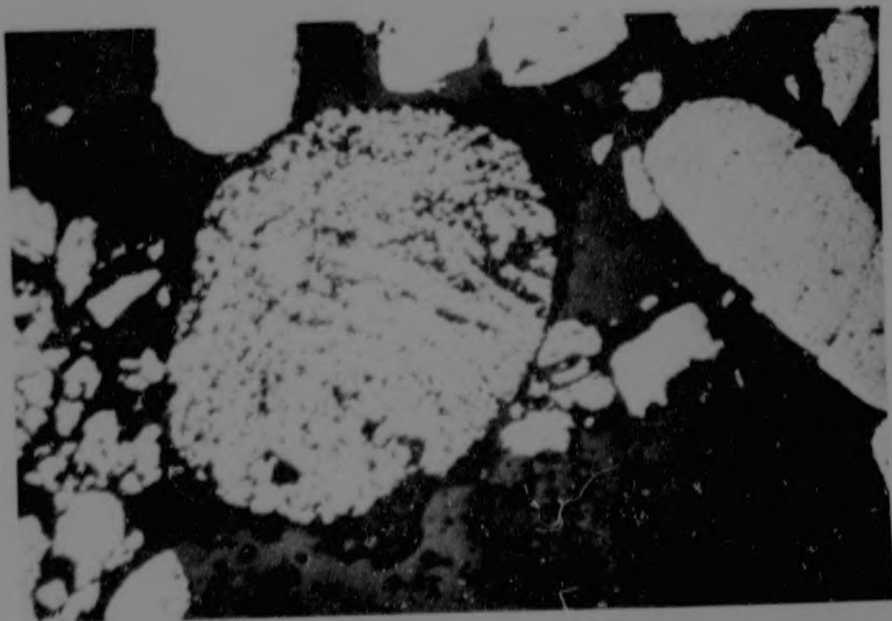
48 X



Rounded pebble, probably originally a ferruginous sandstone rich in quartz, which has been changed into pyrite.

Plate XLII

16 X



Rounded pebble of pyritized sediment.

Plate XLIII

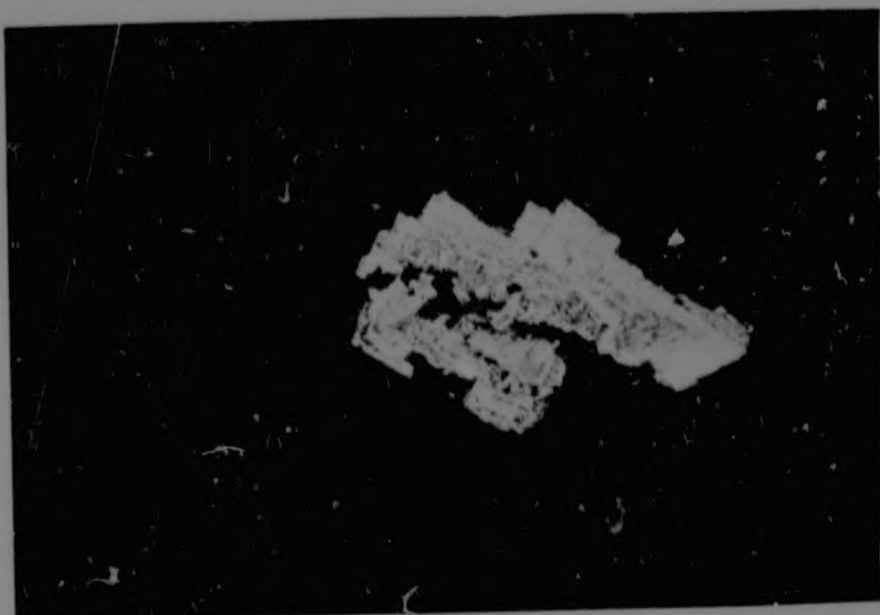
48 X



Pyrite grains formed from smaller cemented angular grains, with inclusion of pyrrhotite.

Plate XLIV

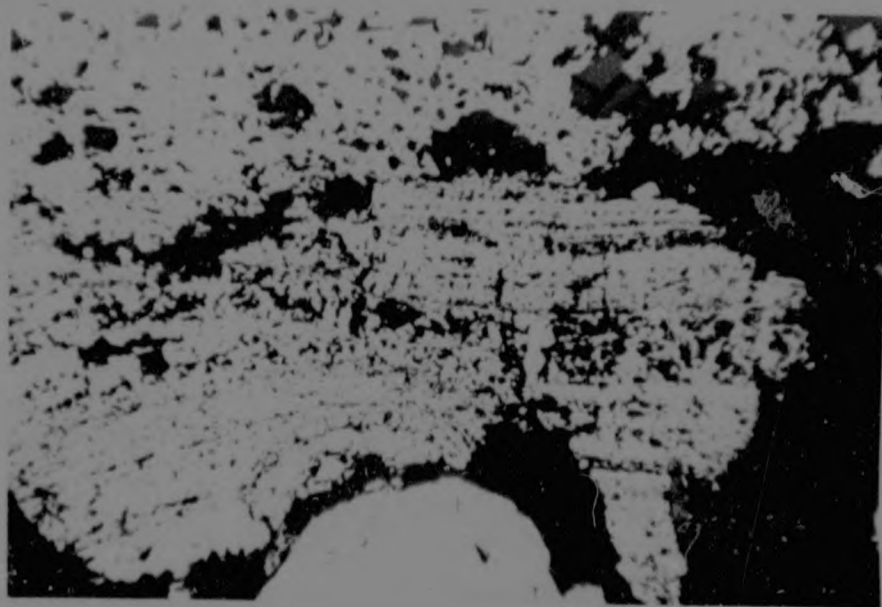
80 X



Authigenic zonal pyrite.

Plate XLV

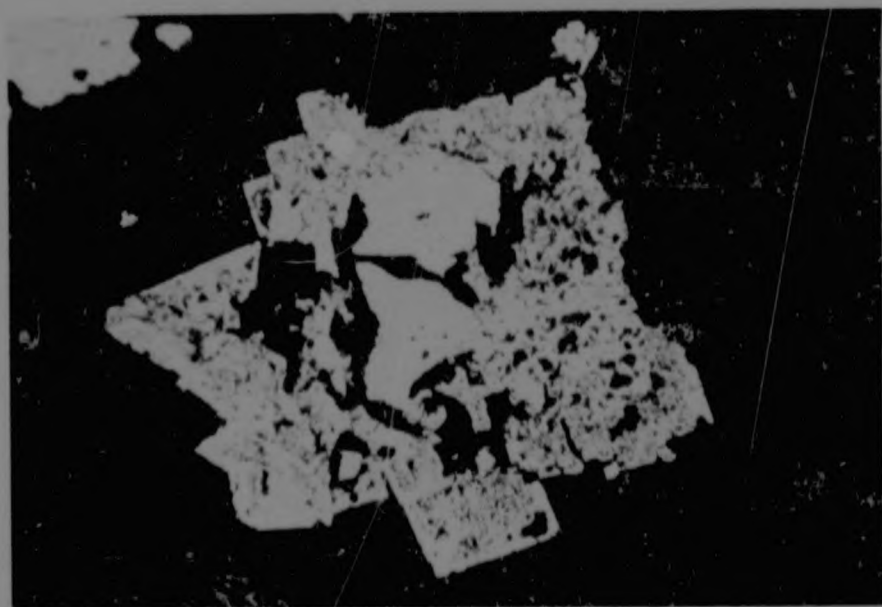
48 X



Banded porous pyrite -- probably a pyritized sediment.

Plate XLVI

80 X



Younger zonal pyrite which has grown around older
"clear" pyrite.

Plate XLVII

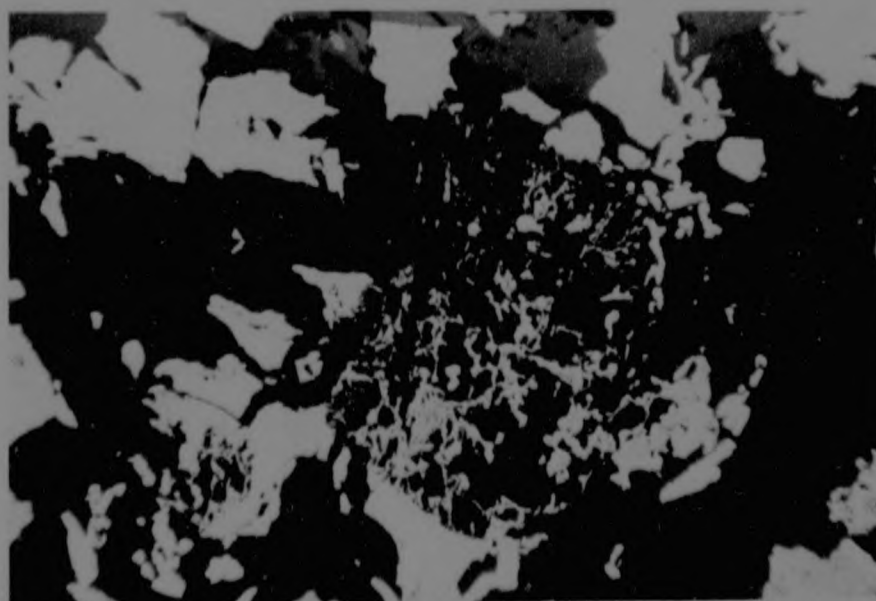
80 X



Pyrite crystal with an overcapping of younger zonal pyrite.

Plate XLVIII

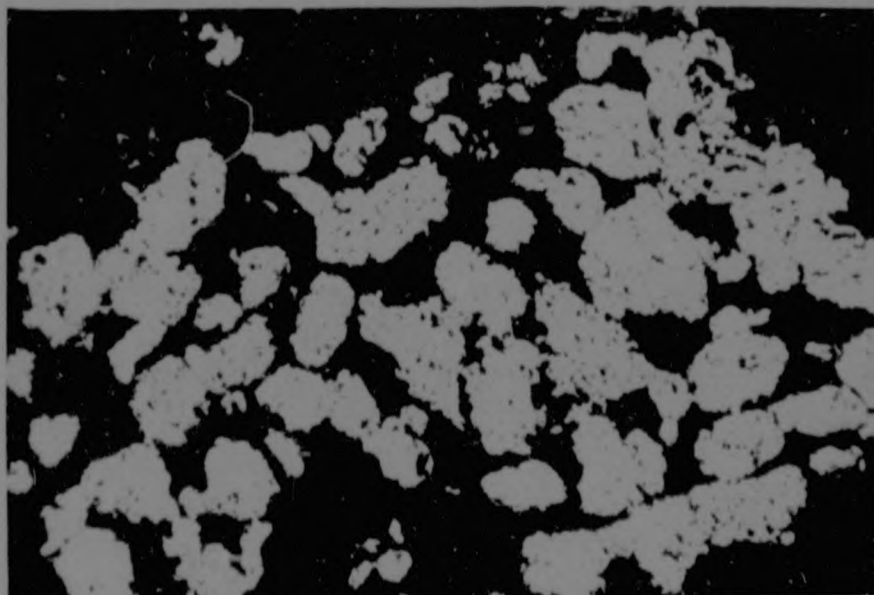
48 X



Juvenile stringer-like pyrite.

Plate XLIX

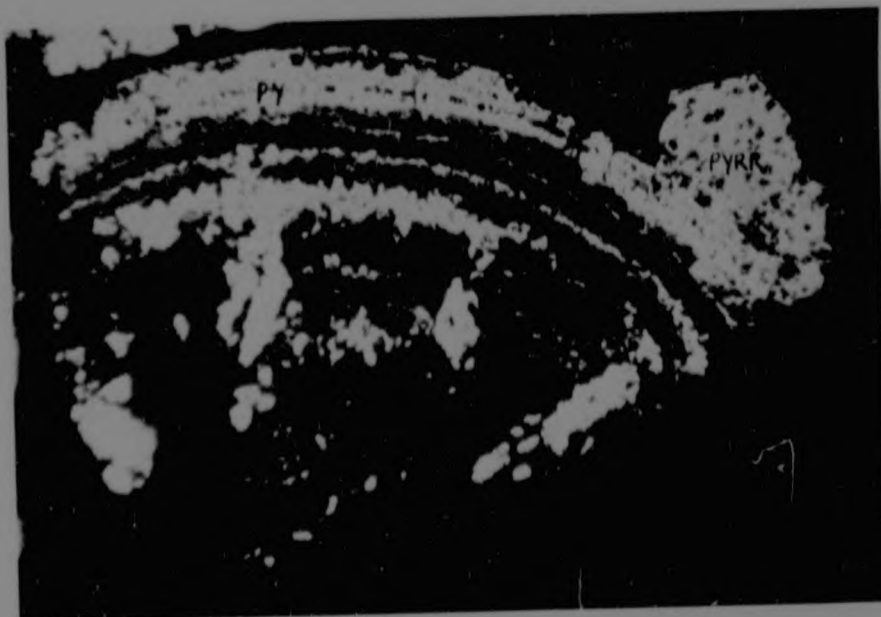
80 X



Fragments of pyritized ferruginous sandstone?
Dark inclusions are quartz.

Plate L

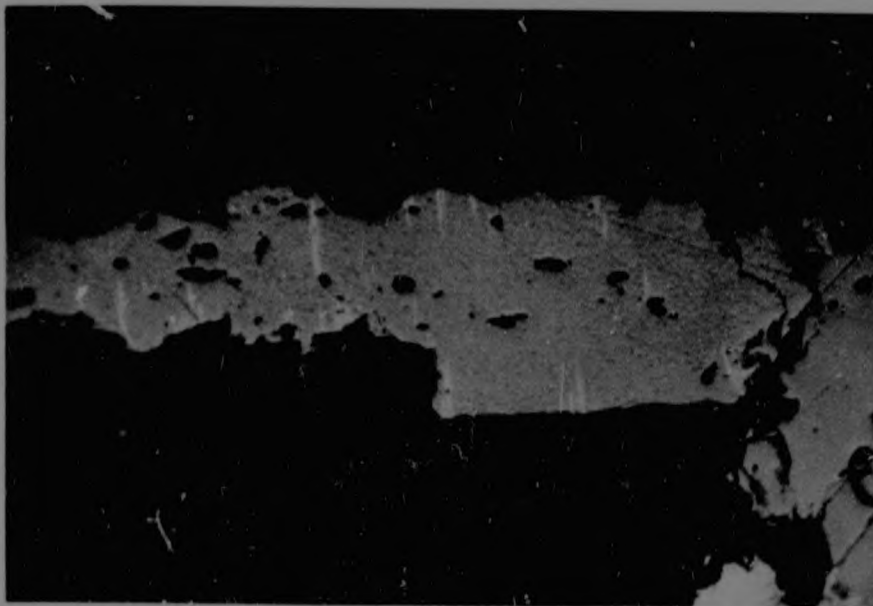
48 X



Subhedral pyrrhotite replacing radial pyrite.

