

pyrite and chalcopyrite. The mineral has a "colloform" texture (the term implies a colloid or gel texture) and occurs as botryoidal, reniform or mammillary shapes arranged in concentric layers (see Plate 48). Pyrite was seen grading into irregular allotriomorphic aggregates of melnikovite-pyrite. Quartz particles often form the cores of the concentric layers. A few radial cracks were noted but concentric spheroidal cracks are more common. Pyrrhotite replaces the melnikovite-pyrite and arsenopyrite in the same sections and the melnikovite-pyrite in turn corrodes and replaces the arsenopyrite aggregates.

Melnikovite-pyrite, an unusual mineral, is only described in a few occurrences throughout the world. It has been described by Schneiderhöhn and Ramdohr (1931) and is considered by them to have formed by supergene processes. Before them however, Smitheringale (1928) described crystalline aggregates arranged in circular form about centres of quartz or chlorite from the George Gold-Copper Mine, Stewart, British Columbia.

de Villiers (1957), in addition to describing melnikovite-pyrite in the Lily Mine also found it to be fairly common in the Barbrook Mine and in the Pigg's Peak Mine in Swaziland.

It appears that the mineral is restricted to zones of alteration and localities where supergene effects have been operative.

(viii) Magnetite

Magnetite was seldom noted in the pyrrhotite ores but occurred locally, especially in some folded zones on Level main crosscut drive. The ore was strongly magnetic and occurred in massive banded form in strongly folded shales. The rock is folded in the hand specimen, yet on microscopic examination the magnetite occurs as idiomorphic crystals entirely disconnected from one another in the sedimentary and silicate matrix. Even in the tight hinge zones of the folds the grains show no evidence of having been deformed and apparently formed subsequent or synchronous to the deformation. A few grains of hematite were seen with the magnetite. Supergene oxidation has caused the latter mineral to revert to hematite. The brittle nature of the magnetite and the fact that much of it is partially altered makes the mineral difficult to polish and the surfaces are seldom free from pitting.

(ix) Hematite

Most polished sections examined contained a little hematite. It was more commonly seen associated with magnetite and in oxidized ores. It is often clearly pseudomorphous after magnetite with sometimes the entire crystal being replaced while in other instances it is only partly altered consisting of magnetite cores enclosed in hematite. These replacements tend to suggest that much of the hematite formed from the oxidation of magnetite.

(x) Limonite and Goethite

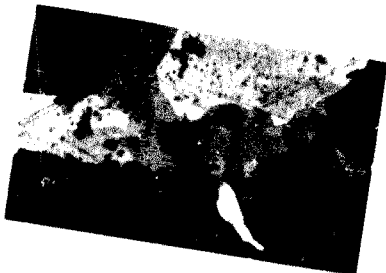
These two ferruginous minerals frequently occur together and were largely formed in situ by hydration of the iron oxides of the banded ironstones and magnetite-hematite minerals. The limonite is largely responsible for the variety of colours ranging from earthy yellow to brick-red found in the oxidized parts of the mine. Both minerals are very soft and occur filling fracture planes and cavities in the ore zones. They also occur frequently in brecciation cavities and exhibit colloform banding or botryoidal structures (see Plate 57).

The two minerals occur in amorphous form but are readily seen under the ore microscope where the goethite may be recognized by its dark gray colouration. The limonite, on the other hand, is light gray in colour and under crossed nicols is orange-yellow.

All the ferruginous mineral assemblages mentioned above, e.g. magnetite, hematite and limonite-goethite, are present throughout the mine and are for the most part original primary constituents of the sedimentary sequence. Some of the magnetite and hematite has probably been introduced by hydrothermal solutions but it is most likely that the original material in the sediment has been recrystallized. Plate 50 shows a narrow vein of gold severed by a later vein of limonite-goethite.

(xi) Gold

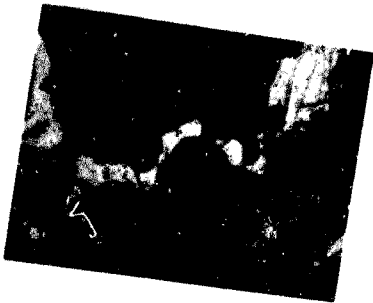
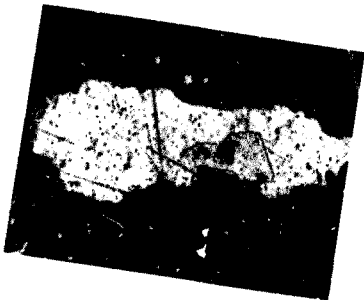
Gold occurs widely but erratically, throughout the mine. It is associated with sulphide ore from 2 Level where it occurs in the rock as veins sometimes 1/16th. of an inch thick (see Plates 51, 52 and 55). More generally however, the gold tends to be associated with quartz only. Where it occurs as free gold it is usually extremely rich, frequently occurring as flattened leaves, plates, particles or veins.



52

52

(Page 53) In turn to
 show the crystal
 over and over.
 reflected light.



54

Page 54

The gold itself reveals no obvious textures but has largely been moulded by its environment. In quartz, disseminated particles at times form stringers, a few microns in size and the gold frequently behaves in a similar manner to pyrrhotite in that it occurs interstitially between amphibole laths or as replacement fillings in quartz (see Plates 55 and 56). There is often no evidence of the quartz being fractured and it is assumed that the gold formed contemporaneously with this mineral leaving some of it trapped within the quartz.

Idiomorphic crystals of arsenopyrite, fractured as a result of shearing are replaced by gold and cavities left in the former are often filled by the latter mineral. Under high powered magnification minute gold particles were seen to be trapped within the arsenopyrite-judmundite crystals from the winzes below 2 Level. This mineral, pink in colour, has been mentioned earlier. There is so much gold present within the sulphide, however, that the reflectivity has been enhanced, possibly explaining also the colour difference between it and arsenopyrite. Numerous tests were performed on this mineral that gave an indication of the presence of antimony. The mineral was also found to be very brittle and gave a Vickers hardness of approximately 800 (i.e. considerably softer than pure arsenopyrite). The abundance of gold also no doubt was responsible for the lower value obtained, although great care was taken to avoid the minute particles when the tests were made.

Much of the gold is considered by the writer to be of epigenetic or secondary origin especially in the oxidized zones of the mine. The depositional sequence apparently overlaps, i.e. some gold formed simultaneously with the sulphides and was trapped within the latter, while other gold occurred later in the sequence and reverses the processes. Idiomorphic arsenopyrite was seen entirely surrounded by gold (see Plate 53).

This later gold was probably released from the altered sulphides in higher levels and made its way down suitable channels to be precipitated and concentrated in structurally controlled localities below.

(c) Causes of the Localization of Gold

As has been mentioned the gold recovered from the mine to date has occurred primarily in veins and reefs and in pronounced zones of disturbance.



Plate 55. A dark, textured surface, possibly a rock or mineral specimen, showing some lighter, irregular patches.

Plate 56. A dark, textured surface, possibly a rock or mineral specimen, showing some lighter, irregular patches.



(reflected light only)



Plate 57. A dark, textured surface, possibly a rock or mineral specimen, showing some lighter, irregular patches.

The channelways and brecciated zones thus provided a more favourable passage through which larger volumes of gold-bearing solutions could pass. Advantage was taken of the greater permeability afforded by the breccias and although the gold elsewhere in the mine was introduced more or less contemporaneously, that deposited in the shoots could have continued for longer periods. Possible supergene gold solutions produced after oxidation and weathering of the sulphides, fractured the breccia channels that probably remained open before being cemented closed by muds, quartz and carbonate veins. After oxidation near the surface the gold from the upper reaches of the deposit was probably taken into solution and reprecipitated contemporaneously with the breccia fill material.

The surface workings consist of broad open quarries on the downslope side of a hill. The opencast workings give way with depth to narrower reefs. The shoot too, narrows and pinches out with depth. Emanating from the northern limit of the body towards the southeast, is an intense system of flatly dipping fractures. It is almost certain that these fractures provided suitable channels for movement of auriferous solutions to lower levels and to the brecciated zones. Invariably it is found that enrichment occurs where a fracture plane intersects a vertical shear zone or reef. Gold concentration diminishes away from the intersecting planes. Roper (1938) on examination of numerous small mines in the Barberton District found essentially the same features as mentioned above, so that this process of enrichment may have been operative to a greater extent than at first might be imagined.

(d) Factors Possibly Favouring Supergene Enrichment

The bulk accumulation of gold within the shoot, and to lesser extent, in certain of the reefs and shear zones, immediately suggested an unusual mode of deposition. The extraordinary concentration of gold in pockets did not appear to be entirely primary and the probability of residual or supergene enrichment of the lodes was considered.

The upper levels of the mine are entirely composed of oxidized ores and most of the mines workings were curtailed once sulphide material was encountered. In the fresh rock the gold is no longer free milling and extraction costs rise prohibitively. Visible gold, apart from rare exceptions, becomes non-existent with depth, but most likely occurs sub-microscopically with the sulphides.

Four spot samples of sulphide ore were assayed from the following localities:-

- (i) Main Reef Zone on 2 Level.
- (ii) Winzes below 2 Level.
- (iii) Ore occurring between the winzes and the Main Reef (2 Level)
- (iv) 70 Ft. Level (western face).

These samples were analysed by New Consort Mine and gave the following erratic results:-

- | | |
|----------------|-----------------|
| (i) 39.1 dwts. | (ii) 0.3 dwts. |
| (iii) Nil | (iv) 1.35 dwts. |

It can be seen that the Main Reef furnished the h'g. to gold value. This fact is regarded as significant for it is considered probable that a large proportion of the gold mineralization found elsewhere in the mine had its origins in the Main Reef Zone.

The oxidized sections of the mine contain the bulk of the easily recoverable gold and the replacement textures of the gold in polished sections studied from most parts of the mine indicated a late introduction for much of this metal.

