THE STRUCTURE AND MINERALIZATION OF VUBACHIKWE MINE GWANDA, SOUTHERN RHODESIA,

by

HECTOR R. KLEINOT

THE STRUCTURE AND

MINERALIZATION OF

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V U B A C H I K W E   M I N E

....

G W A N D A

S O U T H E R N   R H O D E S I A

....

By HECTOR ROGER KLEINOT. B.Sc.Hons. A.M.I.M.M.

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J O H A N N E S B U R G

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1 9 6 3

giving a macabre tombstone effect (See Plates 2 and 3, page eleven). This schist was also probably formed from the metamorphism of original basaltic lavas. Composition variations, which are common, are accounted for by a change of character during vulcanism, resulting in basic tufts and agglomerates being formed. The schist often contains alteration products of original pelitic sediments which might have been absorbed by the lavas.

Jaspilite: Layers of banded ironstone are common, particularly near the contact of greenstone with quartz-schist. Due to the local variety containing more chert than iron minerals, unlike other Rhodesian banded ironstones, these rocks are termed jaspilites. On account of their brittle character they are greatly disrupted and sheared and consequently they are not as persistent as the other formations along their strike, presumably having been dragged apart during folding. Gold mineralization in the district is generally associated with these rocks.

Quartz Schist: The quartz schist lies within the greenstone and consists of leucocratic strongly cleaved rocks forming prominent outcrops. It is dominantly a mica-quartz schist, probably of sedimentary origin.

The texture and composition varies greatly from a schist consisting of

quartz sericitic mica . . / -

ABSTRACT (Cont.)

with folds and oreshoots or payshoots pitching northwest at about 60°.

The mineralisation consists of a suite of minerals charactorised by distinct paucity in sulphur. Lollingite is the main arsenical sulphide present instead of arsenopynite. Pyrrhotite is abundant, whilst pyrite is lacking completely. Gold is present in economic quantities and is characterised by occurring in extremely fine discreet particles closely associated with fine grained arsenical sulphide. The hydrothermal fluids which precipitated minerals in suitable areas and host rocks in the Vubachikwe area, may have emanated from the centres of magmatic activity such as the Insindi and Sizeze cupolas. It is also possible that these fluids were formed by a type of high temperature lateral secretion of migrating minerals caused by granitisation processes beyond the edges of the gold-belt.

The Vubachikwe deposit may be considered as a mesothermal replacement or impregnation along a system of pre-existing fractures. There is a very minor amount of open space filling, but most of the sulphides were introduced by wallrock replacement.

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N 50° W and N 25° W, due to minor gentle folding. It is found on all levels between the surfaces and the twelfth level, and its thickness is of the order of thirty feet.

Wherever observed it is schistose in texture and there is a weak lineation on cleavage faces which pitches northwards between 65° and 85°. (See Structural Section).

The rock is pale grey to greenish in colour, cleaves well parallel to the schistosity, and hence forms a very bad hanging in mining. It is fine grained and contains talc, carbonate, chlorite and amphibole. This rock has a schistose texture with chlorite laths enclosing lenticles of talc and carbonates. A few very small amphibole needles are present. These needles are too small for positive identification, but have the pleochroism of hornblende. A number of those needles are developed parallel to the schistosity. Some minor opaque mineral is also present -- probably magnetite. A slight dissemination of sulphides is found occasionally, particularly as smears on cleavages and partings.

This rock was probably formed through the metamorphism of a basic to ultrabasic sill. It forms part of the local and regional lithological sequence and is almost undoubtedly older than the mineralization since it has been slightly mineralized. (See Slide X47, and Plates Nos. 13 and 46.)

QUARTZ SCHIST:

Since the quartz schist . . / -

Except for the jaspilite and slates, all these sedimentary rocks are locally called quartzite: While these rocks bear little resemblance to altered sandstones, "quartzite" is not an unreasonable lay-term. They are actually an altered sediment of variable grain size. Those portions of them which have significant amounts of iron minerals and have been mineralized form the orebodies of the mine. This "quartzite" rock is notoriously hard to drill and break.

Generally massive, these sediments are sometimes slightly schistose and are cut by joints, fractures and shears. These shears are very nearly parallel to the bedding, and are associated with the ore-bodies.