Plate LI

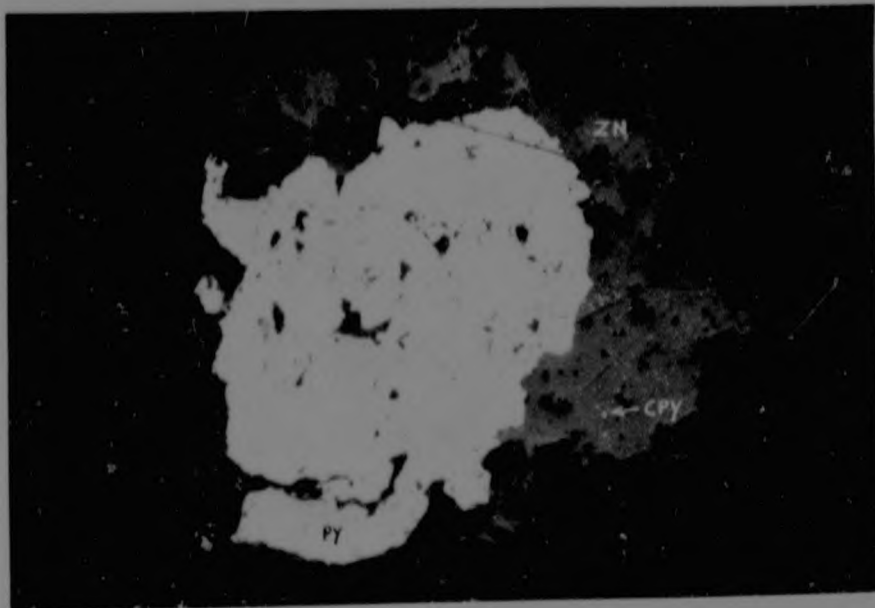
132 X



Pyrrhotite showing Beta Lamellae.

Plate LII

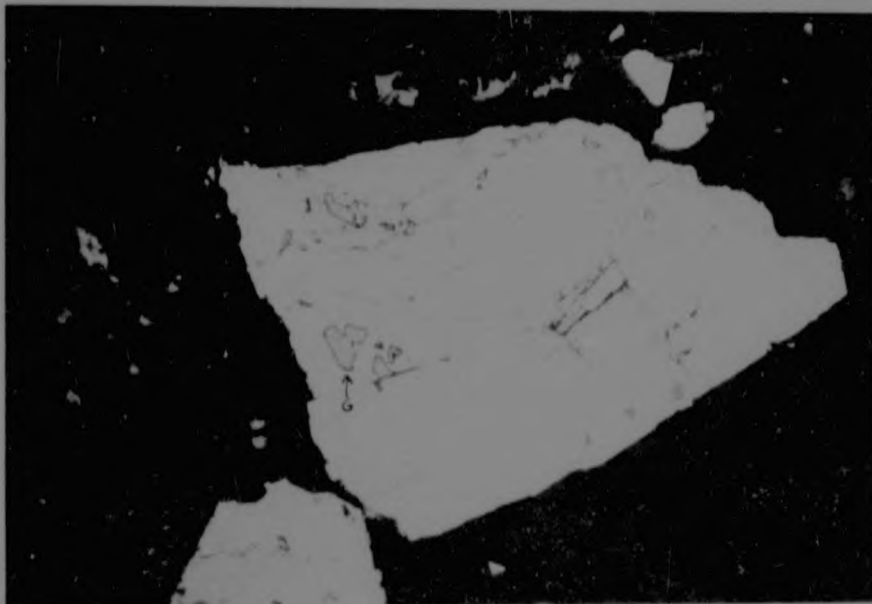
132 X



Sphalerite showing blebs of exsolved chalcopyrite.
The white mineral is pyrite.

Plate LIII

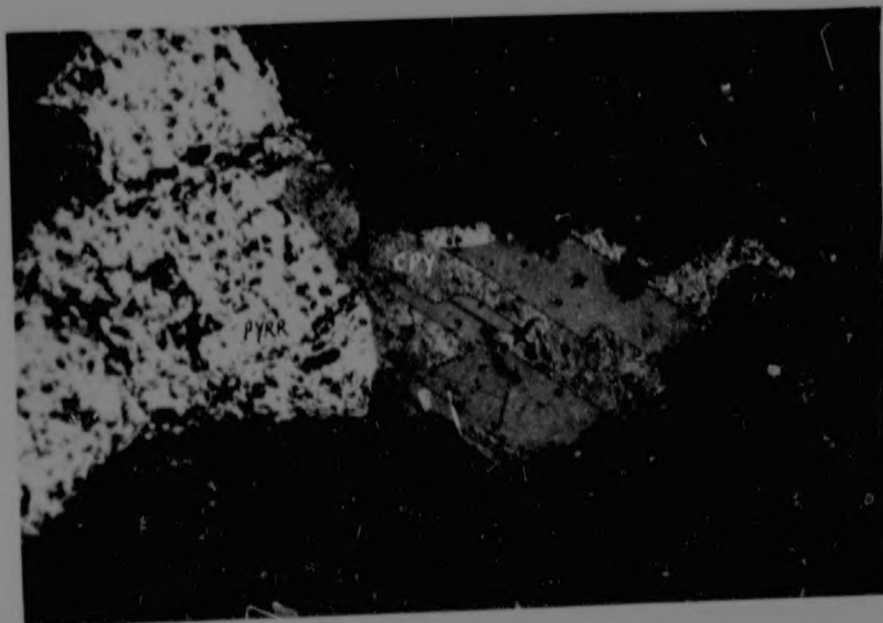
80 X



Galena inclusions in shattered pyrite.

Plate LIV

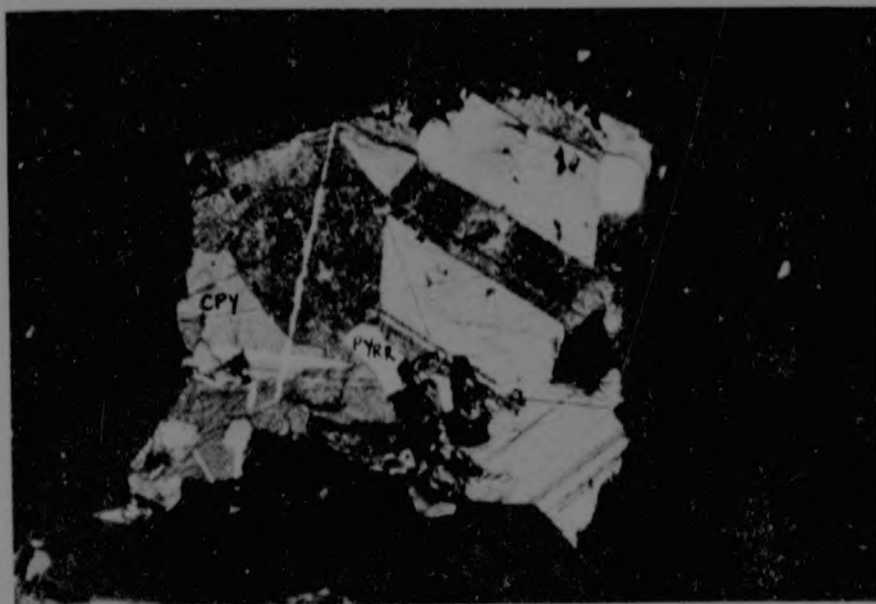
80 X



Chalcopyrite replacing pyrrhotite (chalcopyrite repolished after etching).

Plate LV

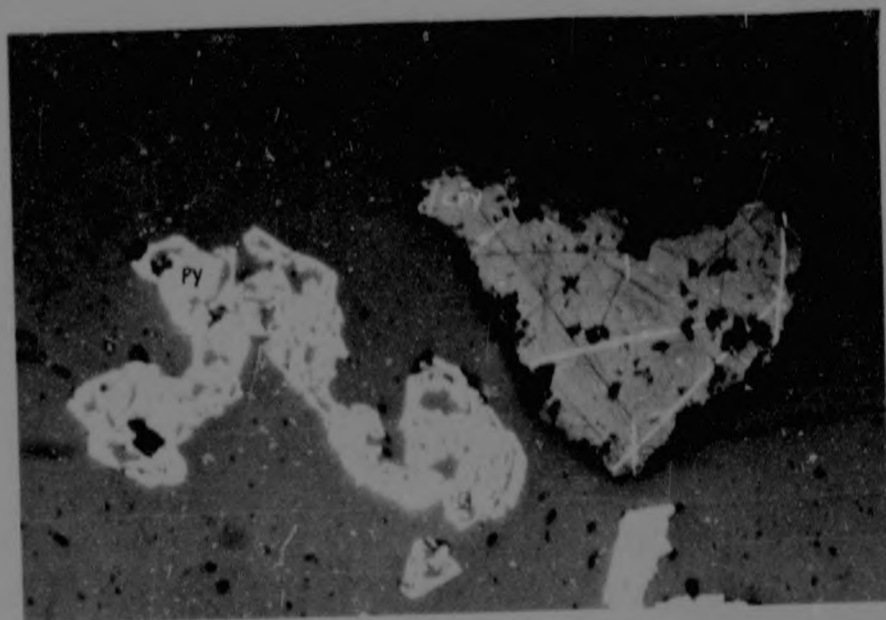
200 X



Stained chalcopyrite showing twinning, exsolved laths of cubanite and inclusions of pyrrhotite.

Plate LVI

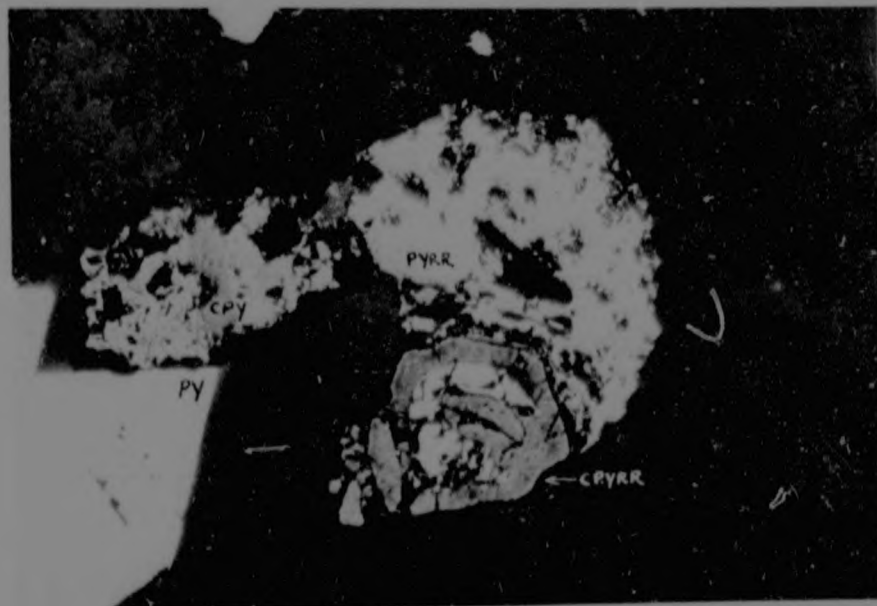
80 X



Stained chalcopyrite showing laths of exsolved cubanite. Other mineral is pyrite.

Plate LVII

132 X



Aureole of chalcopyrrhotite enclosing a pyrrhotite core. Other minerals are stained chalcopyrite and pyrite.

Plate LVIII

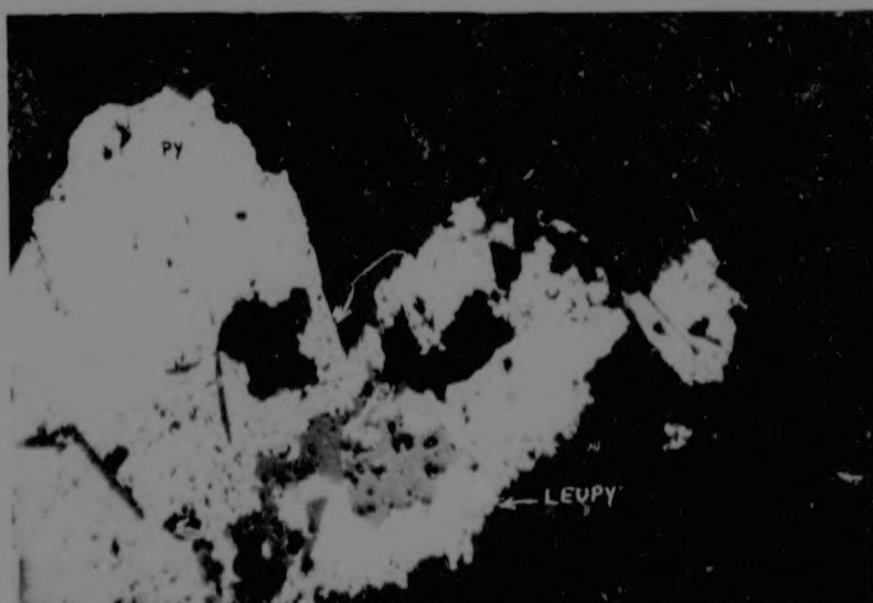
132 X



Pyrrhotite with aureole of chalcopyrrhotite.

Plate LIX

80 X



Leucopyrite intergrown with, and rimming, pyrite.

Plate LX

80 X



Loellingite.

T A B L E I.
SAMPLING SITES, ELEVATIONS AND ASSAY RESULTS.

VENTERSPOST VENTERSDORP CONTACT REEF				
SAMPLE	GOLD DWT/TON	SILVER DWT/TON	APPARENT FINENESS	ELEVATION FEET
1-2S-1 Good	9.13	1.91	812	-2200
1-2S-1 Poor	38.55	3.44	918	-2200
2-3N-6 Poor	34.65	4.21	892	-2300
2-3N-6 Poor	17.08	1.67	911	-2300
1-10S-1 Poor	5.90	0.69	895	-3500
1-10S-1 Good	16.37	1.63	909	-3500
2-10S-12 Poor	3.50	0.56	862	-3500
2-10S-18 Good	22.15	2.52	898	-3500
1-16S-10 RSE Good	22.75	3.48	867	-4600
1-16S-10 RSE poor	11.06	1.47	883	-4600
2-16S-15 Good	39.98	4.53	898	-4600
2-16S-15 poor	6.17	0.58	914	-4600
1-20S-11 Poor	2.61	0.53	831	-5300
1-20S-11 Good	16.07	1.61	909	-5300
2-20S-14 Poor	0.98	0.33	748	-5300
2-20S-14 Good	9.58	3.06	758	-5300
1-22S- 1 Good	60.47	8.41	878	-5700
1-22S- 1 Poor	0.24	0.24	500	-5700

T A B L E II.

SAMPLING SITES, ELEVATIONS AND ASSAY RESULTS.

LIBANON VENTERSDORP CONTACT REEF				
SAMPLE	GOLD DWT/TON	SILVER DWT/TON	APPARENT FINENESS	ELEVATION FEET
19	47.88	4.33	917	-3270
20	5.97	0.50	922	-3270
21	12.41	1.02	924	-3270
22	0.38	0.12	760	-3270
23	1.93	0.39	832	-3270
28	0.92	0.28	767	-4098
29	0.61	0.96	389	-4098
30	0.45	0.25	643	-4098
25	13.42	1.25	914	-5200
26	29.26	2.91	910	-5200
27	11.96	1.68	877	-5200
31	0.29	0.09	763	-5700
32	3.09	0.47	870	-5700
33	4.40	1.50	746	-5700
34	2.80	0.89	759	-6790
35	1.25	0.57	687	-6790
36	6.37	0.80	888	-6790

T A B L E I I I .

SAMPLING SITES, ELEVATIONS AND ASSAY RESULTS.