With the aim of finding additional evidence in support of the idea of secondary enrichment, samples of panned concentrates were obtained from four levels in the Lily Mine. These concentrates were collected over a period of six weeks. The samples consisted of daily panning of ore from working ends and stopes on each level. The fact that the pannings were obtained from several localities on each level makes the final concentrate representative of the depth zone below surface.

The samples were analysed by Gold Fields Laboratories, Johannesburg, and the percentages of gold and silver in each sample were determined. Two of the samples were obtained from thoroughly oxidized sections of the mine, a third from the transitional zone between 1 and 2 levels and the fourth sample was obtained from sulphide ores in the mine below 2 level.

The following table gives the average depth of the samples below surface as well as a depth in relationship to a datum plane. In addition the assay results for the gold and silver samples are listed.

TABLE IV

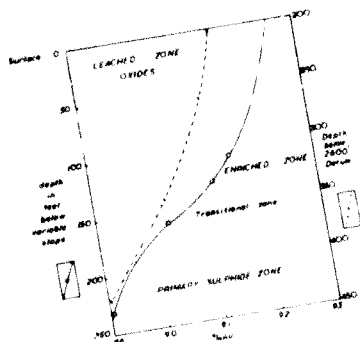
Sample	Level	Average Depth Below Surface	Depth Below 600' Datum Plane	% Au.	% Ag.
1.	50 Feet	100 feet	200 feet	91.50	9.50
2.	1 Level	130 feet	260 feet	91.15	8.85
3.	1 1/2 Level	160 feet	340 feet	90.28	9.72
4.	2 Level	230 feet	420 feet	89.04	10.96

The mine is situated on the slope of a hillside with a gradient of approximately one in four. The upper limit of the sulphide zone roughly follows the surface contour but occurs at an elevation approximately 200 feet below surface.

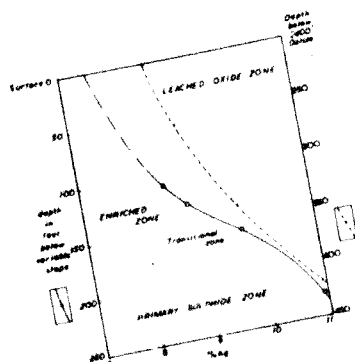
From the table above two graphs, one showing depth of sample against percentage of gold, the other showing depth against percentage of silver, were drawn (see Figs. 24 and 25). Also indicated are the relative positions of the oxide, transitional and sulphide zones.

As can be seen the gold from the upper levels possesses a greater fineness. As one approaches the sulphide ore visible gold disappears and the silver content increases. The fate of the silver in the upper levels is not known. It was possibly disseminated over too large a vertical or horizontal range to be observed.

Under normal circumstances it has been found by several investigators, amongst them Fisher (1945), that gold fineness or purity increases with depth, indicating that at higher temperatures gold is precipitated before silver. In other words, normally one should expect to find greater percentages of silver nearer the surface. The gold-silver relationship in the Lily Mine is, therefore, in direct contrast to the findings mentioned above. Insufficient development in sulphide ore at the mine prevents the writer commenting on findings similar to those mentioned by Eales (1961). He showed that in some Southern Rhodesian mines, gold with decreasing fineness indicated a low grade ore. It is thought possible that with depth the gold fineness will once again increase in the Lily Mine and that the results shown earlier indicate a secondary enrichment within the limits of oxidized and semi-oxidized rock. In addition, therefore, to suggesting that the "bonanza" gold pockets were probably largely due to supergene or secondary enrichment, it is the writer's contention that a great percentage of the "visible" gold ore from the oxidized levels was similarly enriched.



(Fig 24) Graph showing the percentage decrease of gold fineness with depth below surface and the 2600' datum plane.
Lily Mine.



(Fig 25) Graph depicting an increase in the percentage silver content with depth below surface and below the 2600' datum.
Lily Mine.

The gold regarded as secondary, is purer and more easily freed as well as being coarser in texture. It is mostly recovered by amalgamation. The primary gold is smaller, less easily freed by grinding and milling and is mostly recovered by cyanidation.

No records exist at the Lily Mine as to the fineness of amalgamated gold opposed to gold recovered from the cyanide process. It has been noted, however, that the amalgamated material always gave a greater percentage gold recovery. In this respect then, a similarity exists with this and Mackays (1944) observations in Tanganyika and Nigeria. He examined 40 mines and found that in all cases gold recovered by amalgamation was of a greater fineness than that won by cyanidation. He concluded that the divergences in the Au/Ag ratio of the coarse or amalgamated fraction and the fine or cyanided fraction was proportional to the secondary enrichment, with the gold formed by this process having less silver than the primary gold of the same orebody.

(e) Possible Mechanism for Enrichment

Numerous papers have been written discussing the processes both physical and chemical necessary to produce secondary enrichment of gold. It should be realized immediately that when talking about supergene gold, its scale and intensity should not be compared with that of sulphide secondary or supergene enriching processes. Gold is notably a stable mineral but this does not prohibit some solution taking place.

Krauskopf (1951) working on the solubility of gold, confirmed earlier findings of Emmons (1917), Ogryzlo (1935), Tyagintsev and Paulsen (1938 and 1940) and Smith (1943), who found that the greatest and most essential requirement was that the gold be oxidized. They found naturally occurring oxidizing agents, whose effectiveness was conclusive, to be MnO_2 , O_2 , Fe^{+++} and Cu^{++} , but at ordinary temperature neither H^+ nor SO_4^{--} were sufficiently strong as oxidizing agents to affect gold appreciably. Krauskopf suggested that in sulphide solutions gold occurred as a complex ion, probably AuS while in alkaline solutions it was significantly soluble unless sulphide was present.

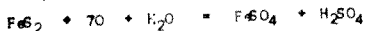
He stated that, "solution and transportation of gold in acid solution is probably the mechanism of supergene movement of gold". The requirements for taking gold into solution were described and these indicated that an acid solution containing Cl^- or a strong oxidizing agent need be present.

The precipitation of gold from a solution does not present the same problem and all that is necessary is a fall of temperature or pressure. No mention is made, however, as to whether these parameters are significant in supergene processes of simple ground water circulation and weathering, but it is stated that gold may appear as a sol rather than a precipitate and in this form can remain in suspension down to low temperatures. Although the writer advocates for the idea of supergene processes of enrichment he does not ignore the possibility that alternative mechanisms could have been involved. The removal in solution of some of the other constituents of the primary ore such as iron, sulphur, arsenic, copper, etc. would decrease the weight of what remained, thereby relatively enhancing the weight of the gold by the process known as residual enrichment. This process, aided by downward descending meteoric waters could have played some part in concentrating the gold. Initial hydrothermal solutions must have been operative in the filling of shear zones and breccia cavities but attention has been diverted from that line of thought expressly in order to bring to the attention the idea of supergene enrichment of gold. This idea has in the past generally been regarded with such scepticism that it is never adequately considered when describing deposits of this type. The writer found a complete inadequacy of literature pertaining to the chemistry of gold in general and its solution and precipitation in particular.

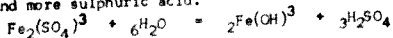
(f) Availability of a Suitable Chemical Environment in the Lily Mine

Having the theoretical as well as experimental knowledge of the chemistry involved in gold solution and precipitation, it now remains for an examination of the chemical environment present in the Lily Mine itself. As was seen from experimental work gold requires an acid environment for solution to take place. Acid is generated by oxidation of sulphides - particularly iron sulphides. The main ore mineral in the mine is pyrrhotite with minor amounts of arsenopyrite, pyrite and chalcopyrite.

The pyrrhotite, although possessing a variable amount of sulphur, still reacts similarly to pyrite on oxidation forming ferric sulphate and sulphuric acid. Bateman (1958):-



the reaction goes further and ferric sulphate hydrolyzes to ferric hydroxide and more sulphuric acid.



Chlorine, according to Emmons (1917), although essential for reaction and solution to take place, need only be present in small amounts. He mentions that sufficient chlorine is usually available in natural waters and in salts in rock strata.

The banded ironstones and shales of the Lower Fig-tree Series contains some manganese (see Table III earlier) that would aid the production of "nascent" chlorine necessary for effective solution of gold. The sulphide minerals could supply an acid environment. The weathered pyrrhotite would probably produce dilute sulphuric acid and ferric iron Fe^{+++} , as well as minor amounts of copper Cu^{++} , would become available as effective oxidizing agents. The gold thus taken into solution would probably be precipitated by reaction of the solution with sulphides or partially altered sulphidic material where too little MnO_2 was present to neutralize the effects of the precipitating agents, ferric sulphate and pyrite. The oxidized zone possesses the rich gold yet there are no sulphides present today.

(g) Wall Rock Alteration

Mineralizing solutions, passing through fractures in the mine, have superimposed a metamorphic effect on the country rock. This metamorphism is not always clearly apparent especially in the oxidized zone. There is no sharp wall rock alteration adjacent to quartz filled veins and mineralized zones; instead the effects are disseminated fairly evenly through zones measurable in feet. As has been shown earlier the mineralization has resulted in impregnations into shear and breccia zones. In the oxidized zones of the deposit there is no very marked difference between the rocks within and outside the limits of the economically valuable zones. Even in the less altered fresh rock zones, gangue minerals in the sulphide ores are for the most part the same as those in the adjacent or wall rocks. High temperature metamorphic minerals are generally absent although occasional euhedral garnets may be found either in the ore zones or in nearby shear planes.

A little green chlorite is often found accompanying tremolite but mostly the chlorite has apparently given way to the formation of tremolite in the higher temperature regions. Biotite is present in practically all the rocks.

Hearn (1943) noted similar features in the New Consort Mine. He also mentions the introduction of quartz and schorlite tourmaline during mineralization. Tourmaline occurs widely throughout the Lily

Mine - being most intensely developed in the 70 Foot Level ores. The mineral decreased in quantity away from the stoped out sections but it could not be determined how extensive was its lateral development. The tourmaline was no doubt introduced together with the quartz as the two minerals are often found together both in the mine and in the rocks surrounding the mine.