In colour, the rocks range from pale grey through buff to a very dark blackish grey. They are very fine grained, and it is probably this fineness which renders them so tough and hard. The rocks are often irregularly banded parallel to the dip. Generally the banding is quite narrow, but may be up to two to three centimetres wide. The banding is probably due to the development of amphiboles in certain bands which alternate with bands of comparatively clean quartzite.

Originally most of the rocks were probably mudstones and siltstones, possibly calcerous in places, and in other localities definitely ferruginous. The material composing these sediments was probably derived from a landmass of granite and basaltic lavas. Weathering conditions seem to have been such that felspars were decomposed - since felspars are all but absent

in these rocks . . / -

quartz sericitic mica to a quartz felspathic grit. Local variations include "felsic schists" which probably represent altered tuffs and agglomerates of siliceous composition. A typical exposure of this quartz schist is Vubachikwe Hill which is composed entirely of brown micaceous quartz-schist of varying texture.

SHAMVIAN SYSTEM:

Greywacke Group: The greywacke group is only found in the northwestern sector of the schist-belt (See Map 2) and consists of strongly banded paragneiss and greywacke.

These are often strongly cleaved and contain many bands of very dark hornblende-schist, possibly representing metamorphosed basic dykes. These rocks bear a strong resemblance to parts of the Shamva Grits of the Mazoe district, and hence were tentatively included within the Shamvian System by Tyndale-Biscoe (1940).

Gneiss and Granite: Surrounding the schist belt, and at places within it, is a mass of heterogeneous siliceous rock conforming dominantly to the composition of granite-gneiss. Where occurring in contact with, and close to, the schist, there is developed a marked gneissic foliation which is parallel to the foliation of the adjacent schist. This foliation becomes less apparent and finally

dies away . . / -

Since the quartz schist is irrelevant to Vubachikwe Mine, no detailed work has been done on it.

A large continuous outcrop of quartz schists lies some 2,000 feet east of the mine. It is of regional dimensions and strikes northwest-southeast. Locally the contact with the greenschist nearest to the mine strikes N 10° W. It apparently lies conformably in the synform previously described (see also Structural Section), and forms a remote footwall to the rocks directly related to the mine, dipping about 70° W.

It is essentially an impure sandstone, very considerably metamorphosed. Tyndale-Biscoe described it as a "white strongly cleaved micaceous quartz-schist probably of sedimentary origin." Being highly siliceous, it is less affected by weathering and erosion agents than the enveloping greenstones and forms prominent outcrops. The dominating mass of Vubachikwe Hill is composed entirely of this quartz schist.

Since the texture and composition of this schist varies widely, several facies are apparent. The finer grained varieties contain as main accessory mostly sericite, and one variety is a brown mica-schist. The coarser portions are gritty micaceous arkoses. These bands of variable texture and composition all form strata parallel to the regional foliation. The original rock was probably composed of sandy felspathic arkoses and shales. Certain rarer bands in the schist described as "felsic schist" are probably the alteration products of originally

siliceous . . / -

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C H A P T E R   O N E

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INTRODUCTION

SITUATION

PHYSICAL GEOGRAPHY

HYDROLOGY

CLIMATE

VEGETATION

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PLATE NO. 4 : A.T. SHAFT
Main Vertical Shaft Headgear

PLATE NO. 5 : VUBACHIKWE MILL. Note two concrete Orebins. Cyanidation circuit is at right of plate, and feed conveyors at left.

dies away further into the granitic mass. On the north side of this schist belt, numerous xenoliths of greenstone lie in the granite.

The granite varies considerably in texture and composition, being in places porphyritic and elsewhere even-grained. A large proportion of the rock is a biotite granite of high microcline content. In some varieties it approaches a quartz monzonite and granodiorite in composition.

Quartz-Monzonite: In the northwest Gwanda schist-belt, two very interesting bodies of granite occur. They have the structure of typical stocks, having intruded through the greenstones and causing updoming of the surrounding rocks. Each occurrence forms a series of rugged hills rising abruptly from the surrounding plain. Forming the Insindi and Sizeze Hills, they appear to be typical cupolas, although insufficient is known of the regional structure to indicate the presence of an underlyong batholith. However, the schist belt is partly surrounded by intrusive granite rock, part of which is similar in composition to these two bodies. Thus the two bodies may be regarded as possibly forming small cupolas of the large granite gneiss body. If this is the case, then it is possible that these stock-like occurrences are part of the parent body which gave rise to mineralizing solutions which permeated parts of the district - including the Vubachikwe area.