WEST DRIEFONTEIN VENTERSDORP CONTACT REEF.				
SAMPLE	GOLD DWT/TON	SILVER DWT/TON	APPARENT FINENESS	ELEVATION FEET
12-16 Dr. W 10274 + 82½' H.G.	46.10	4.80	905	-5100
12-16 Dr. W 10562 + 32½' L.G.	7.40	0.80	903	-5100
14-16 Dr. E 10423 + 115½' H.G.	56.20	5.90	905	-5400
14-16 Dr. E 10292 + 10½' L.G.	6.70	0.90	882	-5400
16-17 Dr. E 10643 + 114½' H.G.	32.60	3.40	905	-5700
16-17 Dr. E 10425 + 93½' L.G.	0.67	0.23	703	-5700

T A B L E IV.

SAMPLING SITES, ELEVATIONS AND ASSAY RESULTS.

VENTERSPOST MAIN REEF				
SAMPLE	GOLD DWT/TON	SILVER DWT/TON	APPARENT FINENESS	ELEVATION FEET
1 - 2 Dr-N Good	12.44	1.76	876	-2200
1 - 2 Dr.N Poor	3.75	0.58	866	-2200
2 - 2N-5 Good	19.06	1.67	919	-2200
2 - 2N-5 Good	13.11	1.60	891	-2200
1 - 10S-9 Good	37.98	2.62	932	-3500
1 - 10S-9 Poor	9.65	1.62	905	-3500
2 - 10S-12 Poor	0.54	0.26	675	-3500
2 - 14S-15 Good	7.23	1.31	847	-4300
2 - 14S-15 Poor	0.29	0.15	659	-4300
2 - 16S-15 Good	8.87	0.94	904	-4600
1 - 20S-11 Good	3.79	0.59	865	-5300
1 - 20S-11 Poor	4.09	0.44	903	-5300
2 - 21S-15 Good	11.37	0.95	923	-5500
2 - 21S-15 Poor	0.57	0.19	750	-5500
1 - 22S- 1 Good	0.64	0.25	719	-5700
1 - 22S- 1 Poor	1.48	0.35	809	-5700

T A B L E V.

SAMPLING SITES, ELEVATIONS AND ASSAY RESULTS.

LIBANON MAIN REEF				
SAMPLE	GOLD DWT/TON	SILVER DWT/TON	APPARENT FINENESS	ELEVATION FEET
1	36.40	3.50	912	-3270
2	66.20	6.10	915	-3270
3	134.30	14.60	902	-3270
4	1.47	0.26	850	-3425
5	1.10	0.29	791	-3425
6	0.55	0.16	775	-3425
10	0.21	0.07	750	-4500
11	7.98	0.94	895	-4500
12	8.90	0.73	924	-4500
7	73.50	5.90	926	-4750
8	4.36	0.48	901	-4750
9	10.32	1.16	899	-4750
16	8.72	1.04	893	-7155
17	2.82	0.48	855	-7155
18	4.48	0.73	860	-7155
13	4.64	0.54	896	-7350
14	17.96	1.73	912	-7350
15	3.23	0.51	864	-7350

TABLE VI.

TABLE SHOWING AMOUNT OF "FREE SILVER", GOLD AND SILVER IN

"PULP" AND "SOLUTION".

MINE	HORIZON	"SOLUTION"		"PULP"		APPARENT AU:AG RATIO	TRUE AU:AG RATIO	FREESILVER PERCENT
		GOLD DWT/TON	SILVER DWT/TON	GOLD DWT/TON	SILVER DWT/TON			
VENTERSPOST	V.C.R.	0.007	0.179	11.670	2.210	4.88	5.28	7.45
VENTERSPOST	V.C.R.	0.090	1.290	22.440	3.900	4.33	5.75	24.65
LIBANON	V.C.R.	0.005	0.175	3.480	0.810	3.54	4.29	17.80
WEST DRIEFONTEIN	V.C.R.	0.010	0.090	24.890	2.090	11.43	11.92	4.19
VENTERSPOST	MAIN REEF	0.017	0.027	7.880	1.200	6.43	6.57	1.99
LIBANON	MAIN REEF	0.004	0.084	2.490	0.540	3.99	4.62	13.45

T A B L E VII.

TABLE SHOWING FINENESS VALUES OF SAMPLES USED IN

"FREE SILVER" DETERMINATION.

MINE	HORIZON	NUMBER OF SAMPLES IN COMPOSITE	HIGHEST APPARENT FINENESS	LOWEST APPARENT FINENESS	AVERAGE APPARENT FINENESS	TRUE FINENESS
VENTERSPOST	V.C.R.	4	831	748	830	841
VENTERSPOST	V.C.R.	18	918	500	813	853
LIBANON	V.C.R.	18	924	389	780	811
WEST DRIEFONTJIN	V.C.R.	6	905	703	919	923
VENTERSPOST	MAIN REEF	17	932	659	868	868
LIBANON	MAIN REEF	4	864	791	800	822

T A B L E VIII.

PROXIMATE ANALYSIS OF "CARBON" FROM VARIOUS HORIZONS.

	1	2	3	4	5
Specific Gravity	1.63	1.63	1.36	1.49	1.51
Moisture %	3.84	4.00	1.20	0.80	3.70
Volatile Matter %	16.82	18.76	21.22	15.54	22.65
Fixed Carbon %	61.84	65.34	65.00	69.16	53.25
Fixed Carbon (A.S.T.M.)%	80.90	79.30	77.80	83.80	71.80
Ash %	17.50	11.90	12.58	14.50	21.30
Sulphur %	2.32	2.50	4.25	2.53	1.04
Calorific Value B.Th.U.	11710	12700	13400	12910	11280
Calorific Value (A.S.T.M.) (B.Th.U.)	14530	14660	15730	14550	14720

- | | |
|--------------------------------------|-------------------------|
| 1. Luipaardsvlei Est. & G.M.Co. Ltd. | - Bird Reef Series |
| 2. Vogelstruisbult G.M.Areas Ltd. | - Main Reef |
| 3. Vogelstruisbult G.M.Areas Ltd. | - Kimberley Reef Series |
| 4. Doornfontein G.M.Co. Ltd. | - Carbon Leader |
| 5. West Driefontein G.M.Co. Ltd. | - Carbon Leader |

(Analysts: Messrs. Goldfields of S.A.Ltd. Laboratories).

T A B L E IX.

TABLE SHOWING ZIRCON ELONGATION/FREQUENCY RELATIONSHIPS.

<u>Elongation</u>	<u>Frequency per cent.</u>	
	<u>V.C.R.</u>	<u>Main Reef</u>
1.00 - 1.25	0.00	1.06
1.25 - 1.50	8.60	4.62
1.50 - 1.75	18.28	15.25
1.75 - 2.00	18.28	13.82
2.00 - 2.25	30.10	30.50
2.25 - 2.50	13.97	17.72
2.50 - 2.75	5.38	9.22
2.75 - 3.00	1.08	3.89
3.00 - 3.25	2.15	2.12
3.25 - 3.50	1.08	0.36
3.50 - 3.75	1.08	0.00
3.75 - 4.00	0.00	0.36
4.00 - 4.25	0.00	0.36
4.25 - 4.50	0.00	0.36
> 4.50	<u>0.00</u>	<u>0.36</u>
	<u>100.00</u>	<u>100.00</u>

FIGURE 1.

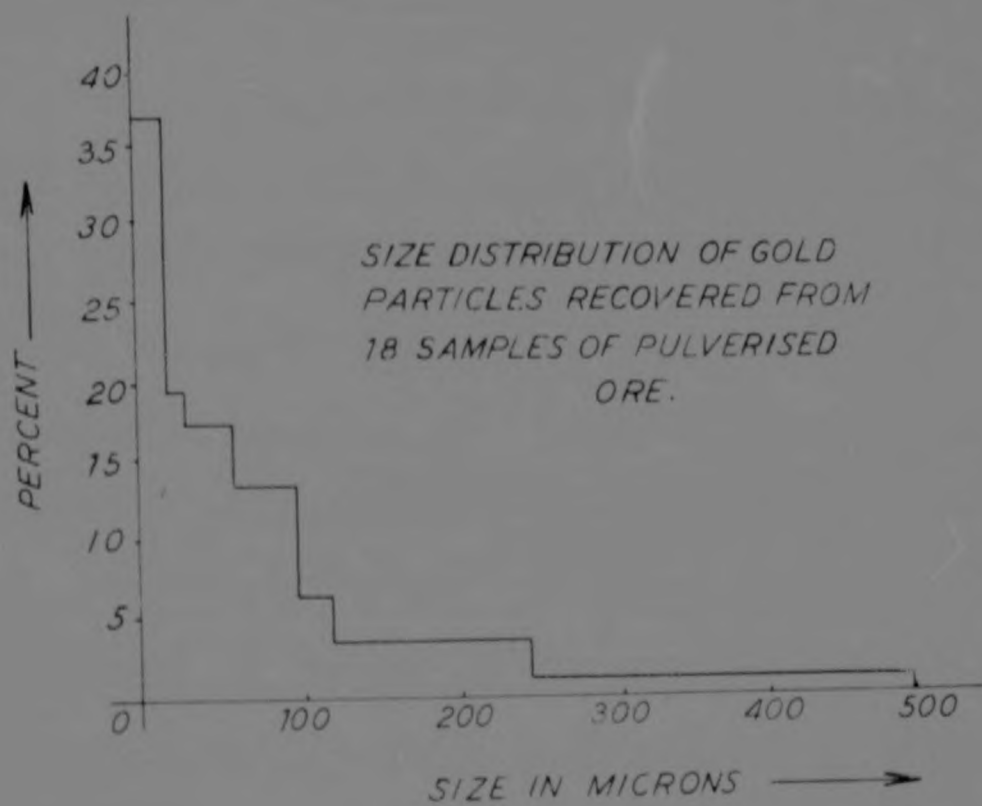


FIGURE 2.

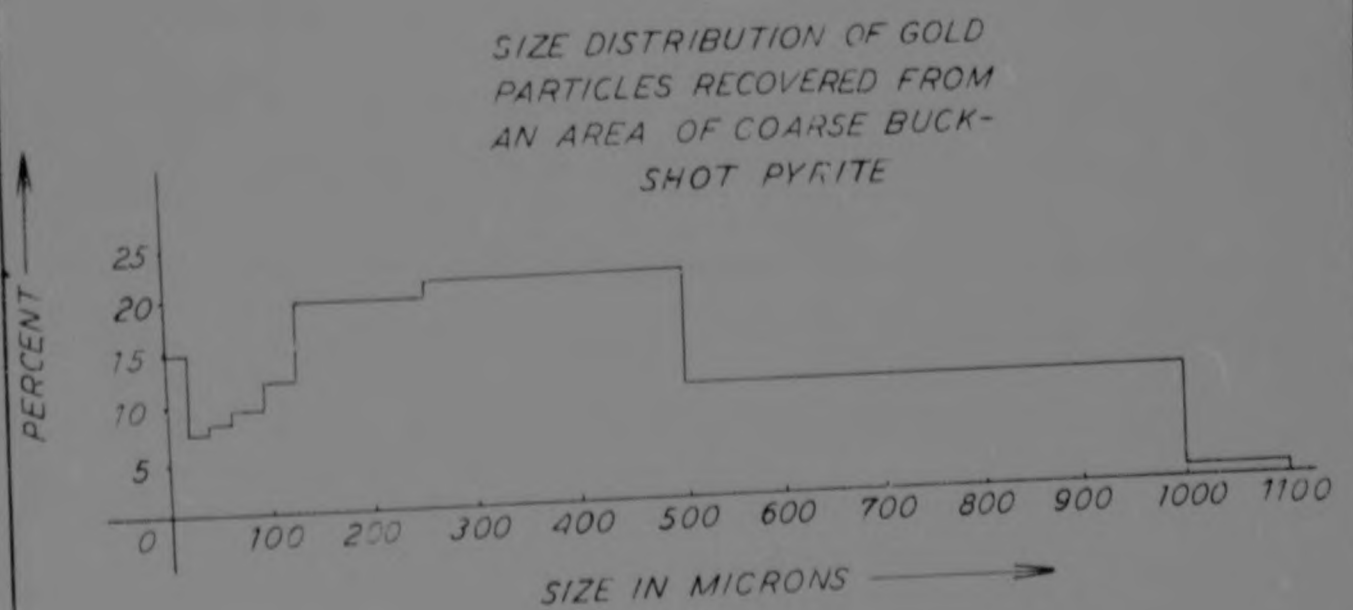


FIGURE 3.

GRAPH SHOWING GOLD/PYRRHOTITE RELATIONSHIP

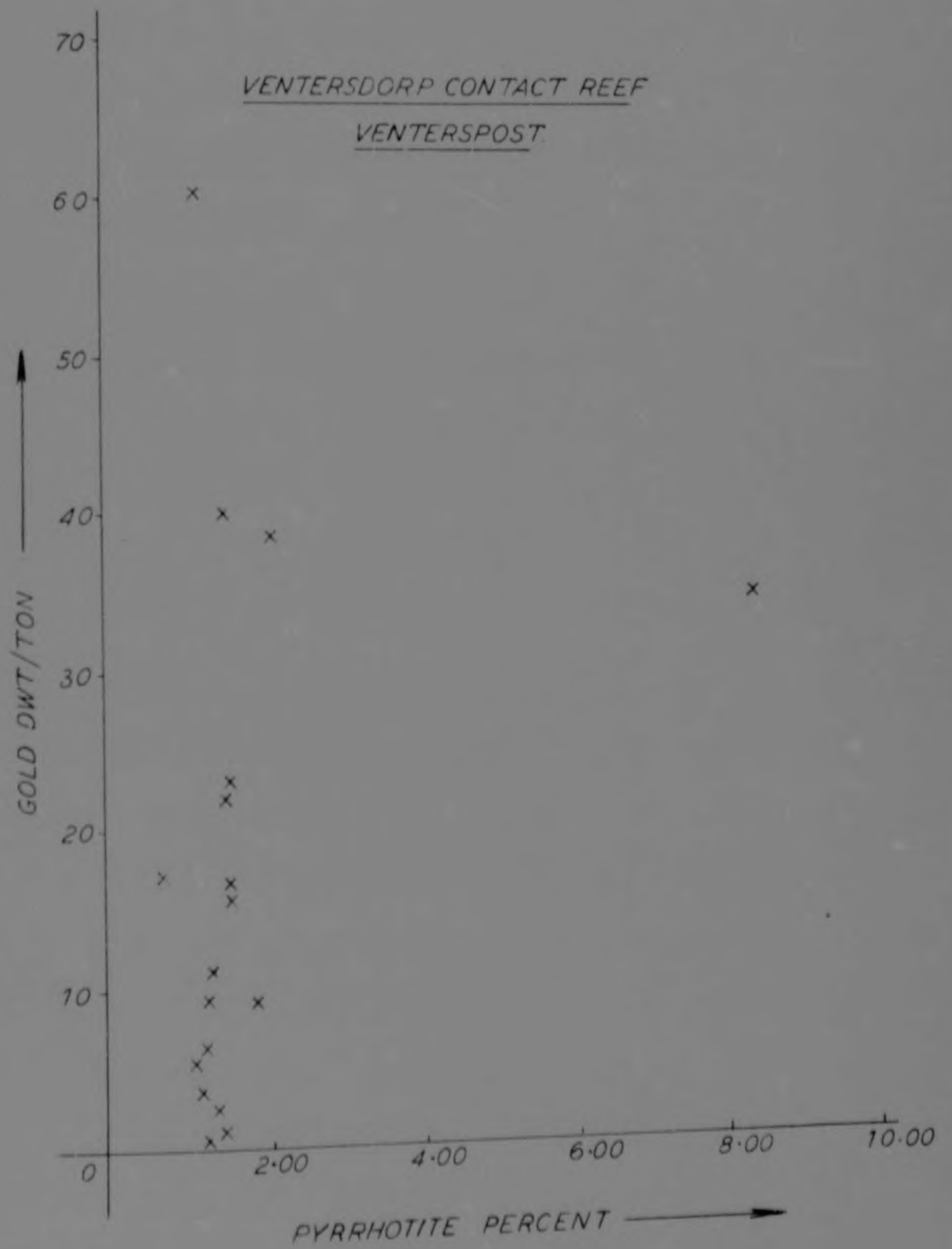


FIGURE 4.