(A) Paragenetic Sequence of Mineralization

As the Lily ores occur in banded ironstones and ferruginous shales of the Lower Fig-tree Series it was thought necessary to subdivide the paragenetic sequence into (i) Primary ores and (ii) Secondary ores.

(i) Primary Ore

These minerals comprise the original constituents of the banded ironstone horizon. This primary suite consists of magnetite, hematite and limonite. These minerals are now largely altered to limonite and goethite. Chemical reaction with later sulphuretted solutions could have contributed to or controlled the formation and precipitation of the secondary ores.

(ii) Secondary Ore

The normal sequence of deposition corresponds with a progressive decrease in temperature, solubility and hardness. Edwards (1954) has drawn up a generalized paragenetic sequence bearing these factors in mind.

The following scheme of events is based on Edward's classification to some extent but has largely been determined by microscopic examination.

Magnetite and arsenopyrite were introduced at an early stage and display well formed idiomorphic crystal outlines. A little gold is considered to have been introduced contemporaneously with some of the arsenopyrite as it is found intimately connected with this mineral. At slightly cooler temperatures (experimentally established at approximately 300°C) pyrrhotite was introduced co-laterally with arsenopyrite. Pyrite and hematite, although only of minor amount, display textural relationships suggesting that they were precipitated subsequent to the arsenopyrite and magnetite and prior to the pyrrhotite formation. Melnikovite-pyrite being largely due to the

effects of alteration would, therefore, be classed as a supergene mineral (Schneiderhöhn and Ramdohr, 1931)

A second age of gold is envisaged. This gold was precipitated prior to and together with secondary quartz in veins and breccia cavities. Although no gold was seen together with pyrrhotite, it nevertheless does occur with that mineral, as assay sampling has indicated. The gold deposited in hypogene form together with minerals such as arsenopyrite and pyrrhotite was probably liberated in the altered and oxidized zones. The gold subsequently taken into the solution was reprecipitated as supergene gold. Other supergene minerals produced by the chemical weathering of the rocks include the goethite-limonite association. These were formed over quite an extensive range of time right up to the present and were probably derived from the alteration of the iron minerals in the banded ironstones as well as some pyrrhotite.

The only non-metallic mineral closely associated with the ores is quartz. This mineral too, has a complex history. It was evidently introduced at very earlier stages and again later together with supergene minerals. On the paragenetic chart (Fig. 26) it can only be depicted as having been deposited over a great time range. The malinkovite-pyrite, although a supergene mineral, must have formed in a reducing environment. Oxidizing conditions later took over and limonite-goethite was able to form.

(1) Mineralization of the Lily Mine

Bearing in mind the various mineralization types mentioned by Gribnitz (1961) earlier in this chapter, it was found very difficult to stipulate any one particular type or category into which the Lily Mine might fall. Features pertaining to all his sub-divisions are equally well represented.

If it is accepted that the Main Reef Zone of brecciation represents a plane of weakness or a fault then the first type, represented by sulphide and gangue replacement in a faulted or brecciated zone, will hold.

The principal source of free gold in the Lily Mine has been largely confined to quartz veins (Gribnitz's second type).

Finally, to the pipe-like features occurring at Sheba Mine may be added the plunging shoot or pipe or body of the Lily Mine. This breccia filled zone is an example of a structure caused by tectonic disturbance.

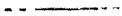
MINERAL	HYPOGENE	SUPERGENE
Malachite		
Arsenopyrite		
Gold		
Hematite		
Pyrite		
Pyrrhotite		
Chalcopyrite		
Meinikovite-pyrite		
Limonite-goethite		
Quartz		

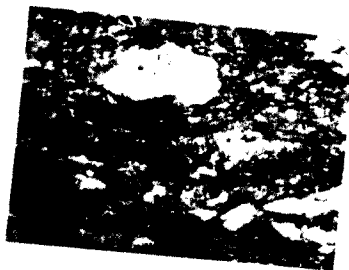
Fig. 26 : Chart Depicting the Paragenetic Sequence of Ore Deposition in the Lily Mine

Note : Magnetite and Hematite are principally the original constituents of the sedimentary succession but have locally been introduced or were recrystallized from the existing material.



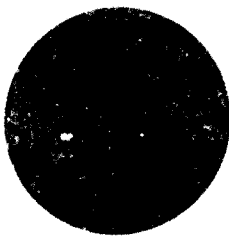
Plate 58
The mineral inclusion
in the matrix of the
quartzite, showing
a dark, irregularly shaped
inclusion.

(Plate 59) Photomicrograph
showing a ferruginous band with
prismatic needles growing at
right angles to the band and
into chert-quartz. Lily Mine.
(Free and nicols x40)



(Plate 60) Pseudomorph quartz
"nest" in schists of the
Gneiss series.
(Ordinary light x5)

(Plate 61) Radiating of the plates
of scheelite mica crystals in the
quartzite (orthostatic) of the
Siding.
(Ordinary light x5)



CHAPTER 4.

SUMMARY AND CONCLUSIONS

The basement upon which were laid the Archaean volcanic and sedimentary rocks consisted for the most part of granites and gneisses of the Nelspruit Migmatite.

The geosynclinal cycle began with the deposition of the lavas and sediments of the Onverwacht Series. These rocks have undergone considerable change since they were first laid down and are seen in the field today as dark contact amphibolites or quartz-hornblende schists, green amphibolite schists consisting in the main of tremolite and actinolite schists and talc-carbonate-quartz-chlorite schists. These basic varieties are accompanied by zones of acid rocks probably altered from acid lavas and quartz porphyries or even orthoquartzites. The alteration was assisted by intense shearing resulting in these rocks being transformed into quartz-sericite schists, mylonites and even cherty horizons.

Subsequent to the Onverwacht deposition uplift is thought to have taken place with the result that the Fig-tree Series, consisting of an argillaceous succession, was not developed within the Lily Syncline except for a minor amount towards the New Consort Gold Mine. The Fig-tree sequence, essentially a flysch type of deposit, was laid down in the deeper portions of the geosyncline immediately south of the area.

Subsidence is envisaged at this stage and the whole area was transgressed by the arenaceous or molasse successions of the Moodies System. Due to the shallow nature of the depositional environment within the area of the Lily Syncline, only the lower members of the Moodies System are present. These consist of a restricted but well developed basal conglomerate and lower quartzite horizon.

A period of orogeny, no doubt associated with the geosynclinal sequence of events, took place in a series of phases or pulses. At first there developed a number of major folds, the traces of which trended in an approximate northeast-southwest direction. The folding was responsible for the formation of the major synclines in the Barberton Mountain Land, including the Lily Syncline. Basic igneous rocks intruded mainly around the periphery of the deformed area. Longitudinal strike faulting accompanied the folding and in some cases

appears to have provided the weak zones into which basic bodies were intruded.

The Lily Fault, occurring between two synclines in much the same manner as several other major faults such as the Barbrook and Sheba Faults, is considered to have formed during the initial orogenic phase.

Compression continued with the regional strain being directed from the N.N.W. and S.S.E. The folding became more intense and a slaty cleavage was produced at cross-cut and a folded folds. Further evidence of the intense flattening that occurred during this time can be seen in the deformed conglomerate pebbles found in several localities along the Kaap River Valley. Numerous rock fabrics were also initiated at this time and included lineations, foliation and schistosity. The Nelspruit Granite intrusion took place and was responsible for many changes in the rock types bordering on the granite belt.

The most marked change involved the production of a contact metamorphic aureole that extended for a comparatively short distance into the sedimentary and volcanic successions to the south. Three separate facies of contact metamorphism could be distinguished in the area examined. That closest to the granites was classified as the hornblende-hornfels facies. Minerals ranging from sillimanite to garnets and hornblende were included in this zone.

Hornblende schists gave way with increasing distance from the contact, to a zone of tremolite-actinolite schists that were classified into the albite-epidote-hornfels facies. Finally and furthest from the granites several varieties of basic schist were grouped in the greenschist facies. Sediments entirely unaffected by the wave of metamorphism exist within a mile of the contact belt.

The emplacement of the granites was responsible for considerable shearing along the contact and immediately adjacent areas. The rocks underwent a destructive type of alteration involving considerable reduction of grain size. Where the effects of this alteration were extreme as in the case of the quartzite-conglomerate ridge of the Lily Syncline the rocks were changed to mylonites and cherts.

The late phase of granite intrusion involved the injection of pegmatite and aplite bodies and veins accompanied by further folding along the contact. Probably also introduced at the same

time were the hydrothermal mineralizing solutions. The major fault planes in the Mountain Land are considered to have provided a suitable means of egress for the escaping ore-bearing fluids.

The next important deformational event occur in the Barberton Mountain Land was the great inflection - the Eureka and Ulundi Synclines. At the same time it is thought that the Lily Syncline was involved in a swing from northeast-southwest to an approximately east-west direction.

A final stage in the deformational history involved further stress directed in a vertical or near vertical direction and was responsible for the imprinting of minor crenulation and conjugate folds over a wide area. Each successive event either rejuvenated earlier structures or was instrumental in their obliteration.

It is likely that the orogenic cycle was a continuous one and that each diastrophic event can be related to the updoming of the granites. The subdivision into phases merely emphasizes the main events that took place and relates them chronologically to one another.

The economic geology of the area centres mainly around the occurrence of gold. Two small mines, viz. the Lily and Rose's Fortune Mines, have until mid-1963 been in production. Apart from several exceptional finds of gold pockets, the values have been too erratic to warrant continued mining. Work has been carried out solely in the oxidized sections of the mine with the result that very little is known about the sulphide ores.

The Lily Mine occurs in banded ironstones, cherts, graywackes, shales and intercalated basic schistose rocks of the Lower Fig-tree Series. The rocks may tentatively be correlated with the Zwartkoppie Zone of the Sheba Valley.