GRAPH SHOWING GOLD/PYRRHOTITE RELATIONSHIP

VENTERSDORP CONTACT REEF

LIBANON.

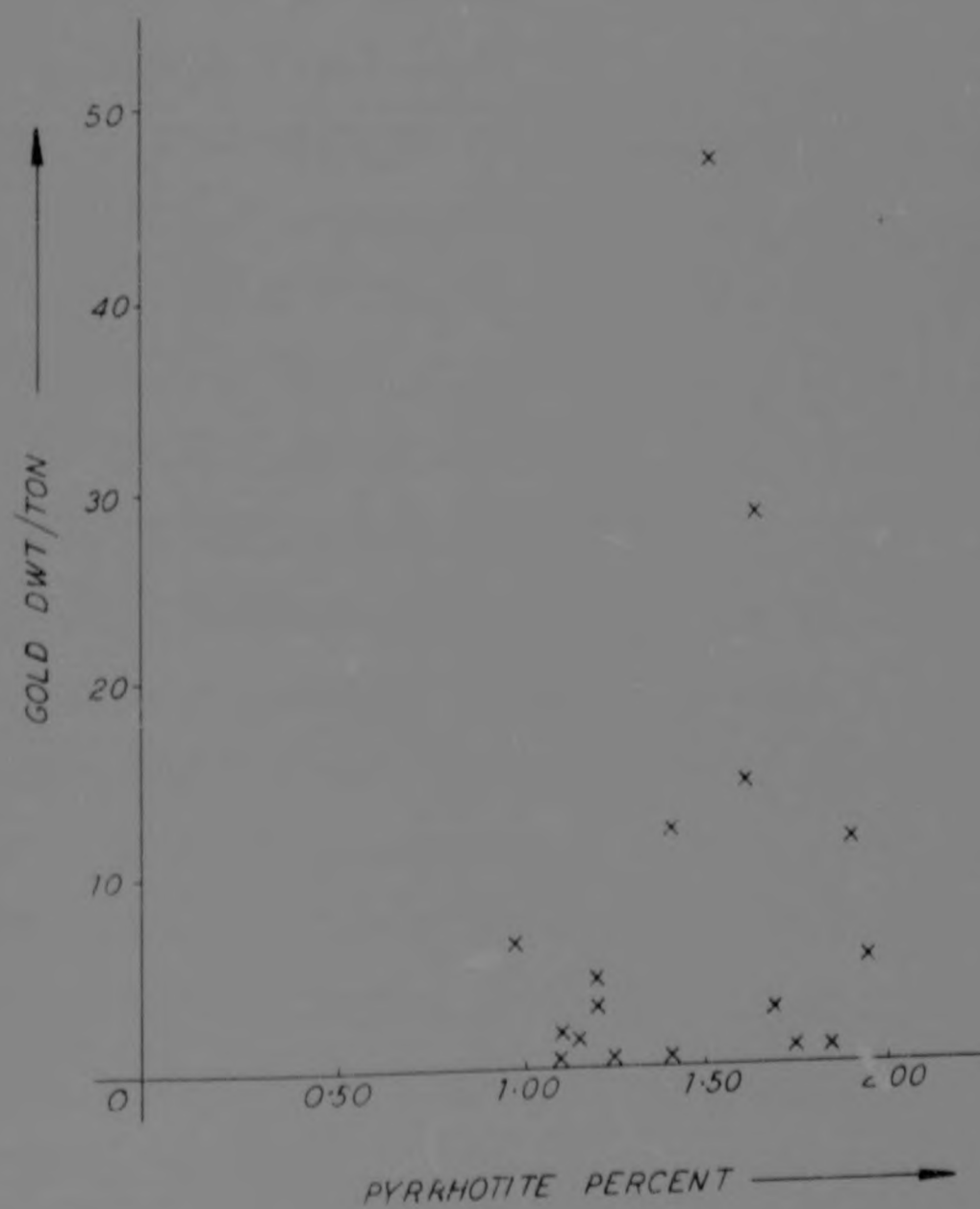


FIGURE 5.

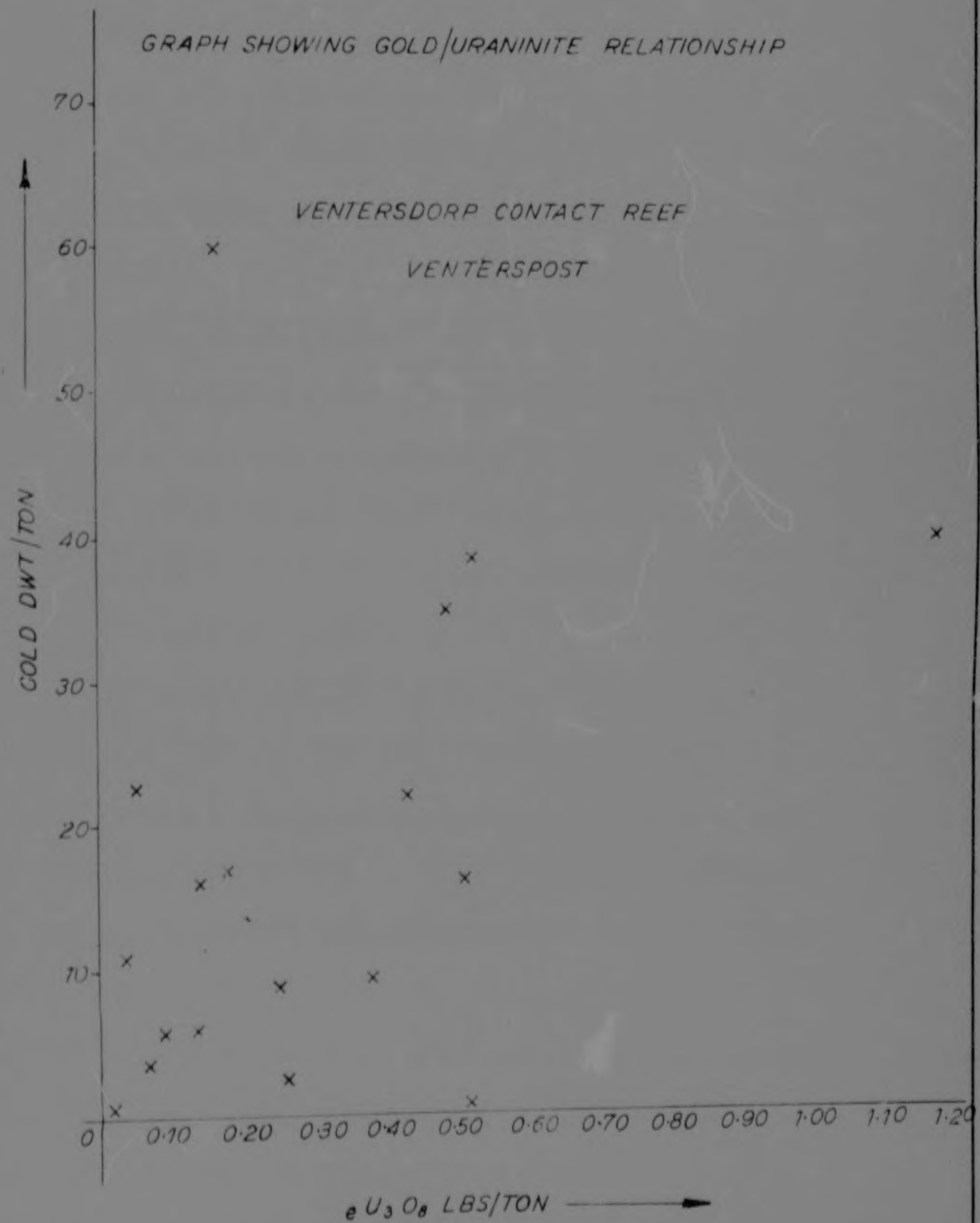


FIGURE 6

GRAPH SHOWING GOLD/URANINITE RELATIONSHIP

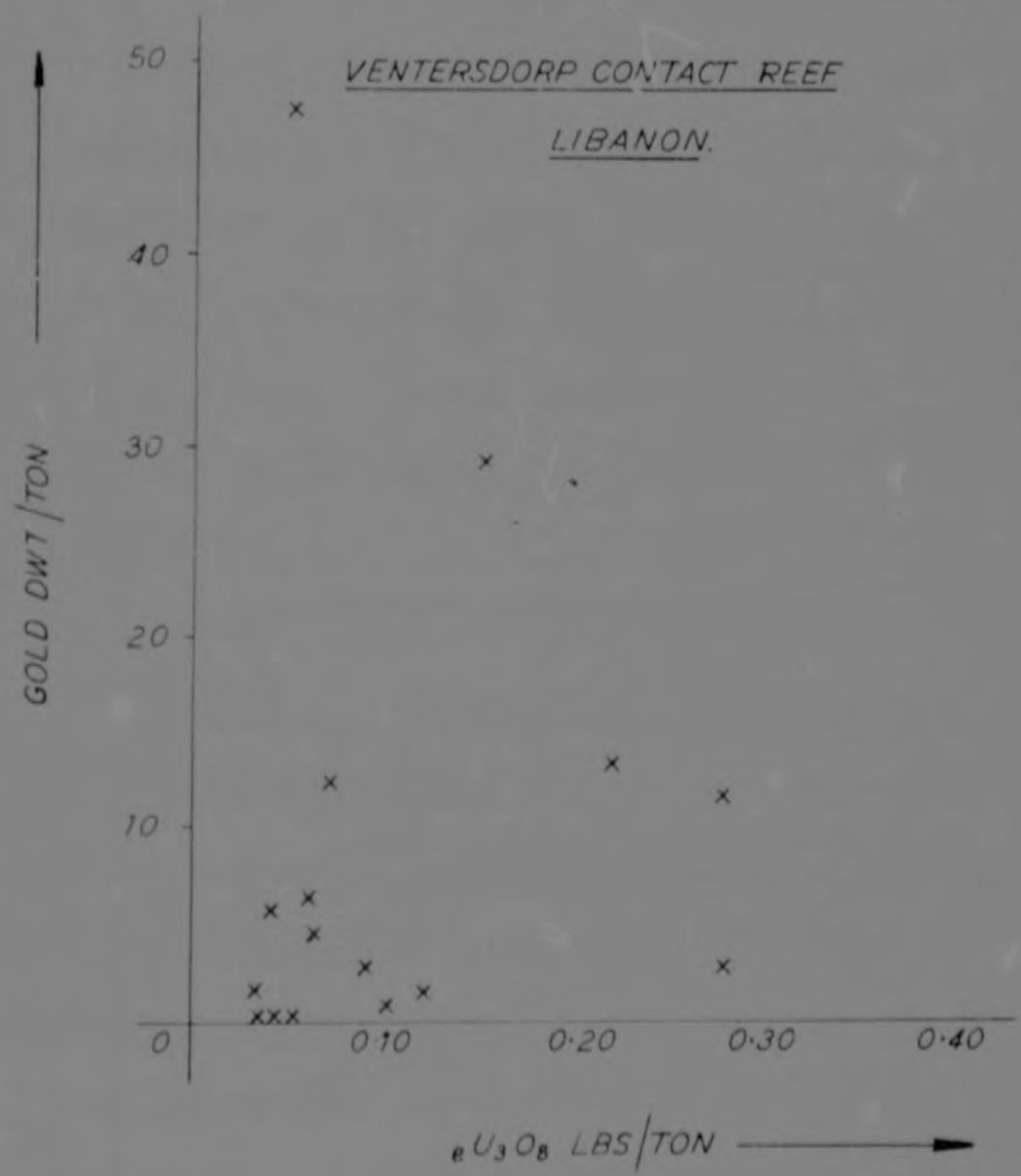


FIGURE 7

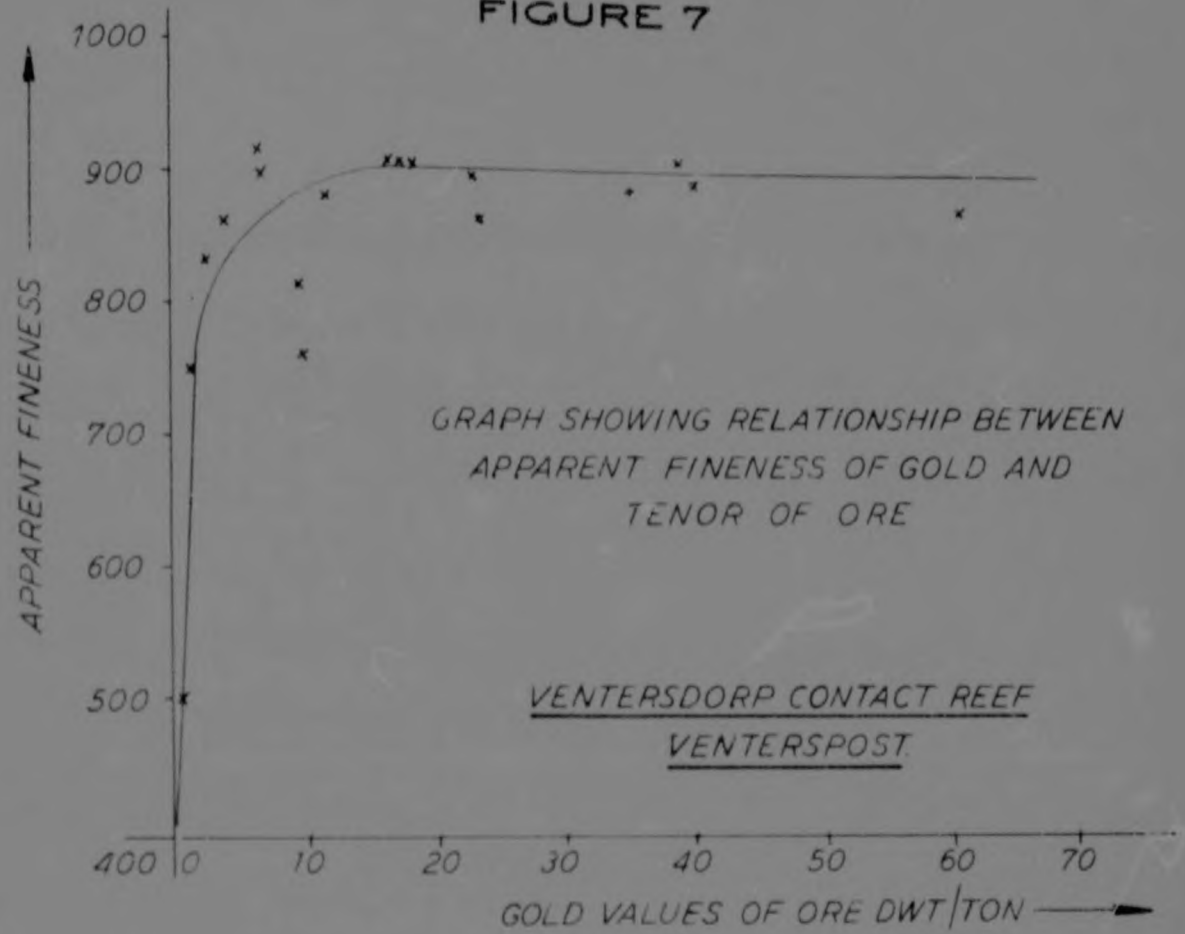


FIGURE 8.

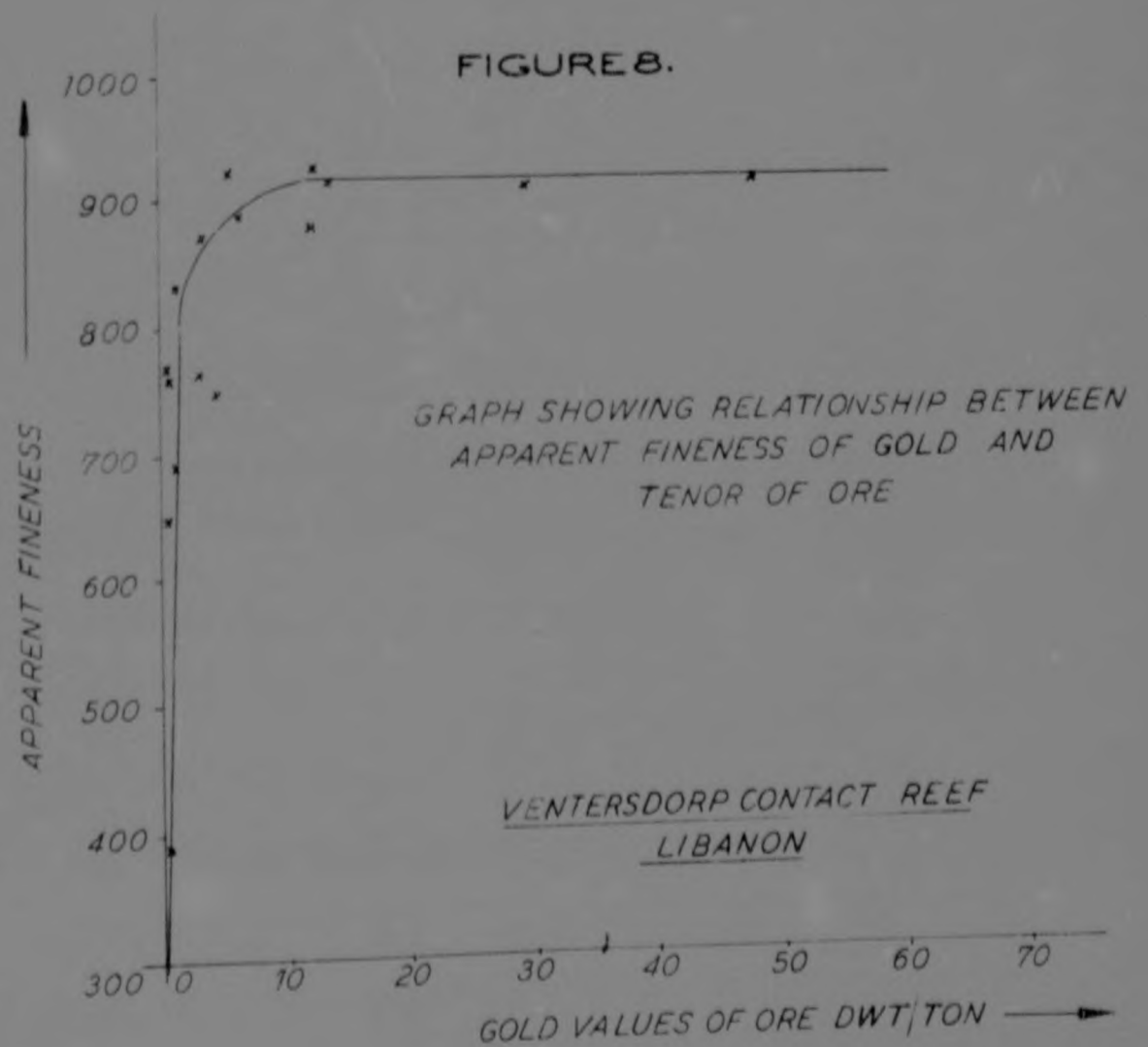


FIGURE 9.

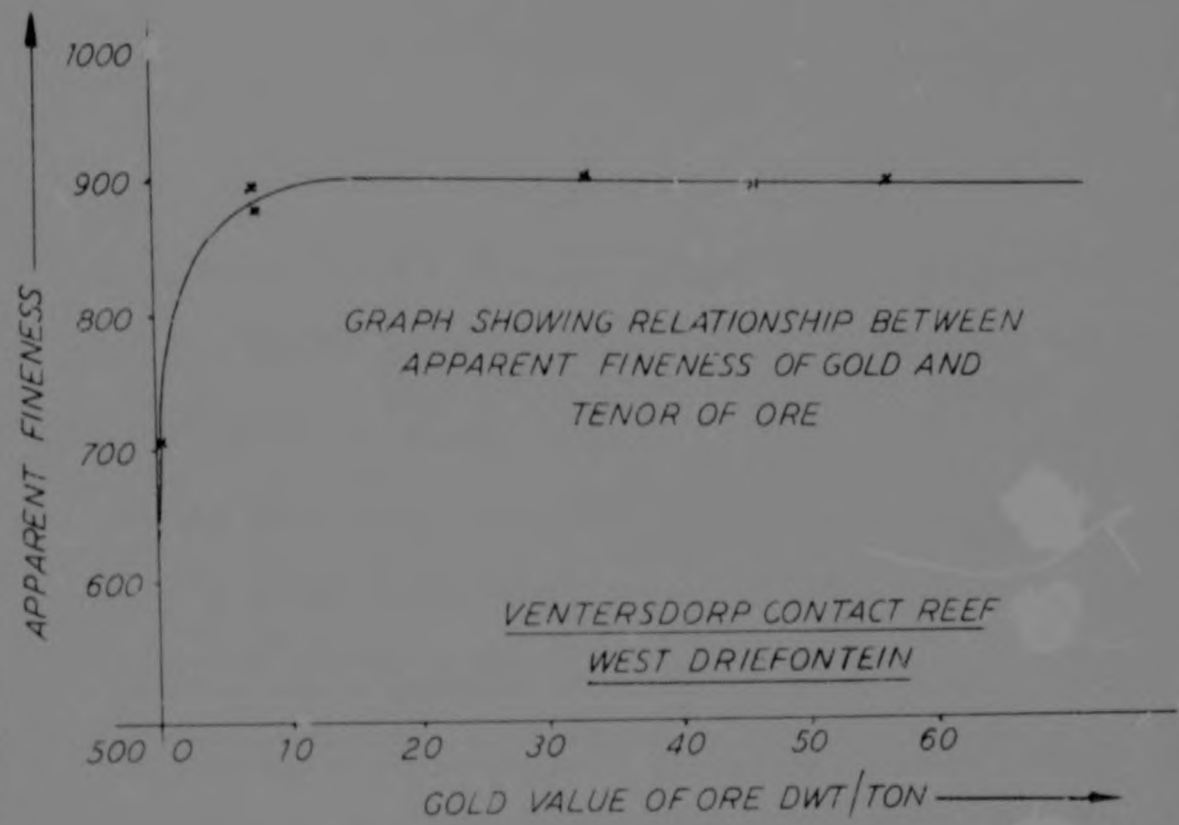
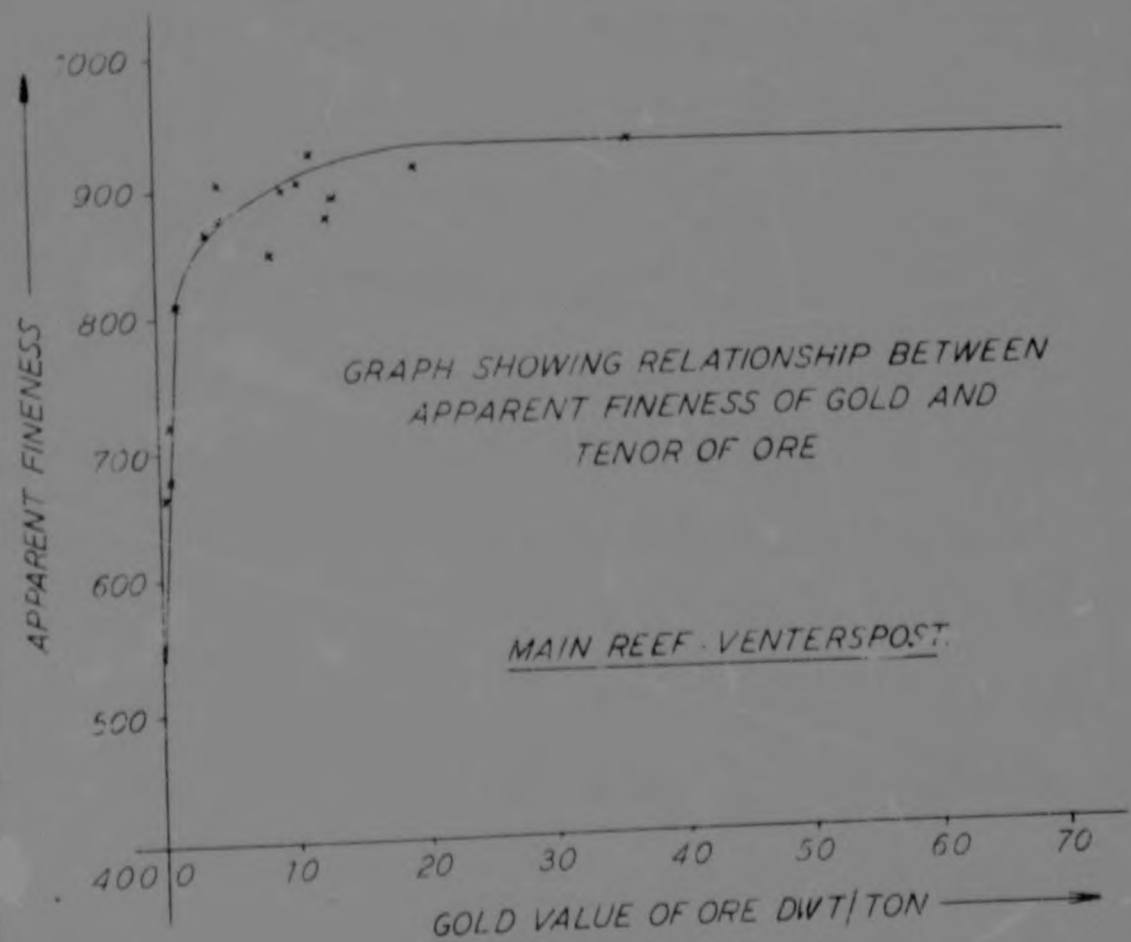
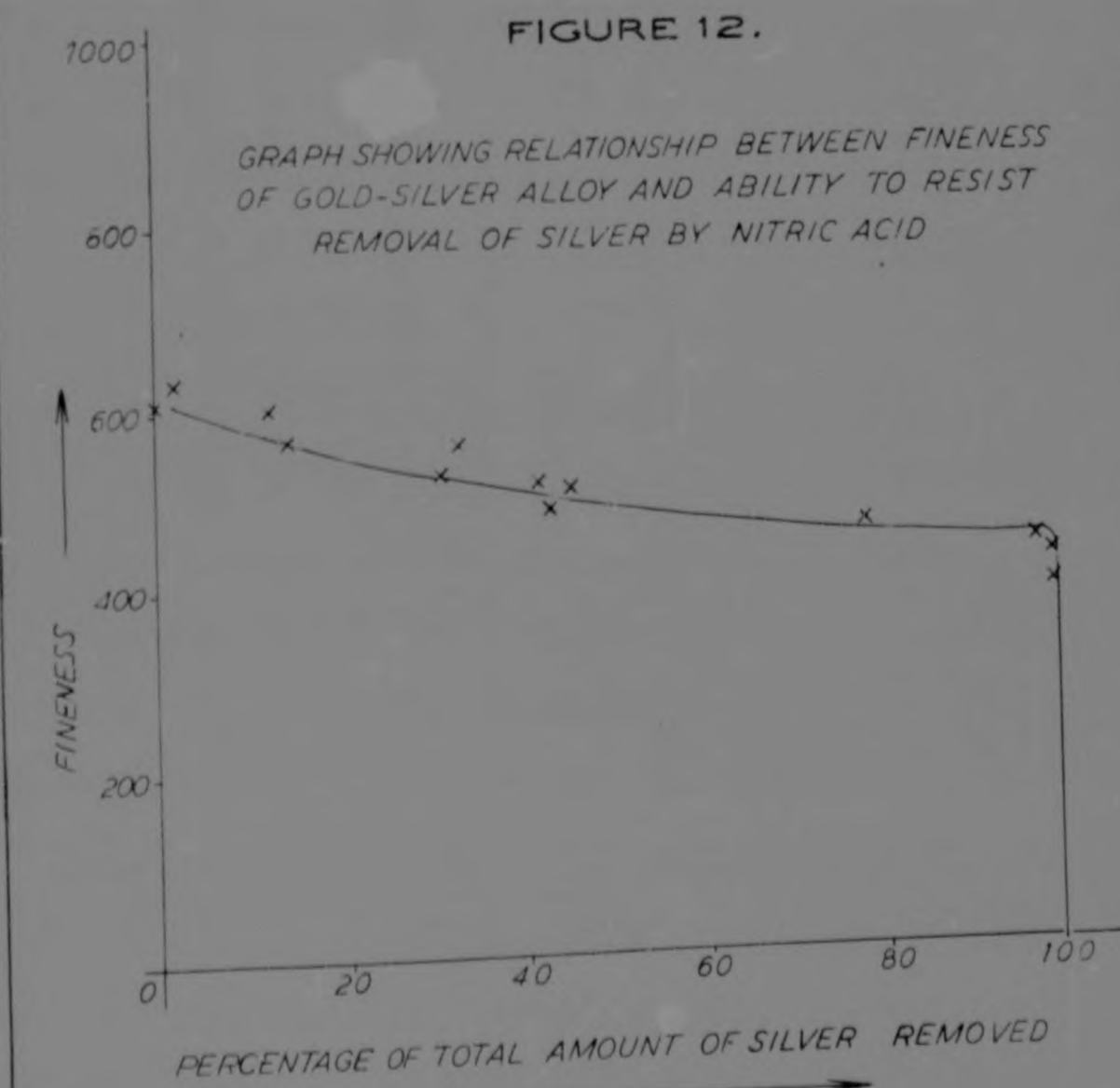
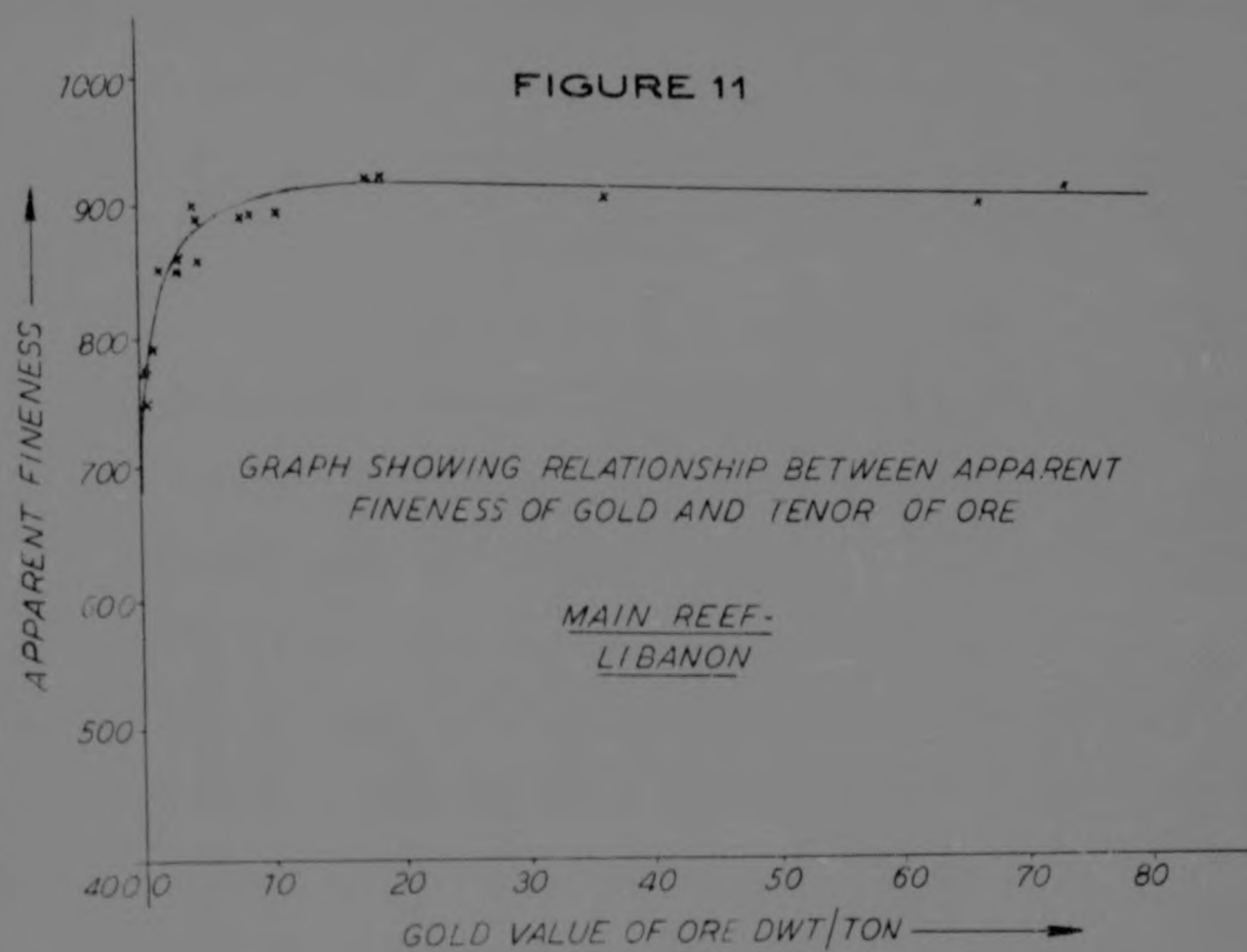