Reefs of vein quartz fill shear zones in the steeply dipping thinly bedded strata.

The Fig-tree succession has undergone an extensive shortening and flattening deformation that produced tight isoclinal folding of the strata.

The folding in the mine was probably initiated during the first phase of regional deformation when the Lily Syncline and other major synclines in the Mountain Land were formed. The variation of fold plunges in the mine suggests either differential movement in the 'a' fold direction or a superimposed set of folding.

The plunge of the folds and the plunge of the ore shoot are roughly coincident. The mineralization is considered to have been introduced some time during the second phase of regional deformation - though probably at a late stage.

The main mineralizing solutions are considered as having been introduced along the Lily Fault or Main Reef breccia zone.

The Main Reef Zone has provided the most consistent values in the mine. The zone is partly brecciated and abuts up against a footwall of talcose schists. The Main Quarry was developed on the Main Reef and only oxidized ore was extracted.

Two sets of fractures exist in the mine. The strongest set is a vertical fracture system with a weaker set of crosscutting-flat fractures. The strongest reef development occurs in the vertical shear fractures that are considered to have formed during the second phase of regional deformation.

The formation of the pipe-like brecciated ore shoot which was buckled into a cymoid shape is thought to have developed by strike-slip or shear movement synchronous to the development of the vertical fractures.

The brecciated zones both in the Main Reef and in the ore shoot are thought to have provided suitable channelways for ore-bearing solutions of both hypogene and supergene origin.

The flat fractures provided suitable channelways for the dispersal of meteoric solutions to deeper portions of the mine and probably assisted the processes of residual or supergene enrichment of the gold.

The Lily Mine can be classified as an ore deposit containing essentially pyrrhotite and arsenopyrite with subordinate amounts of chalcopyrite, pyrite and melnikovite-pyrite.

The gold is associated primarily with vein quartz but occurs with arsenopyrite and to a lesser extent with pyrrhotite.

Several "bonanza" gold pockets were recovered from the ore-shoot in the mine. The enriched zones occurred primarily in the oxidized zone with some exceptional values also occurring in the transitional zone between oxide and sulphide material. A smaller pocket was encountered in the sulphide ore but no further indications

of gold were noted below this point although sulphide mineralization was present.

Concentrates of pannings from the workings on different levels were assayed and the results indicated that the gold from the upper levels possessed a greater fineness than that occurring at depth. There is a corresponding increase in the proportion of silver in the lower levels. These facts suggest that gold from the oxidized regions has been enriched by the leaching from it of silver.

The coarse gold is usually recovered in the mill by amalgamation while the fine gold is recovered by cyanidation. The amalgamated material always gave a greater percentage of gold recovery.

In order that gold be made soluble an acid solution containing Cl^- and a strong oxidizing agent are required. The chlorine necessary need only be slight and is usually available in natural waters and as salts in the rock formations. The banded ironstones of the Fig-tree Series probably contains sufficient manganese necessary for the production of nascent chlorine required for the effective solution of gold.

X-ray diffractometer work on pyrrhotite enabled an approximate temperature of formation of the mineralization to be calculated. The pyrrhotite formed at about $330^{\circ}C$. Arsenopyrite was found to be earlier than pyrrhotite in the paragenetic sequence of deposition and it is considered that a maximum temperature not exceeding $350^{\circ}C$ or $400^{\circ}C$ existed at the time the ore was introduced.

The paragenetic sequence of sulphide ores in the mine was found to be arsenopyrite followed by pyrite, pyrrhotite, chalcopyrite and malnikovite-pyrite. Two ages of gold are envisaged. The first occurred early in the sequence and is thought to have been introduced contemporaneously with the arsenopyrite. The later age of gold is regarded as being of supergene origin deposited after considerable oxidation of the original sulphides.

Wall rock alteration has occurred but only to a slight extent. Generally only low grade metamorphic minerals such as biotite and chlorite are present. Tremolite is the most common amphibole and occasionally garnets were noted. Tourmaline is also quite common both in the sediments and in quartz veins.

The problem of finding or even predicting more ore in the Lilly Mine is not an easy task. The limited scale of operations and

development failed to indicate further structural features similar to that of the pipe-like ore shoot. The whereabouts of the quartz filled vertical fractures or reefs have generally been determined by mining but have proved very erratic and it is naturally difficult in an ore-body of this character to predict economic zones. The Main Reef has in the past proved to be the most consistent source of gold. This reef has scarcely been investigated except in the oxidized zone. Sulphide mineralization is exceptionally plentiful where this reef has been exposed in deeper levels and a spot sample assayed 39.1 dwts. The reader will have to draw his own conclusions from this point on.

Further work in the oxidized sections of the mine might uncover additional rich pockets but unless some structural phenomenon can be related to the find, the chances of locating more ore will be considerably lessened. It is the writer's opinion that pockets similar to the "bonanza" gold discoveries of the past will only be found in oxidized or semi-oxidized zones or in fracture planes directly connected with these altered zones.

Regional mapping has shown that the Lily Mine and the Rose's Fortune Mine, together with several other smaller workings and trenches are located along a line of mineralization over 12 miles in extent that is thought to be associated with the Lily Fault. Again, as much of the critical zone is covered by soil and scree, prediction is difficult. Only considerably more detailed prospecting in the form of trenches or drill-holes along the suggested mineralized zone will prove or disprove additional gold ore.

Talc is at present being mined north of Sheba Siding at the Scotia Talc Mine. The talc is considered to have formed within a basic intrusive body as a result of deformational shearing coupled with hydrothermal metamorphism.

Magnesite occurrences near Sugden Siding are of poor quality and quantity. The magnesite also occurs in a basic intrusive body and formed by processes involving chemical weathering and the introduction of carbonate solutions.

Magnetic nickeliferous deposits of tremorite occur in shear zones in the serpentinites north of Sheba Siding. A nickel silicate mineral nephelite is also present. The nickel probably occurred in disseminated form within the ultrabasic body and was subsequently concentrated by hydrothermal activity associated with the Nelspruit Granite intrusion. The mineral does not appear in sufficient quantity to warrant mining.

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THE GEOLOGY OF THE LILY SYNCLINE
AND PORTION OF THE EUREKA SYNCLINE BETWEEN
SHEBA SIDING AND LOUW'S CREEK STATION,
BARBERTON MOUNTAIN LAND

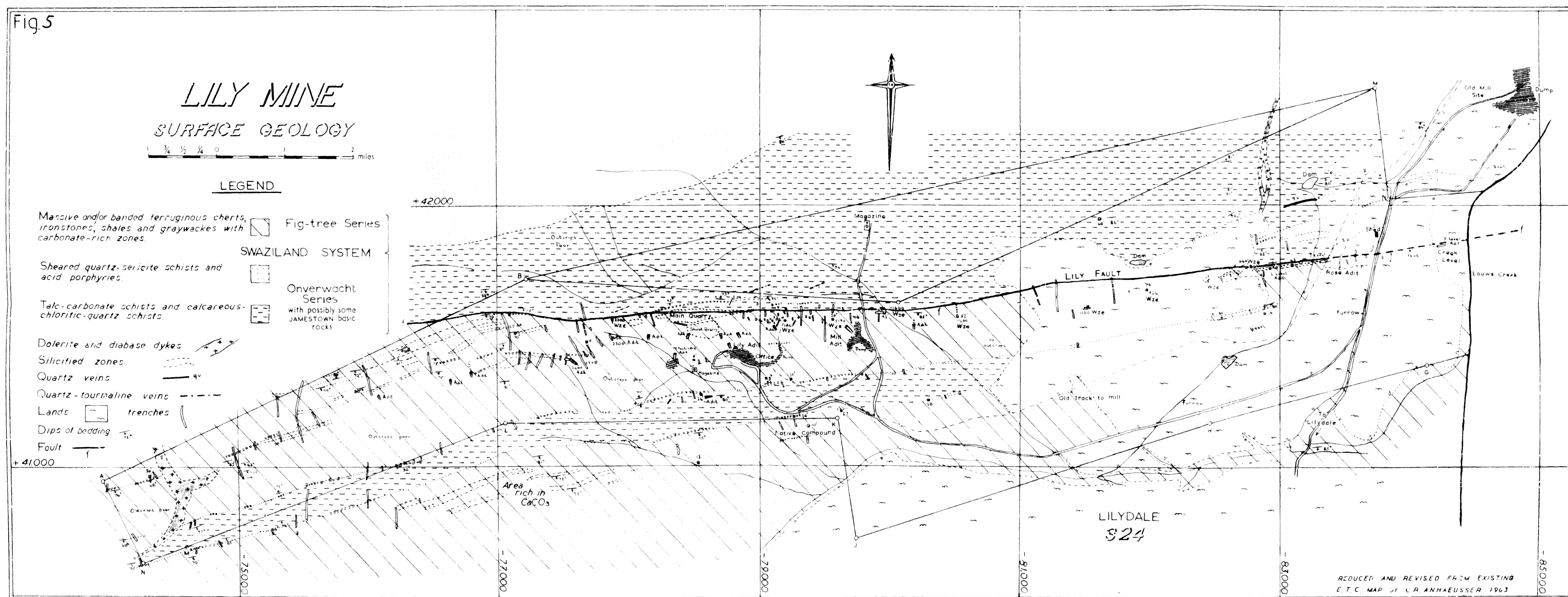
by

C. R. ANHAEUSSER

Thesis submitted for the degree of
Master of Science at the
University of the Witwatersrand