FIGURE 10.





CLASSIFICATION OF CARBONACEOUS MATERIALS

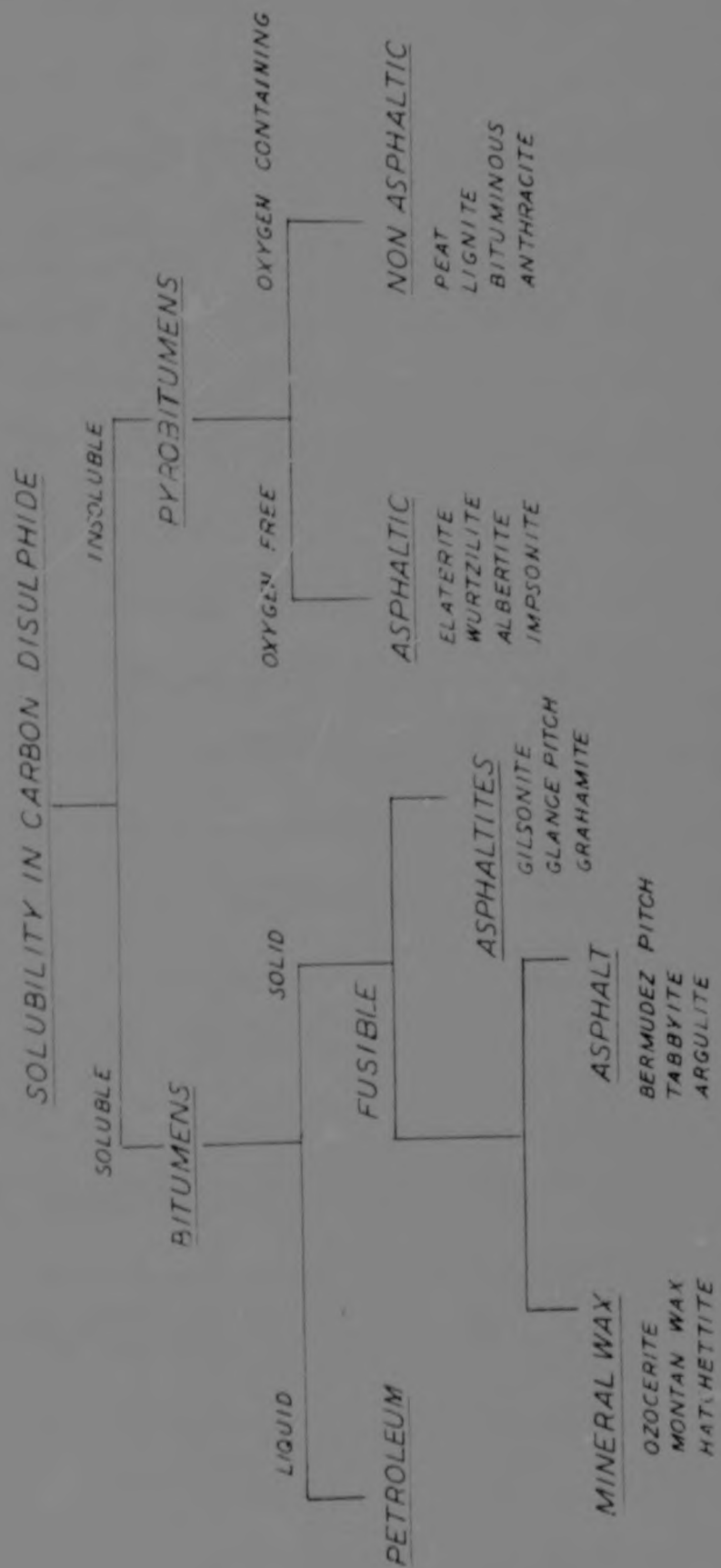


FIGURE 13

(AFTER HUNT STEWART AND DICKEY 1954)

FIGURE 14

HISTOGRAM SHOWING SIZE DISTRIBUTION OF
URANINITE PARTICLES RECOVERED FROM
PULPED ORE

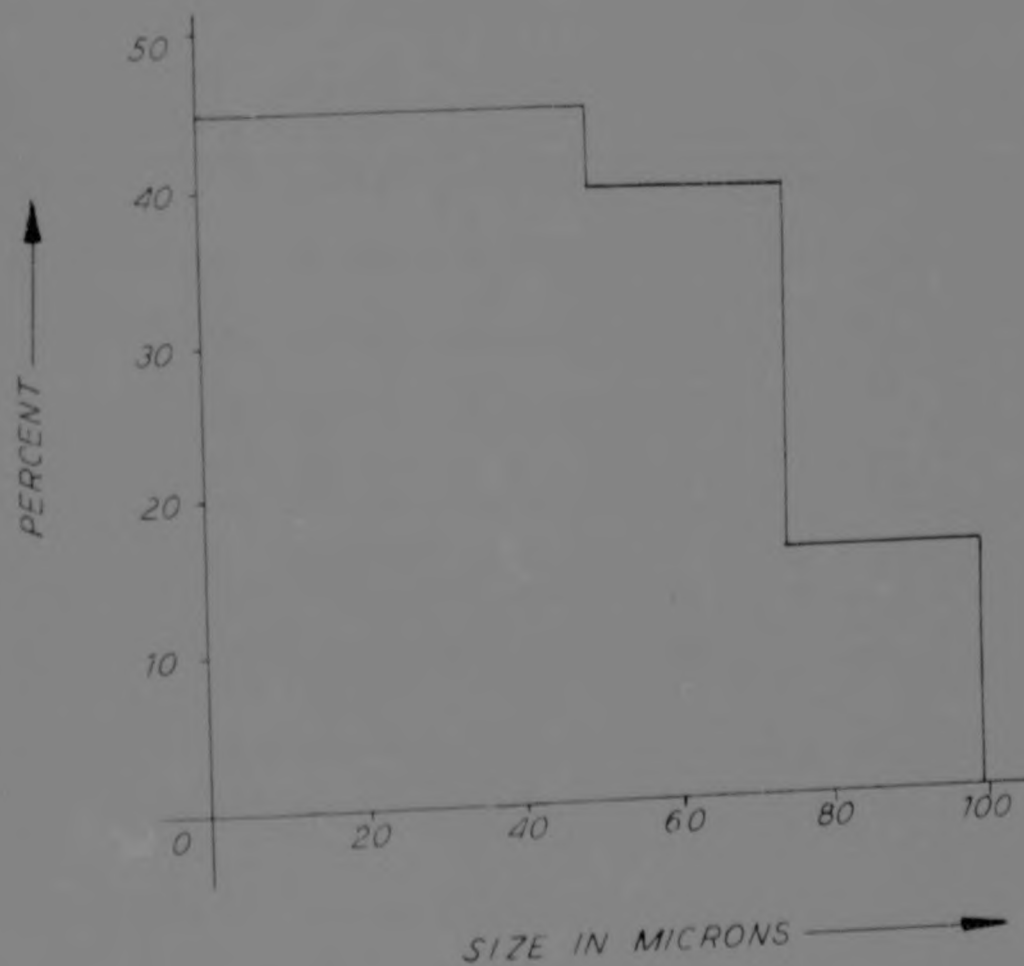


FIGURE 15

GRAPH SHOWING RELATIONSHIP
BETWEEN ZIRCON AND URANINITE

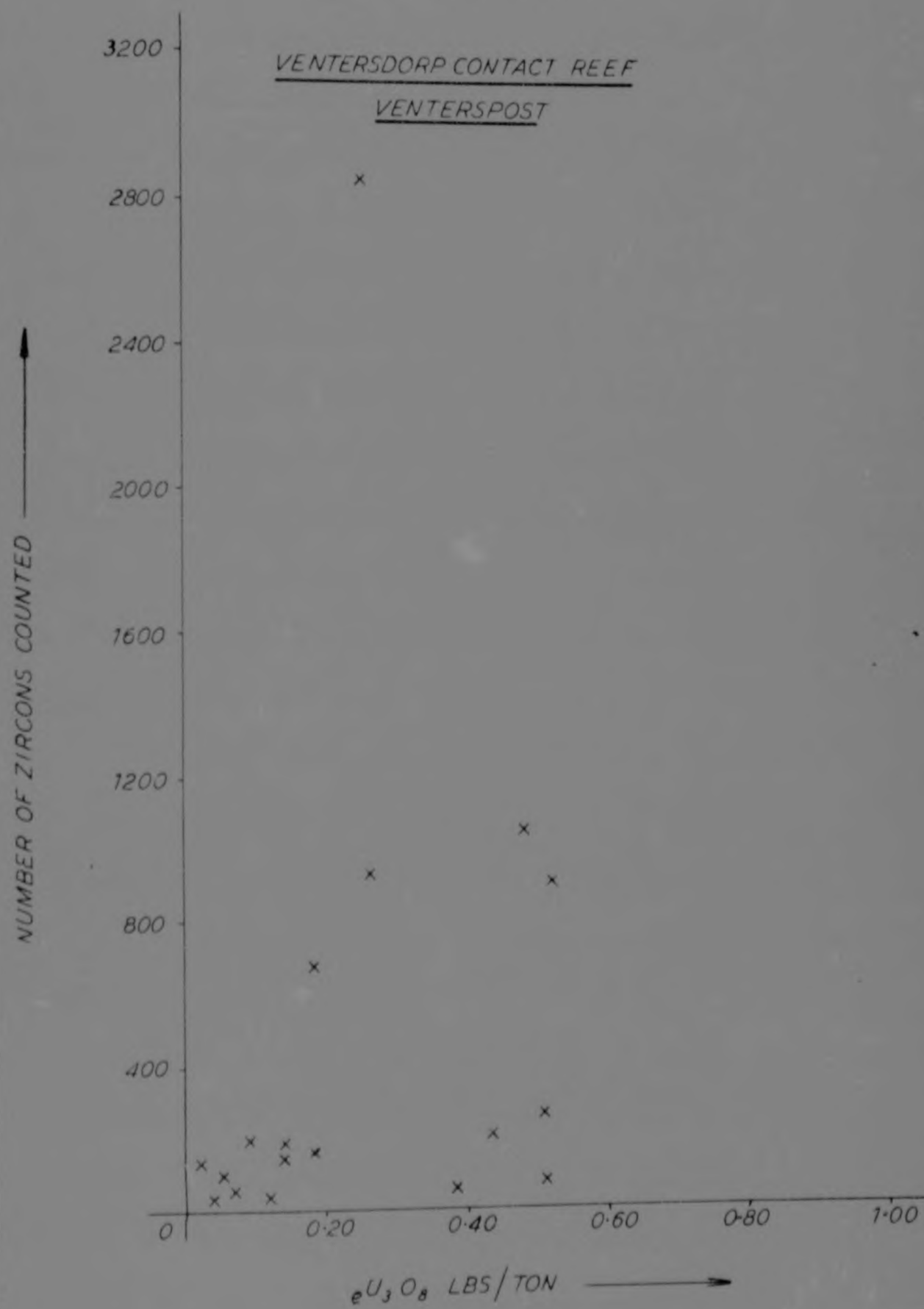


FIGURE 16

GRAPH SHOWING RELATIONSHIP
BETWEEN ZIRCON AND URANINITE

VENTERSDORP CONTACT REEF

LIBANON.

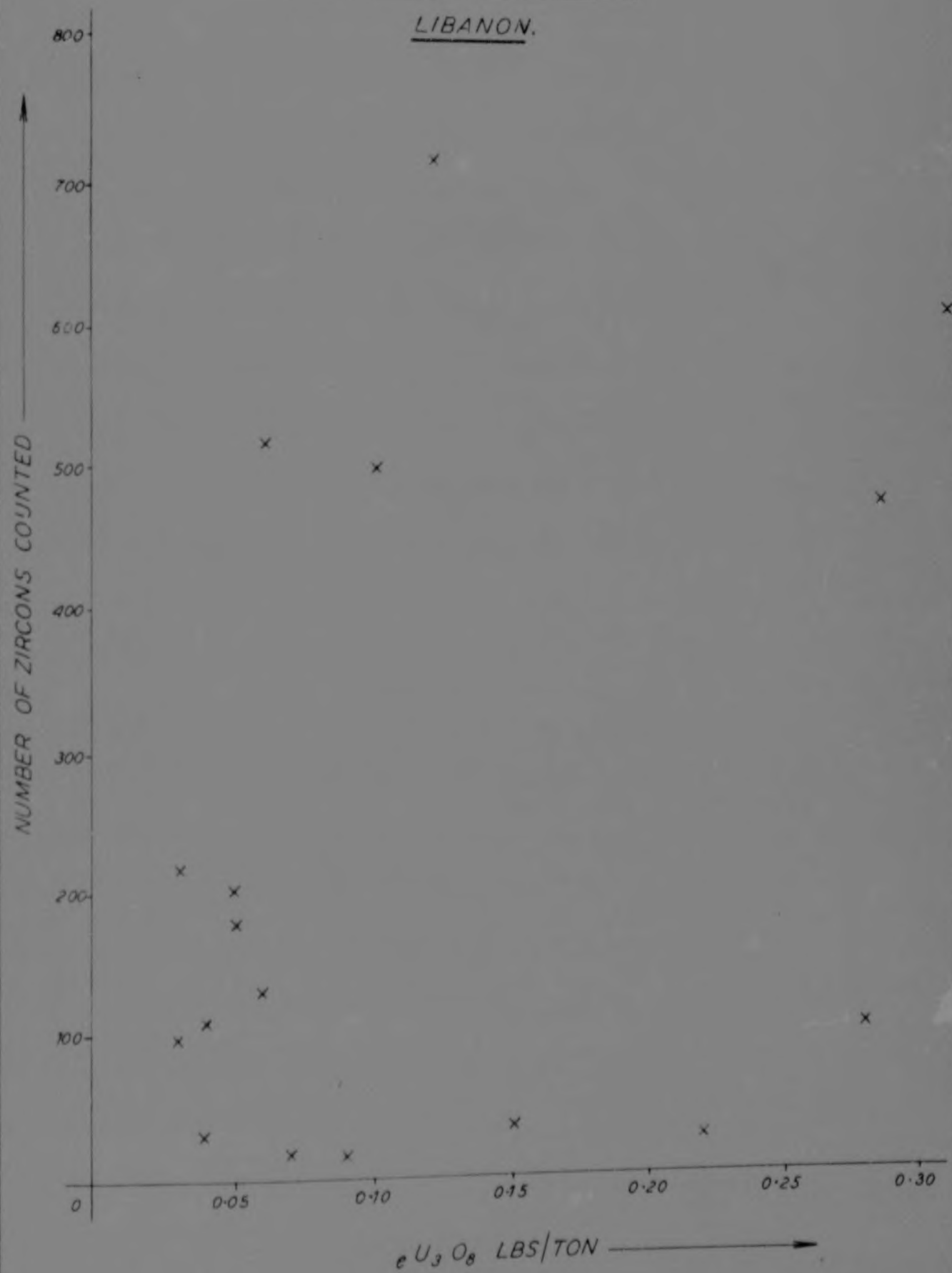


FIGURE 17

ZIRCON TYPES - (AFTER DANA 1909)

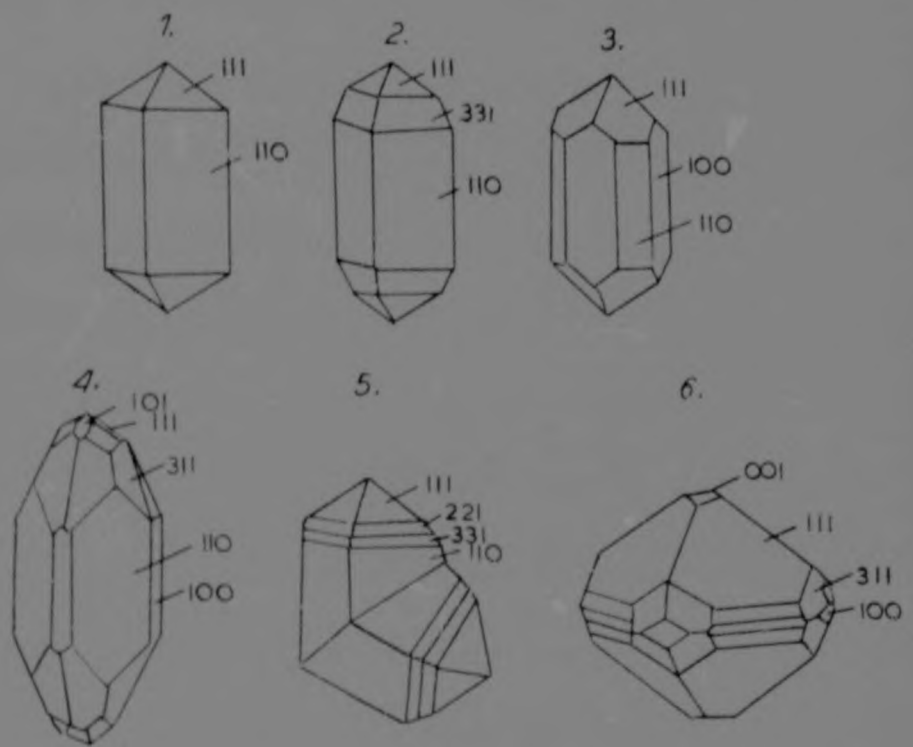


FIGURE 18

ZIRCON FREQUENCY/ELONGATION DIAGRAM

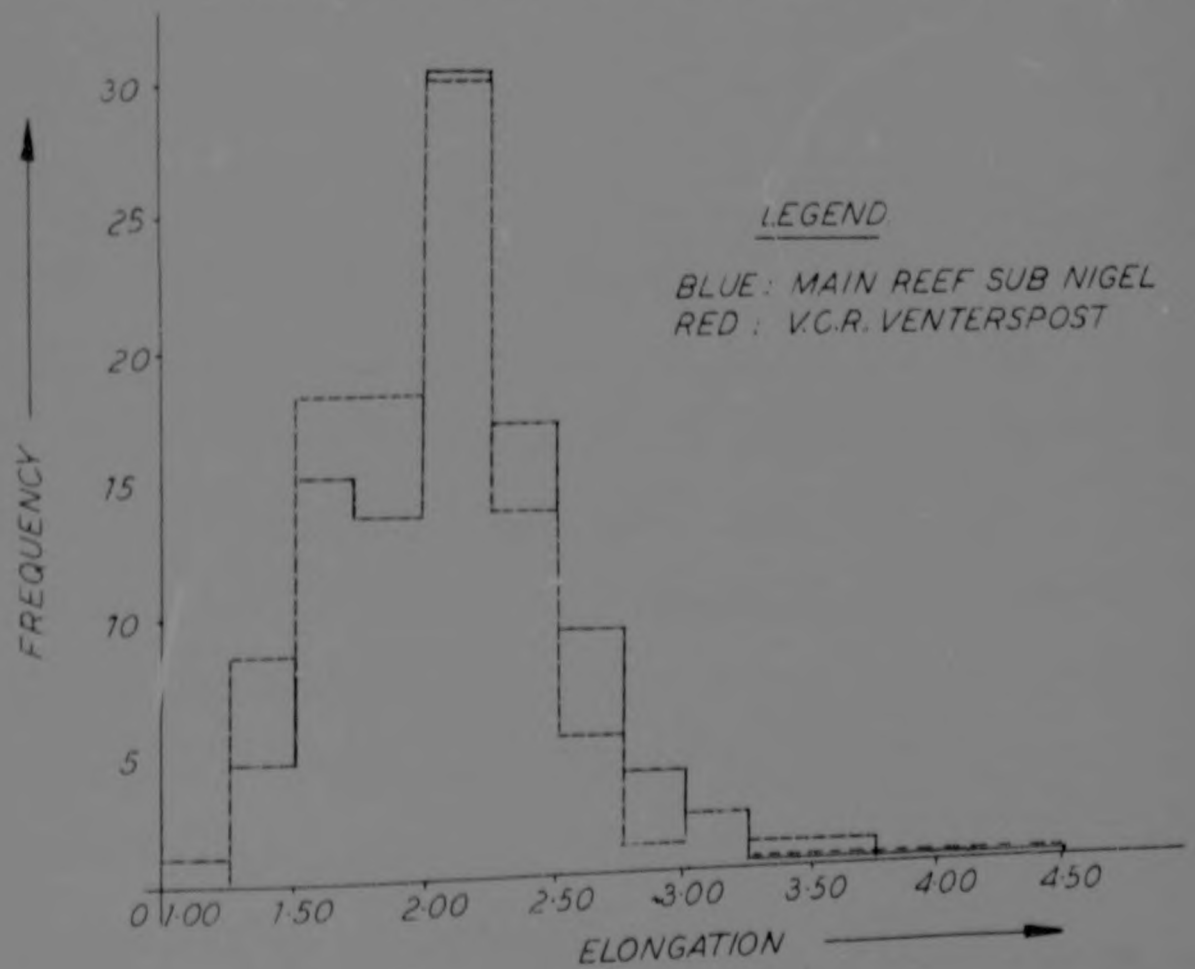


FIGURE 19

ZIRCON FREQUENCY/ELONGATION DIAGRAM
FOR COARSE GRANITE A 124
(AFTER WYATT 1954)

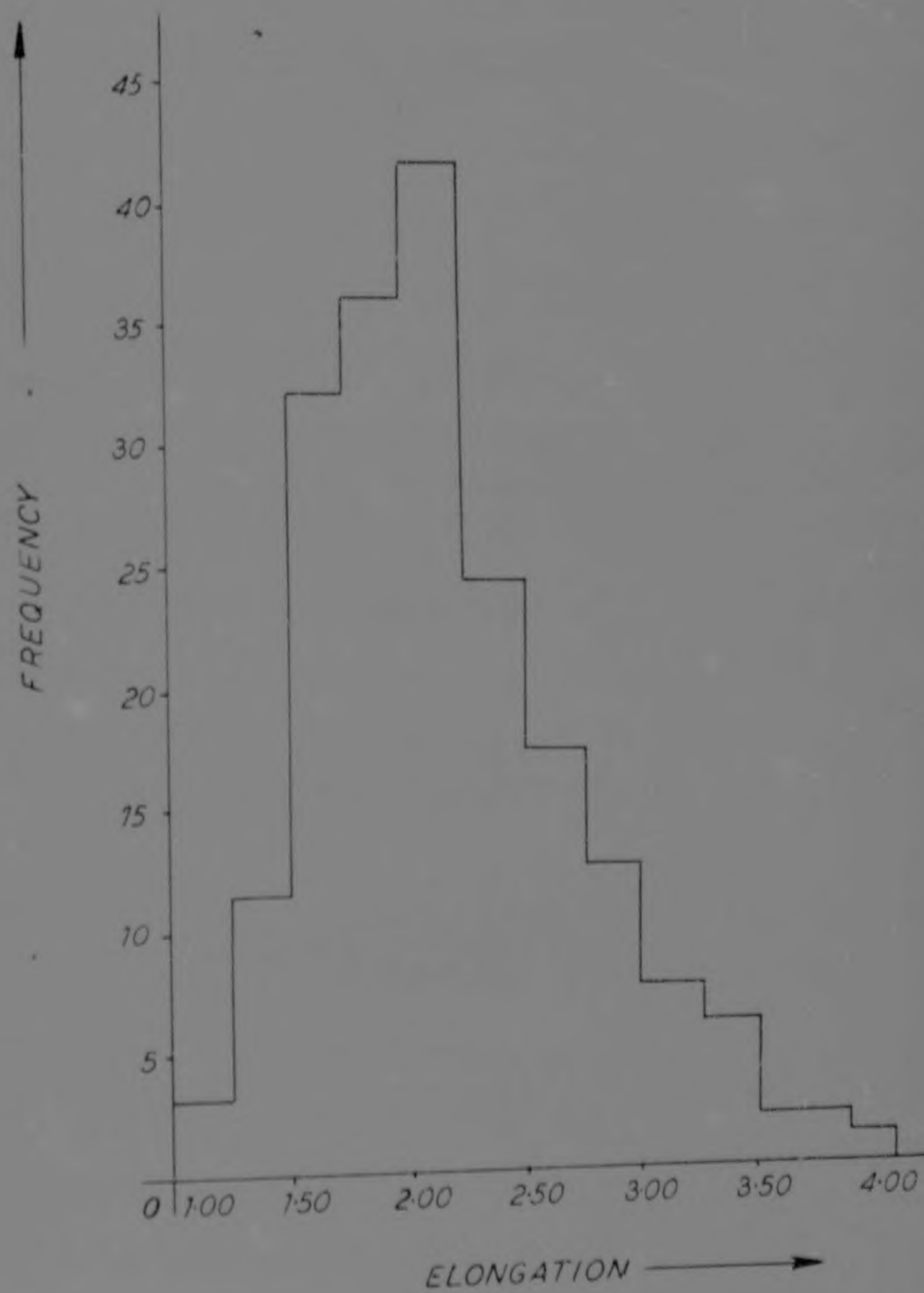


FIGURE 20.