JOHANNESBURG
1963

Fig. 5



GEOLOGICAL MAP
OF THE AREA BETWEEN
SHEBA SIDING AND LOUW'S CREEK

MADE IN THE UNHABITATED DURING THE YEAR 1980

STRUCTURAL LEGEND

DIPS AND STRIKE // BEING AND FOLIATION
 GEOMETRICAL DIPS $\frac{1}{2}$ // VERTEBRATED STRATA
 1. SUBSIDENCE + LOSSES
 2. SUBSIDENCE + LOSSES
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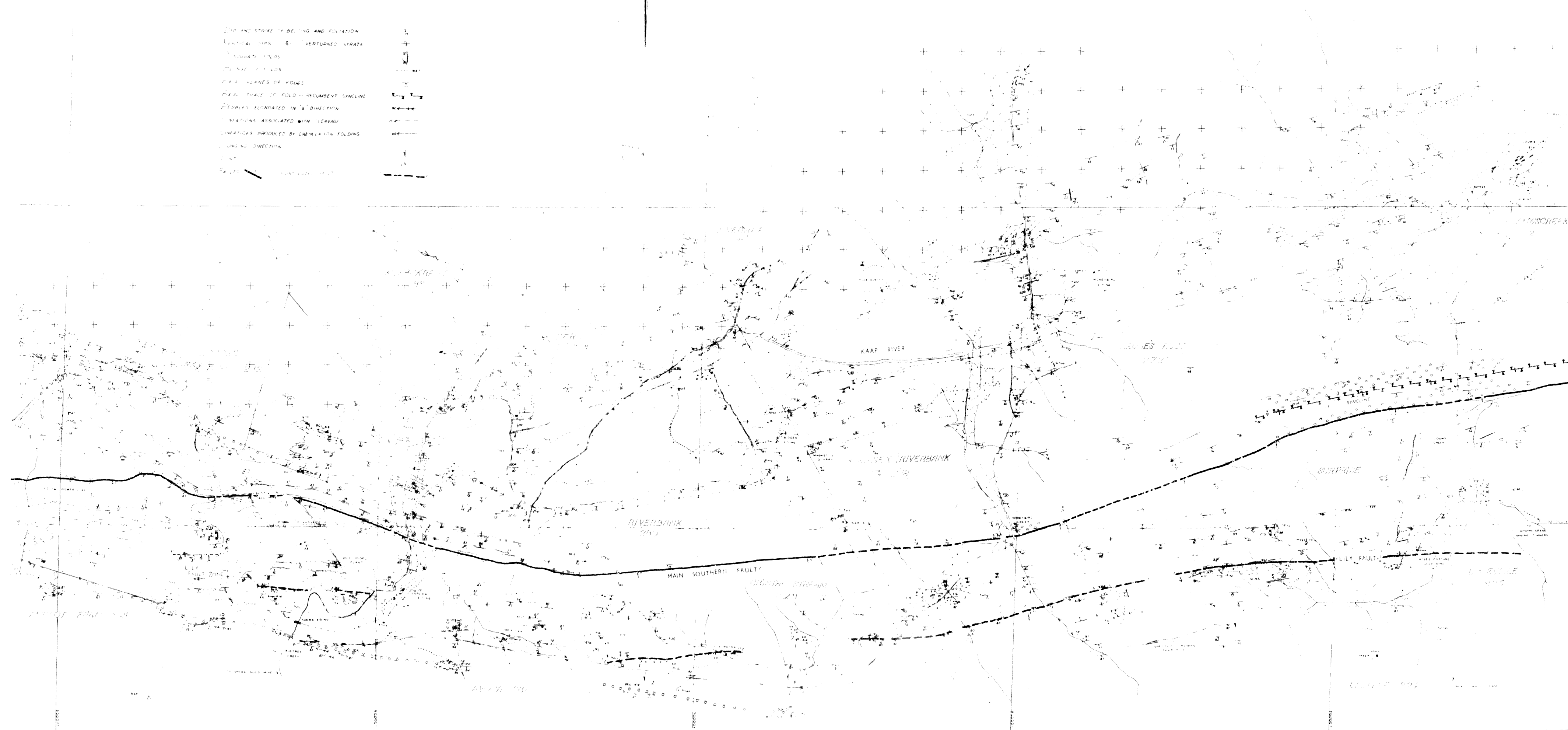
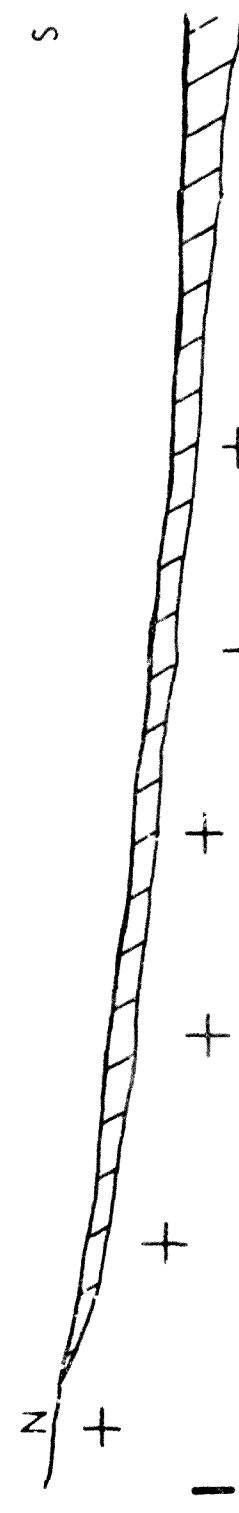
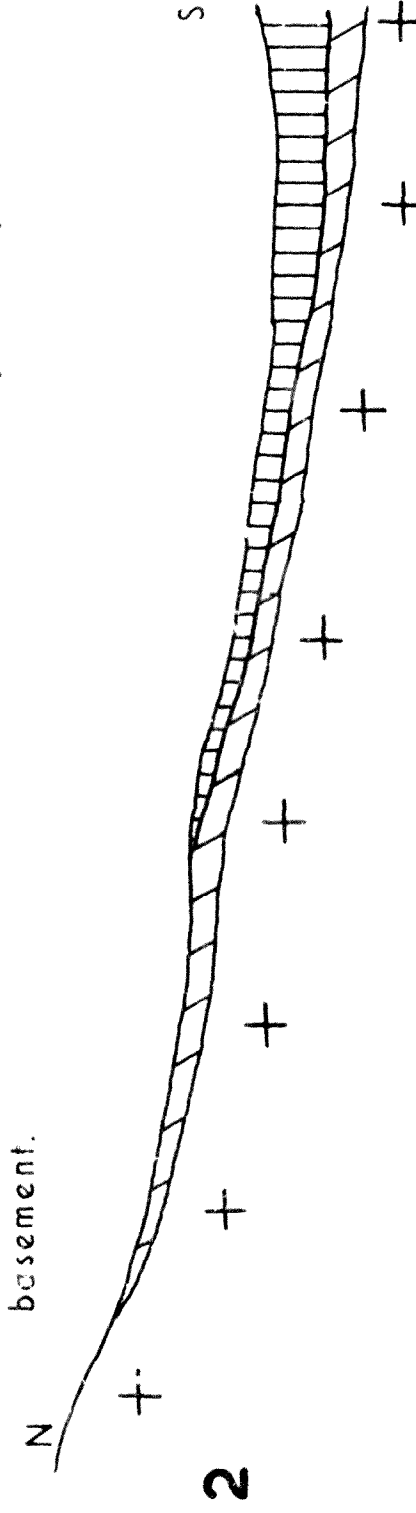


Fig. 8

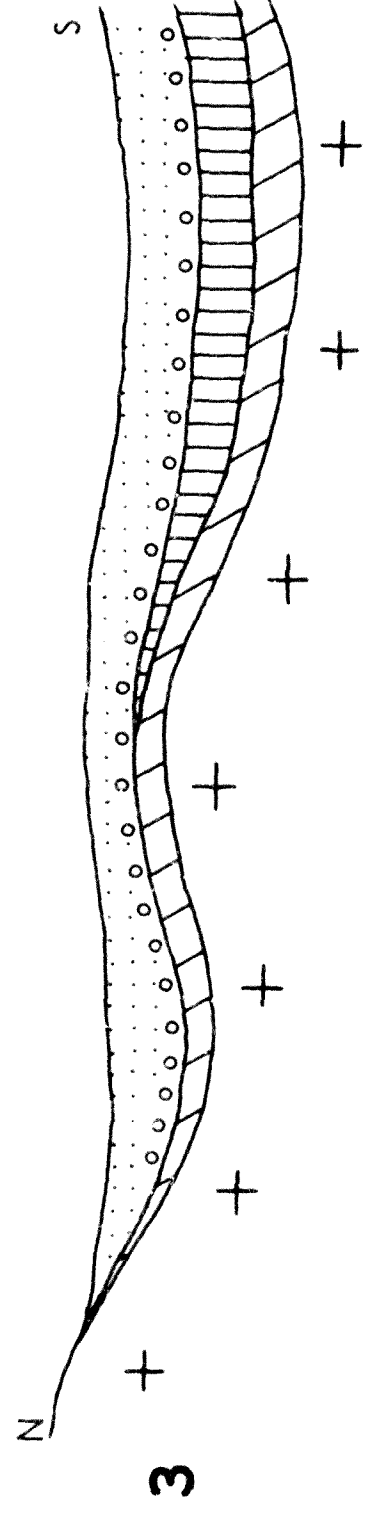
DIAGRAMMATIC SECTION DRAWINGS SHOWING THE POSSIBLE PALAEOHISTORY OF PORTION OF THE LILY SYNCLINE ALONG THE NORTHERN FRINGE OF THE BARBERTON MOUNTAIN LAND



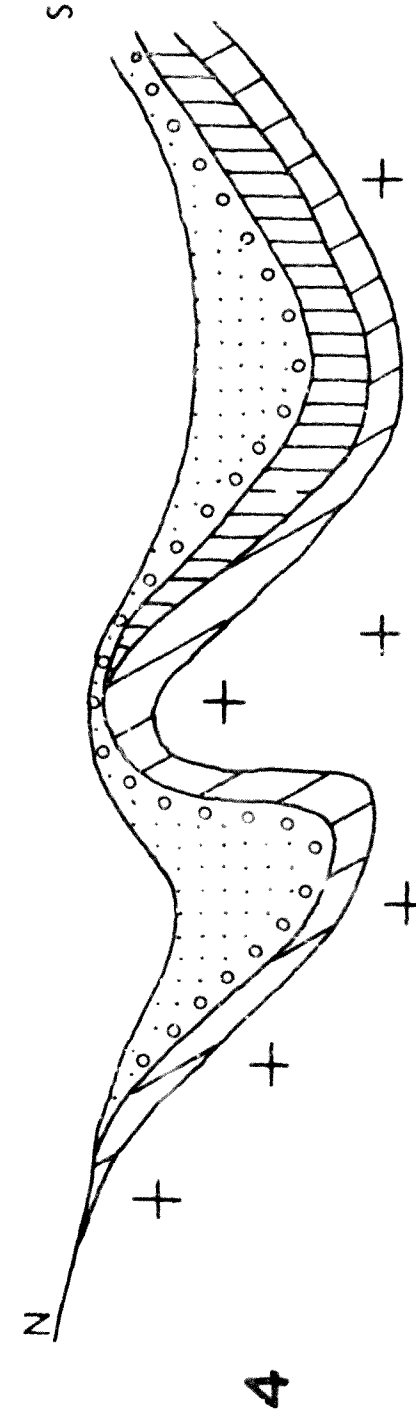
The Onverwacht succession is deposited on the granite-gneiss basement.



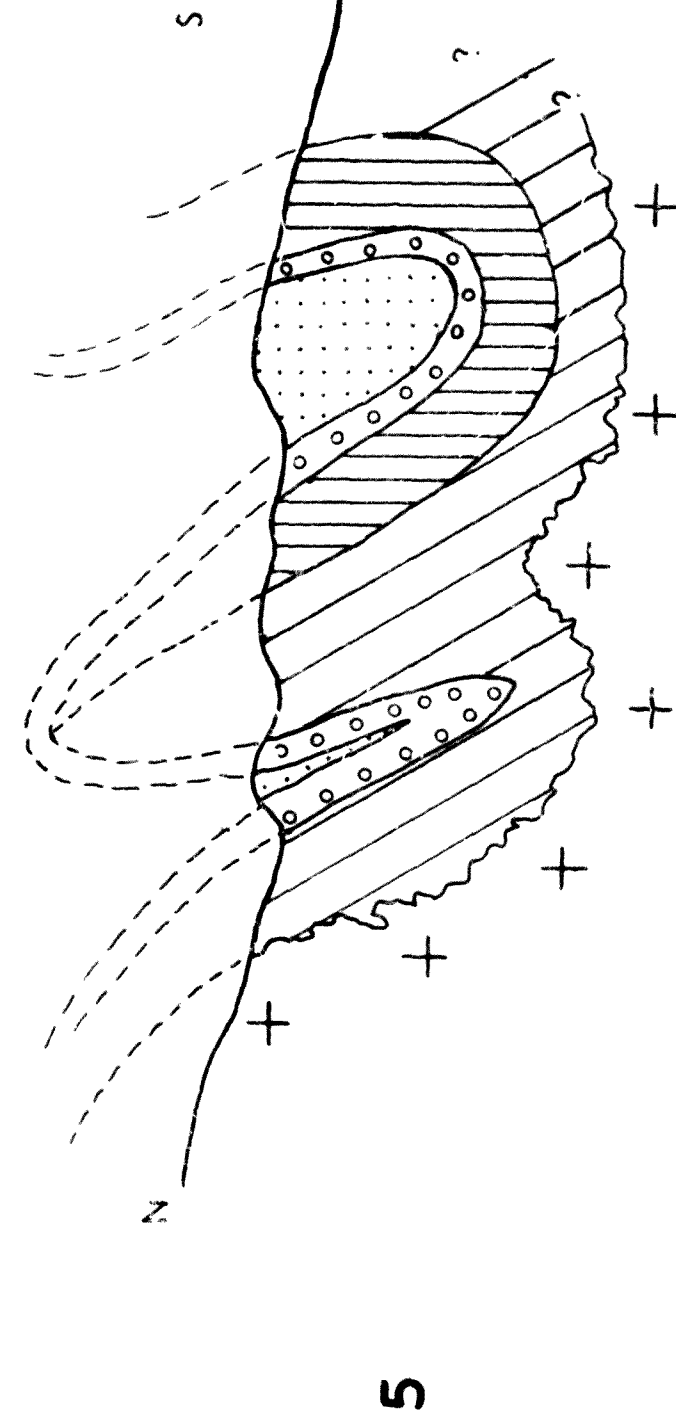
The shoreline retreats as the basin fills. Deposition of flysch type sediments occurs in the deeper areas.



Orogenic processes begin and the area is transgressed by molasse sedimentation of the Moodies System.



Folding becomes more intense and the Lily and Eureka Synclines start to develop.

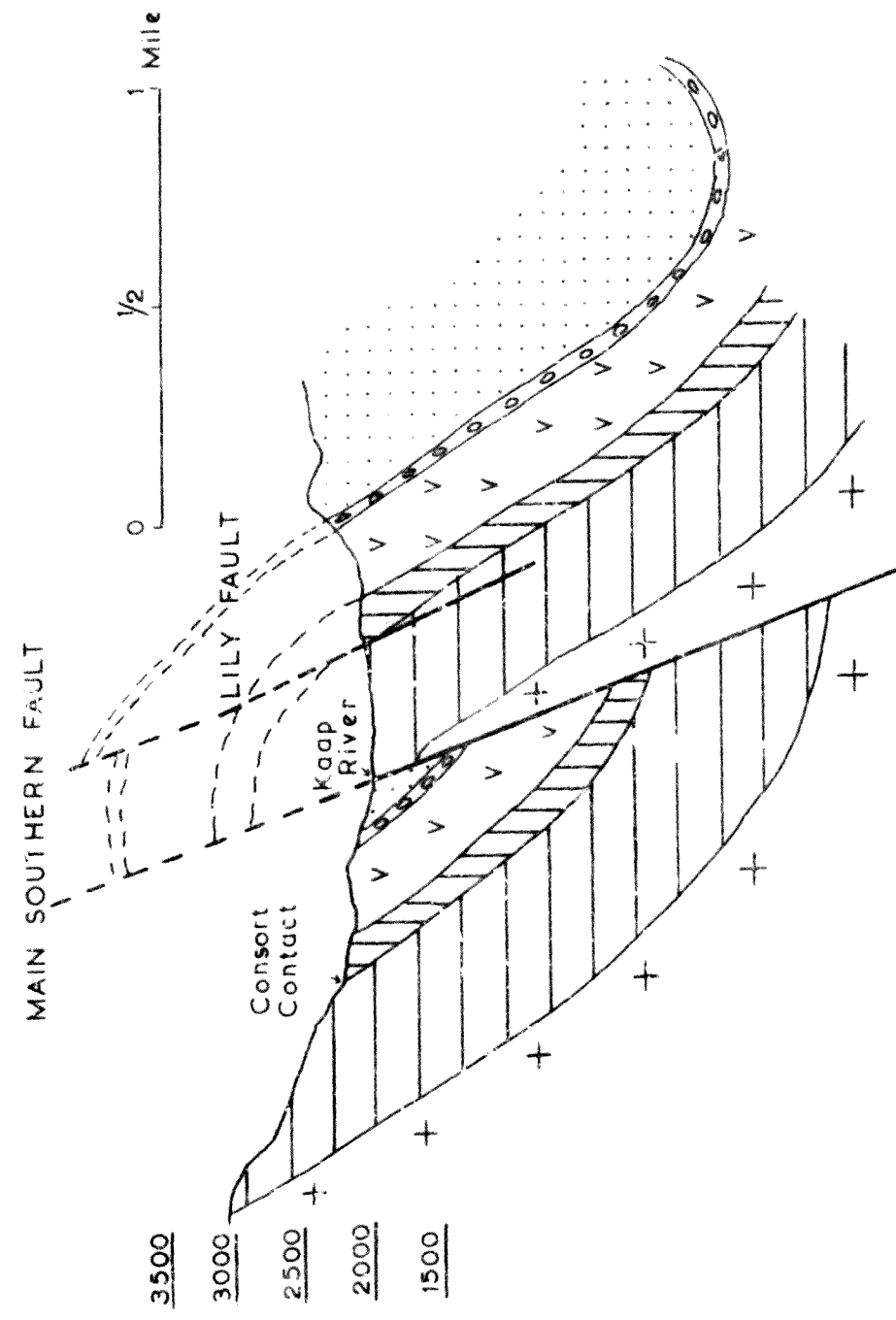


Late phase of the deformation where the Lily and Eureka Synclines are overfolded to the north.