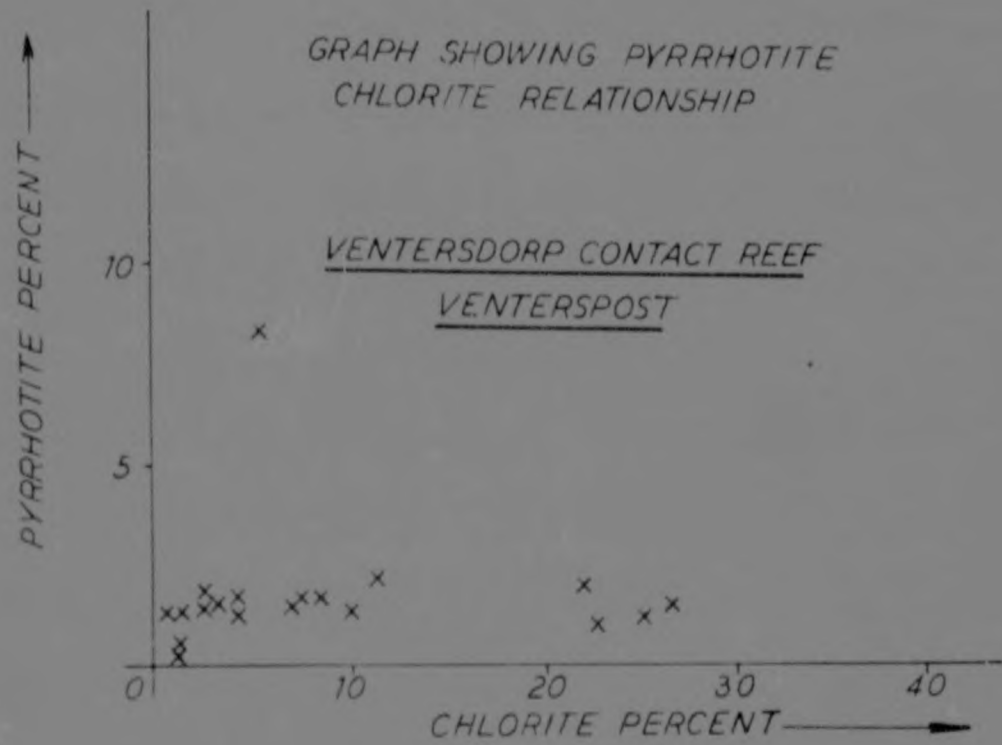
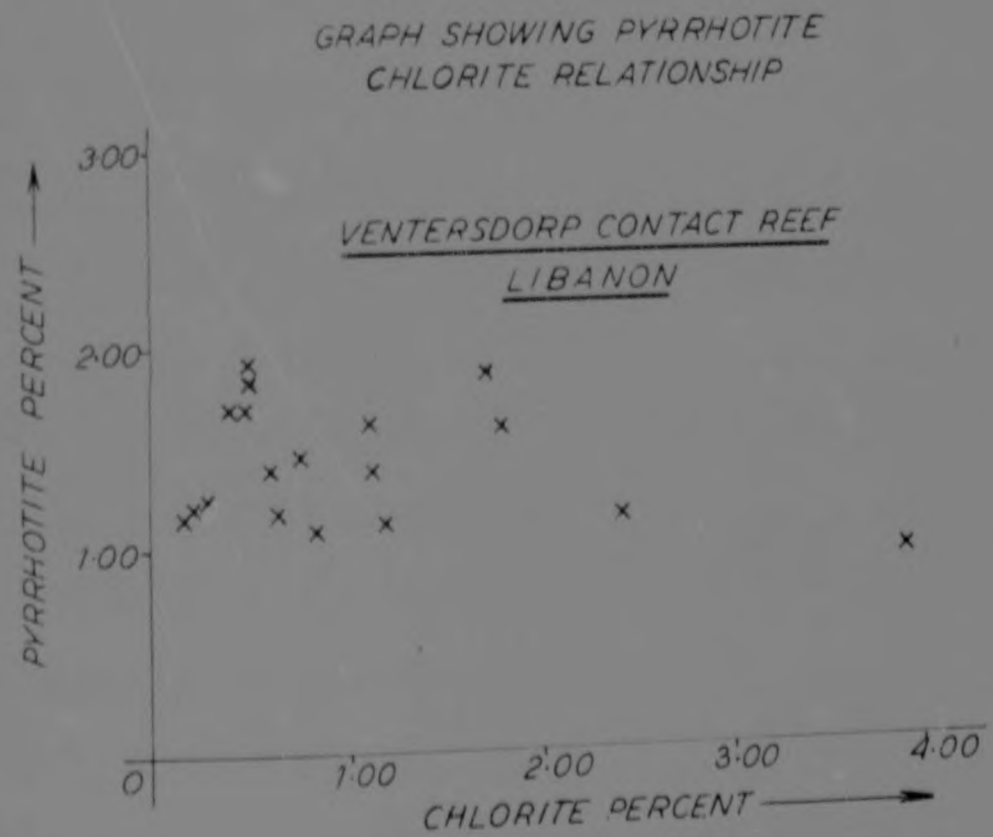
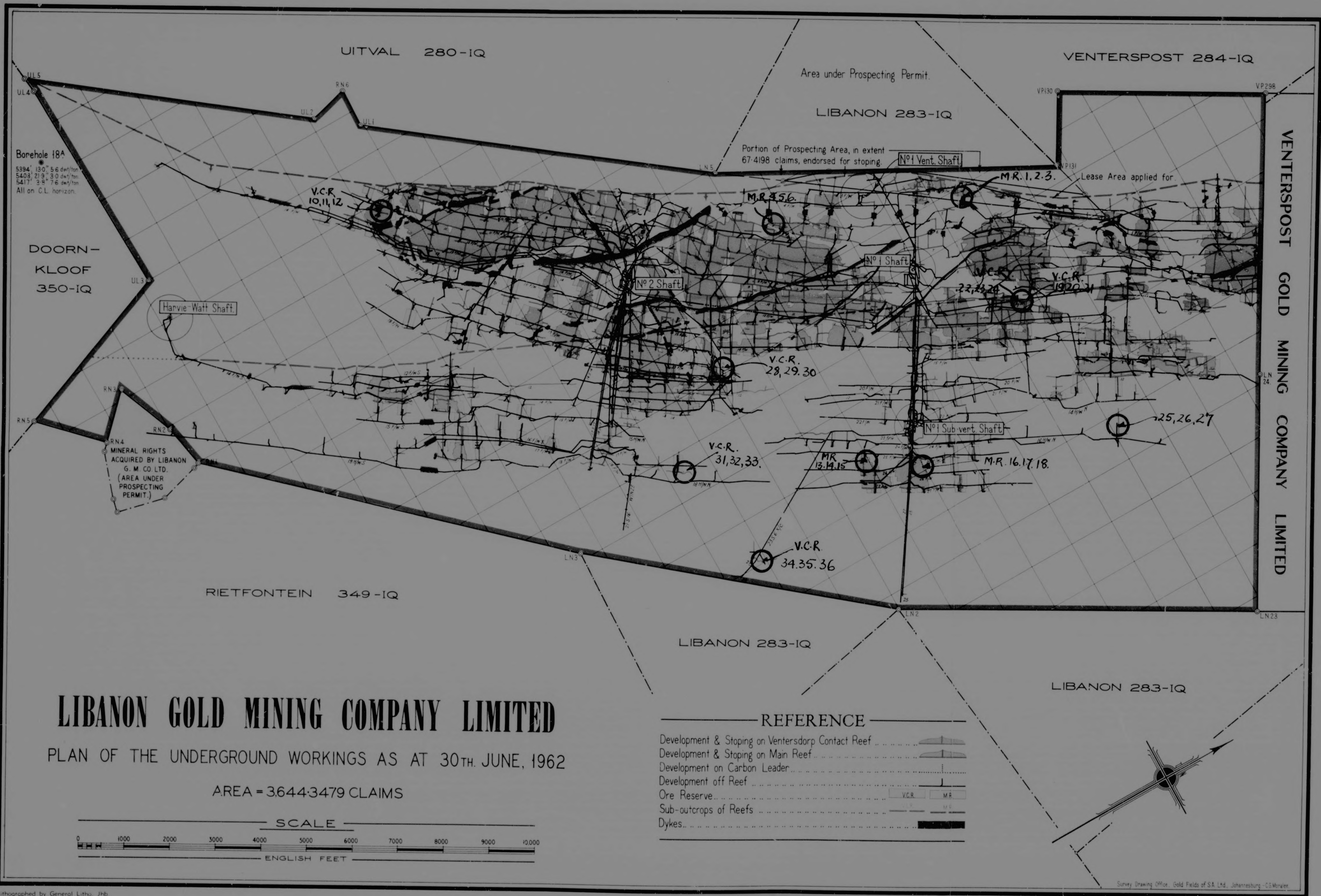


FIGURE 21





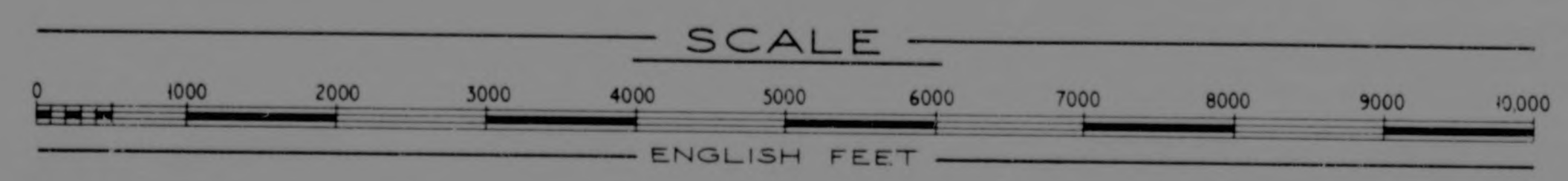


VENTERSPOST GOLD MINING COMPANY LIMITED

LIBANON GOLD MINING COMPANY LIMITED

PLAN OF THE UNDERGROUND WORKINGS AS AT 30TH. JUNE, 1962

AREA = 3644.3479 CLAIMS

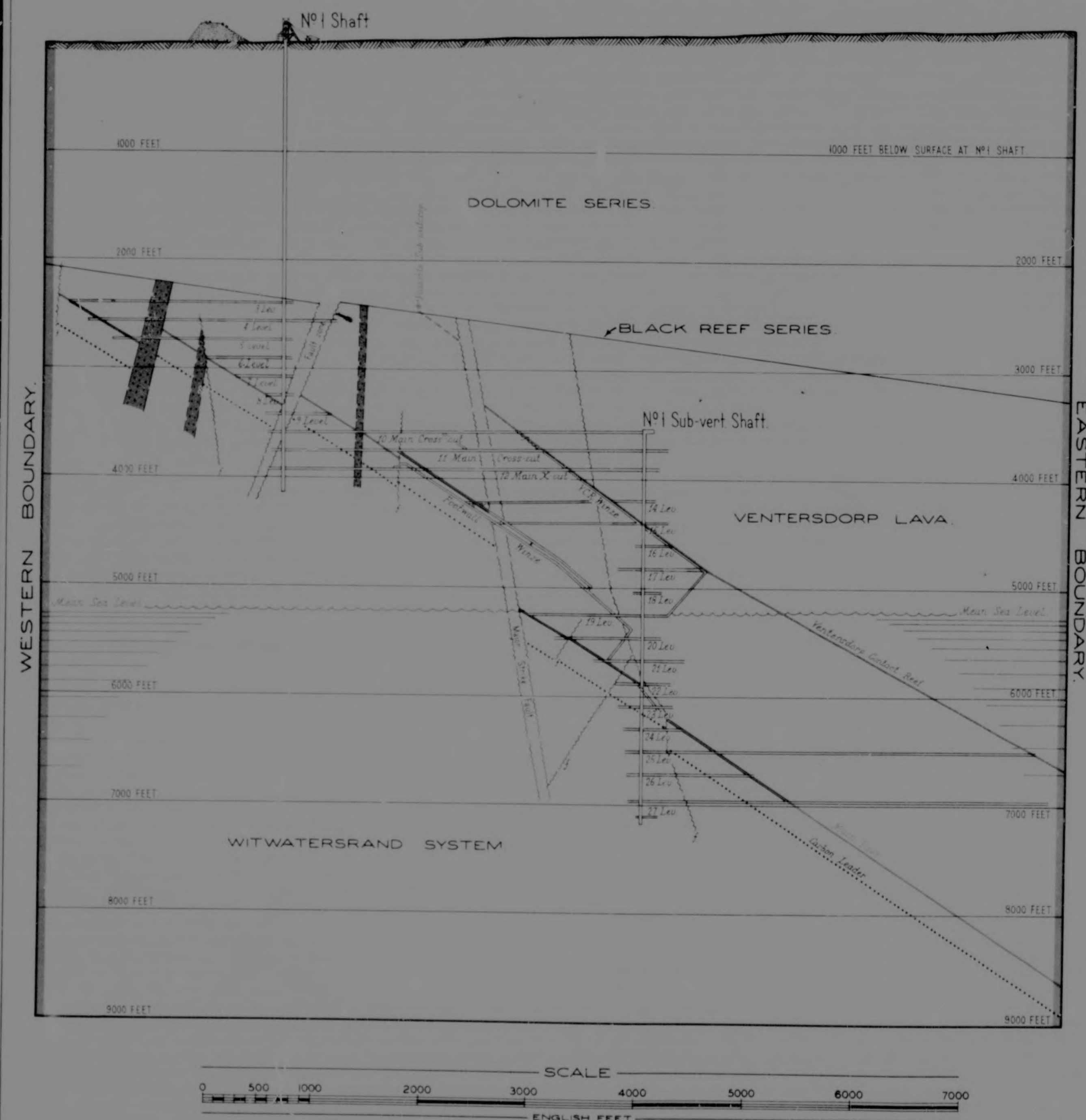


REFERENCE	
Development & Stopping on Ventersdorp Contact Reef	
Development & Stopping on Main Reef	
Development on Carbon Leader	
Development off Reef	
Ore Reserve	
Sub-outcrops of Reefs	
Dykes	

TRANSVERSE SECTION THROUGH N°1 SHAFT LOOKING NORTH

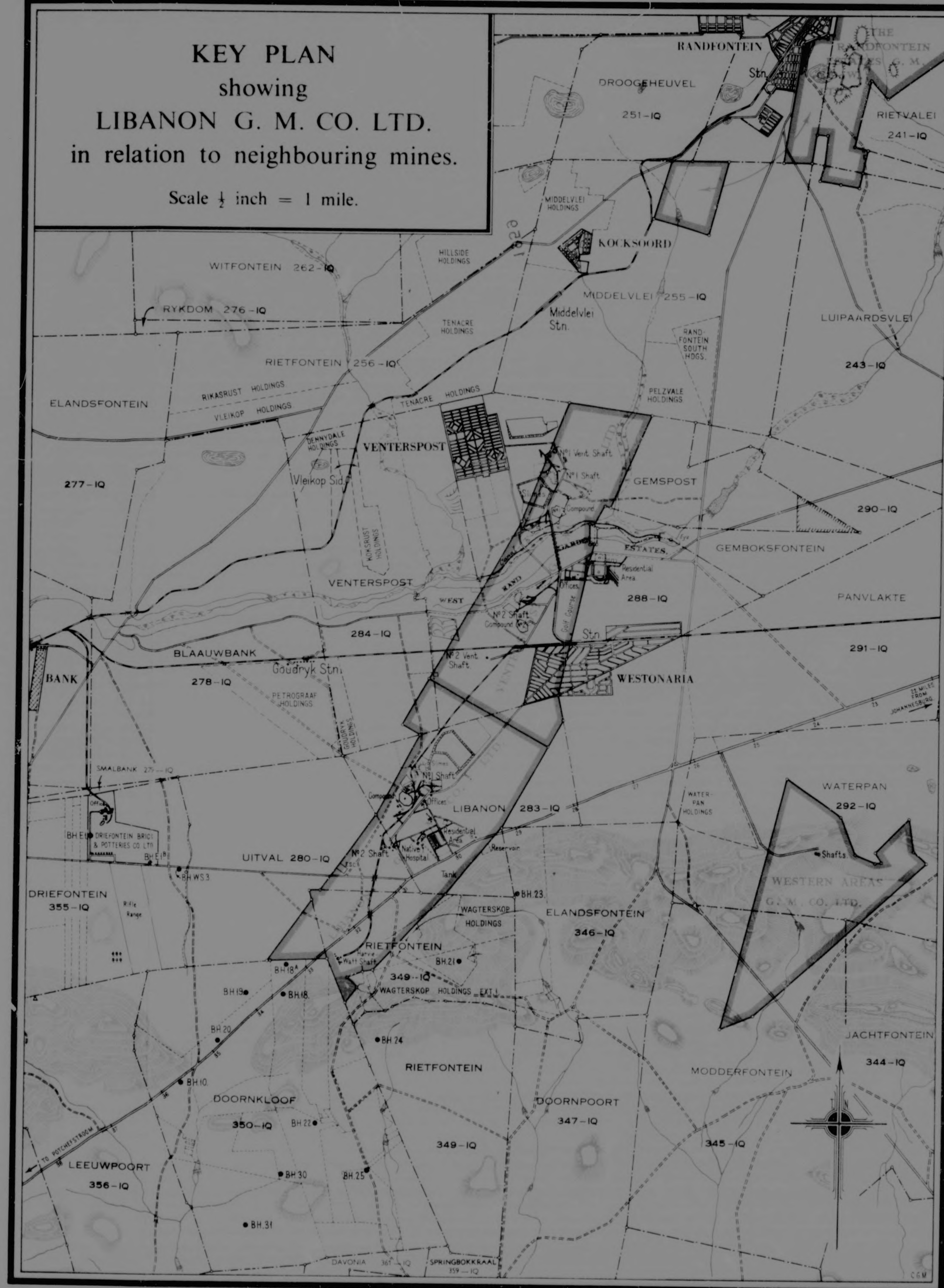
REFERENCE

Ventersdorp Contact Reef..... Main Reef..... Carbon Leader.....
 Faults..... Dykes.....



KEY PLAN showing LIBANON G. M. CO. LTD. in relation to neighbouring mines.

Scale 1/4 inch = 1 mile.



For Key Plan see overleaf.

Author Rahden H V R

Name of thesis A detailed mineralogical investigation of the Ventersdorp contact Reef at Venterspost and Libanon Gold Mines, West Rand, with special reference to the mode of mineralization of this horizon 1963

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