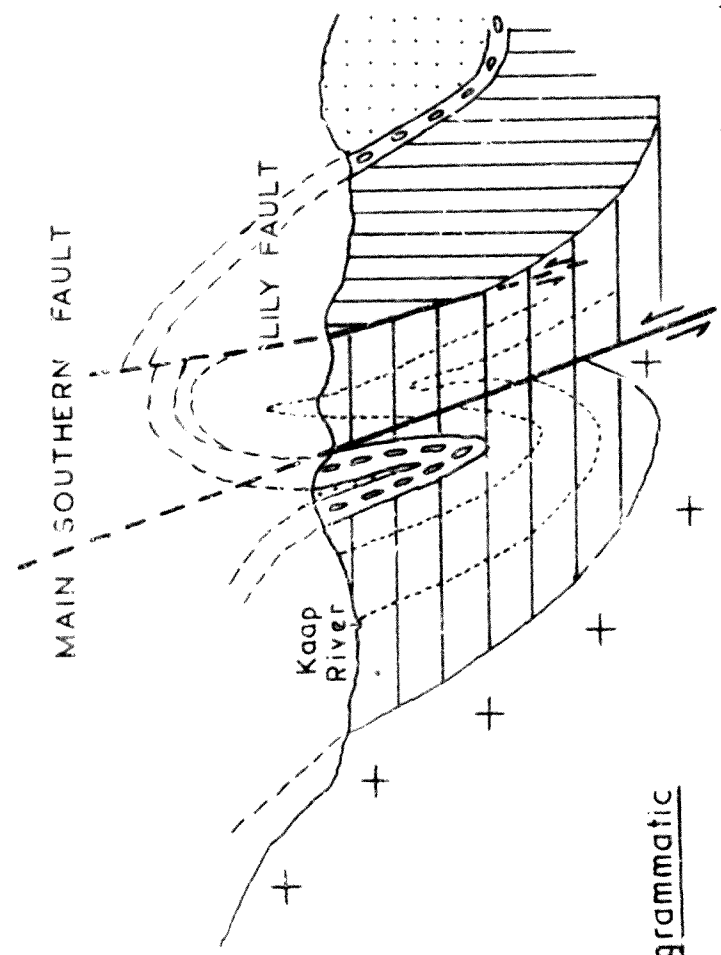
KEY

| | | |
|--|--|-------------------|
| | Basal conglomerate and quartzites | Moodies System |
| | "Lava" Shales, graywackes, chert, etc. | Fig-tree Series |
| | Basic and acid schists | Onverwacht Series |
| | Nelspruit Granite | Swaziland System |

Fig. 7



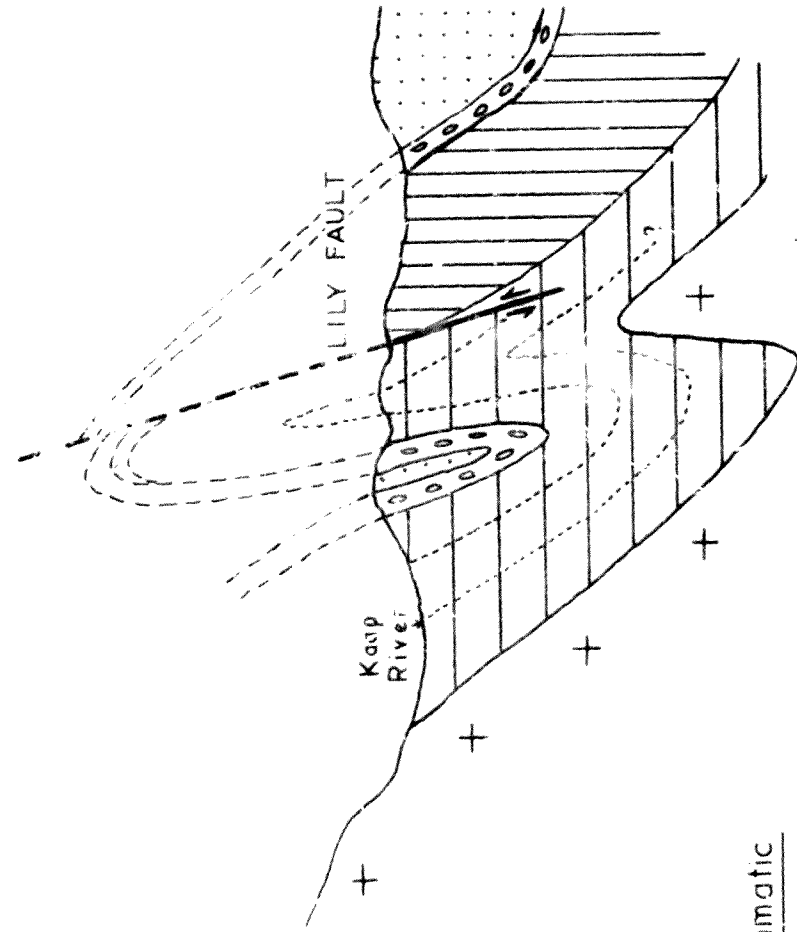
N/S Section of the Lily Syncline near Noordkuap showing the repetition of the successions on the south side of the Main Southern Fault (After M.J. Viljoen)



Diagrammatic

N/S Section of the Lily Syncline near Louw's Creek Station. The Fig-tree succession is absent in the central portion of the Syncline but is developed in the west. (see Fig. 8)

or ALTERNATIVELY



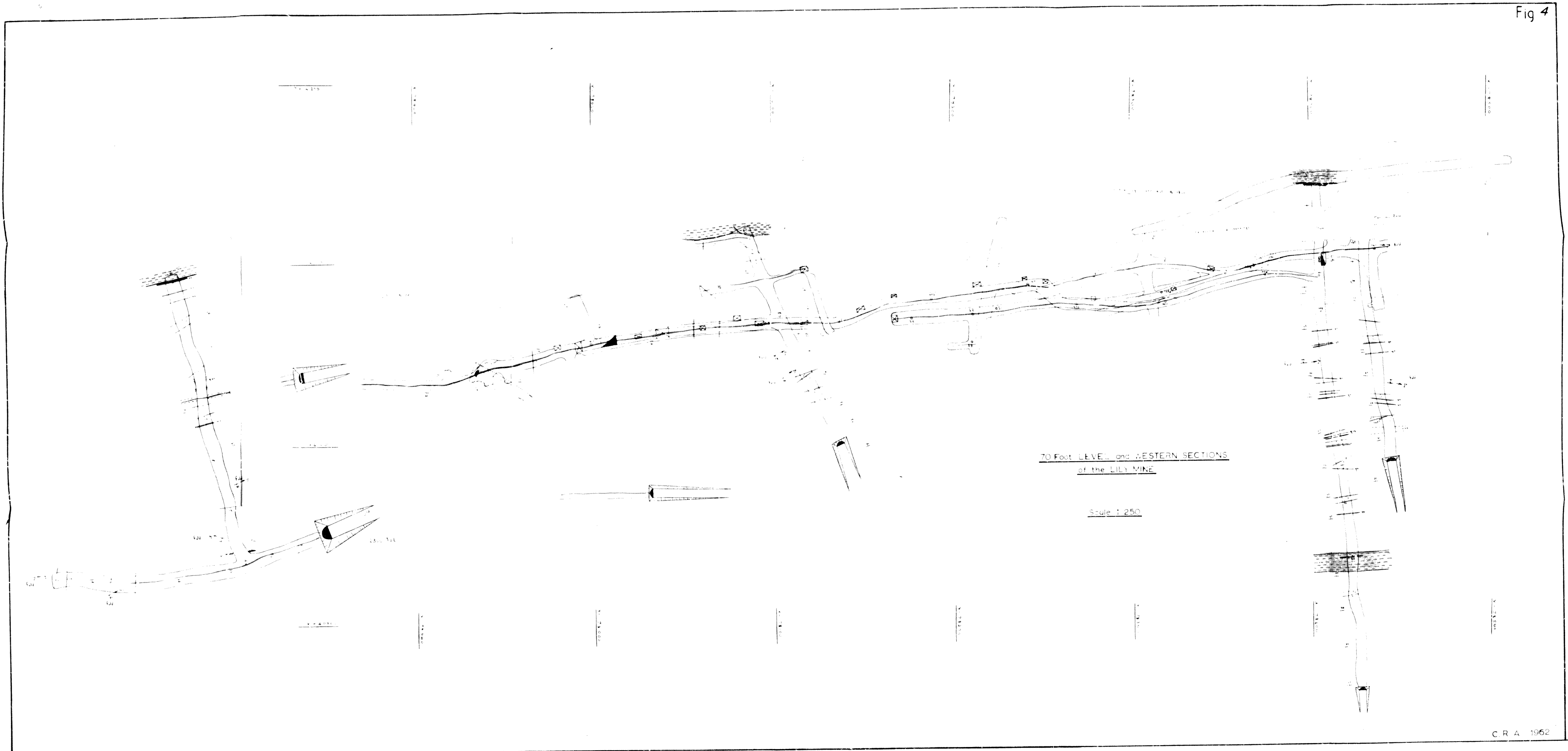
Diagrammatic

N/S Section of portion of the Lily Syncline without the Main Southern Fault to explain the repetition of the successions south of the Lily conglomerate horizon.

KEY

| | |
|-----------------------------------|-------------------|
| Basal conglomerate and quartzites | Moodies System |
| "Lava" | Fig-tree Series |
| Shales, graywackes, chert, etc. | Swaziland System |
| Basic and acid schists | Onverwacht Series |
| Nelspruit Granite | |

Fig 4



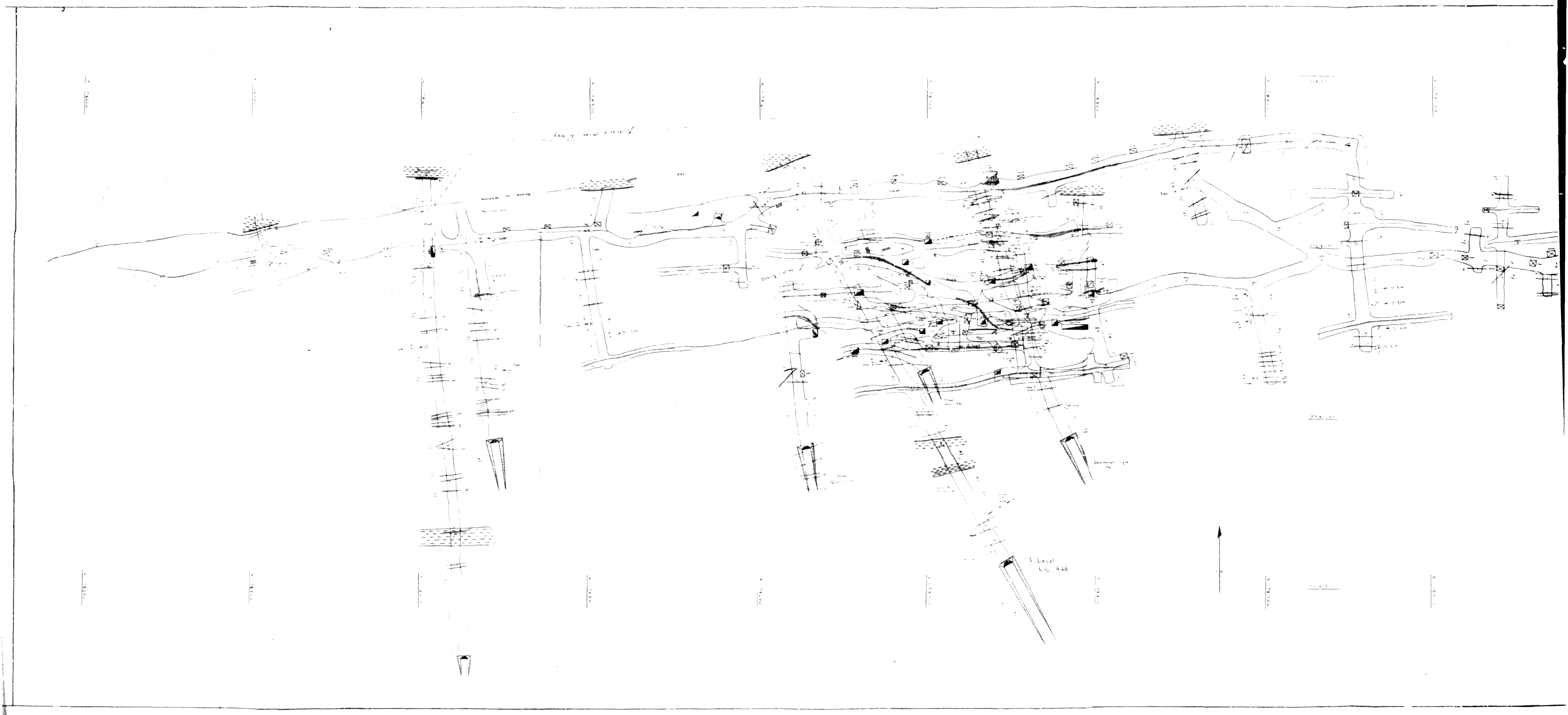
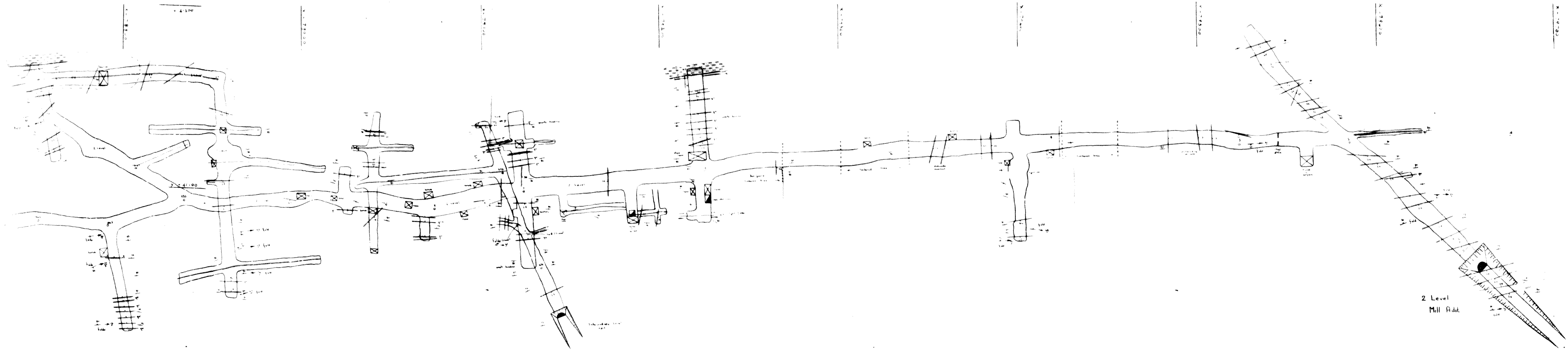


Fig. 4



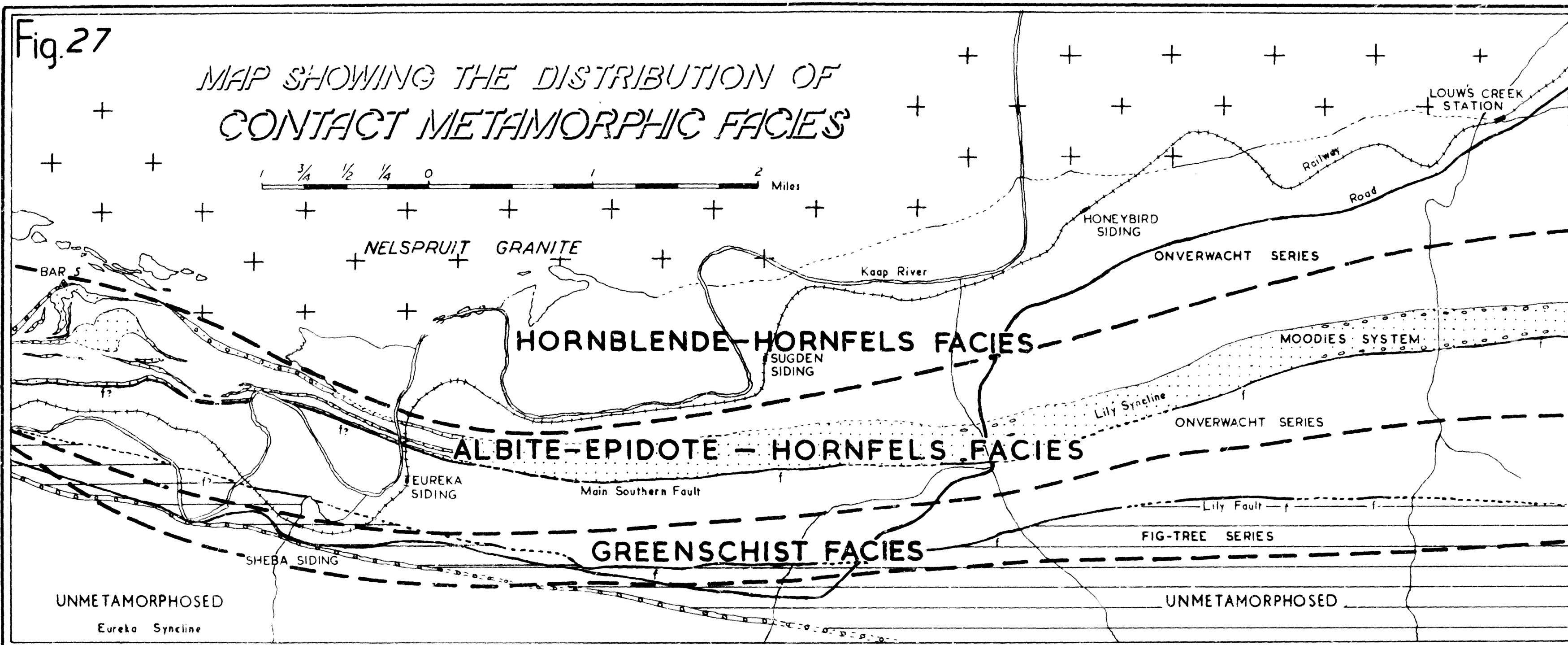
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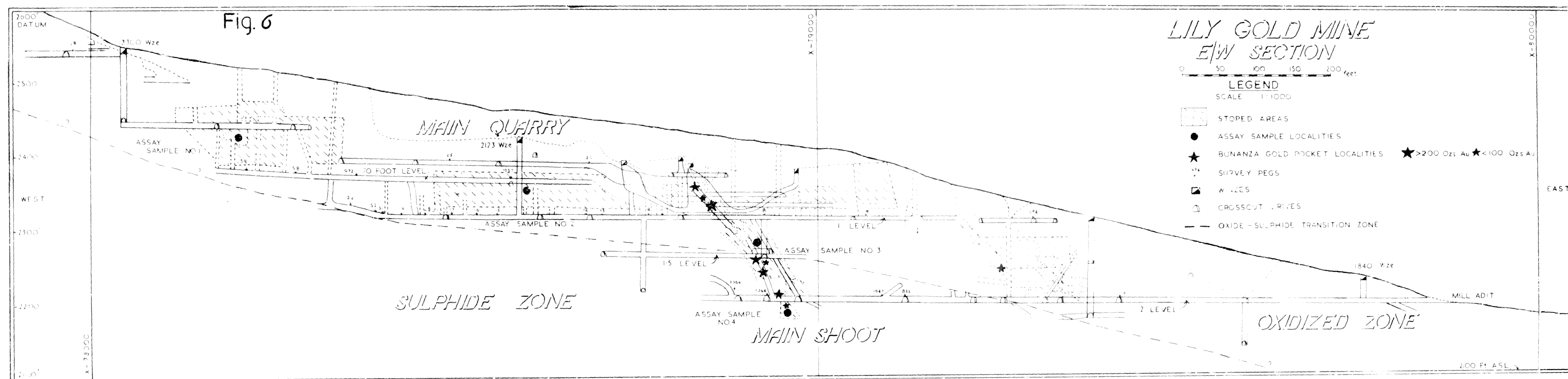
LEGEND

- Talc-carbonate schists
- Massive and banded ferruginous cherts ironstones shales and graywackes
- Quartz veins
- Fractures
- Fold axial plane and plunge of fold
- Dip and strike of bedding
- Onverwacht or Jamestown?
- Figtree Series

GEOLOGICAL PLAN
OF THE
LILY GOLD MINE
LOUWS CREEK
BARBERTON DISTRICT

MAPPED BY C. R. ANHARUSSER IN 1902





Author Anhaeusser C R (Carl Robert)

Name of thesis The Geology Of The Lily Syncline And Portion Of The Eureka Syncline Between Sheba Siding And Louw's Creek Station, Barberton Mountain Land. 1963

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