General Structure: . . / -

in these rocks. The ferro-magnesian minerals were probably formed from the original deposition of clays while the major constituent was quartz, deposited over a considerable range in grain size. Whatever the Precambrian atmospheric conditions were when these rocks were deposited, it is possible it was under conditions which supported some very primitive life. This primaeval life may have been the origin of the graphite which is commonly seen associated with the slatey rocks. (See slates, and Plate 22.)

In surface mapping, these sediments are distinguished from the greenschist by their appearance, although the distinction between the greenschist and the more phyllitic parts of the sediments is very arbitrary. In underground mapping, the distinction between these rock types is very much less easily recognisable. Hence, underground mapping was based more on the iron-mineral content and degree of mineralization of the rock. All barren material of schistose "greenstone" nature is mapped as "amphibolite".

These mudstones and siltstones are now composed chiefly of amphiboles, biotite and chlorite arranged in roughly parallel crystals up to three millimetres long in a microcrystaline matrix of quartz and carbonate grains. The quartz portion varies very appreciably in grain size, degree of interlocking and proportion of the rock - but is generally about 30%. The amount of carbonate varies, and there are also very minor amounts of magnetite as well as pyrrhotite and chalcopyrite.

A general description of some typical specimens

follows... / -

siliceous tuffs and agglomerates.

Just to the North of Vubachikwe Summit Beacon occur several bands of brown kyanite about four inches wide, which lie parallel to the schistosity. The schist in this vicinity is cut by many small quartz veins. These quartz veins are probably not strictly hydrothermal, but may represent silica migrations formed during metamorphism.

The quartz schist is only important to Vubachikwe Mine in that it forms the dominating topographic feature, viz. Vubachikwe Hill.

DOLERITE:

Outcropping to the West of the Magano Section in the Southern part of the area shown in Map 5, are two large bodies of dolerite. These form part of a larger body of subregional dimensions. This body is a gently rolling or undulating sill occupying a very large area in the northwest portion of the Gwanda schist belt. It is intersected in all the deeper shafts of the Vubachikwe Mine and, from its outcrop near the Magano Section, seems to be dipping at about 10° N.W.; so that in the Cheque Shaft almost 5,000 feet north of its Magano outcrop, it was intersected between the sixth and seventh levels. In the Main Shaft it lies between the fourth and fifth levels. As can be seen from its interpolated position in the Longitudinal Sections of the Mine, its dip is not constant, but the sill actually rolls slightly. Its thickness varies between 50 and 150 feet, and averages just under one hundred feet.

In levels 6, 7, 8 and 10 . . ./ -

PLATE NO. 1 : Looking Eastwards from the Greenstone Hills towards Vubachikwe Hill with Vubachikwe Mine at foot of the hill.

C O N T E N T S

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follows.

Quartz Grunerite Schist:

This is a mottled grey-green rock with patches of apparently cherty quartz and mostly composed of fine needles up to two millimetres in length. Microscopically this rock is a quartz-grunerite schist consisting of a mass of fine felted needles of grunerite with a matrix of extremely fine grained intergrown quartz particles. In those portions where there is less amphibole and the quartz is dominant, the grunerite forms plumes and horses' tails in the quartz. There is a minor amount of opaque iron ore (presumably magnetite) occurring as small subhedra. See specimens K21 and K46, and Plates Nos. 9, 14, 15, 16.

Altered Siltstone:

This is a grey fine grained rock with some glossy quartz and min · sparsely disseminated sulphides. Microscopically it consists of large growths of felted acicular grunerite and hornblende. Small bands of magnetite occur. There are bands of sorted quartz grains, some extremely fine and all with a pavement-like mozaic texture. This rock was probably originally a sandy shale. See specimen K29, and Plate 16.

Altered Shale:

There is a rock of dark grey colour which exhibits a peculiar grain on fractured surfaces. It has a weakly schistose cleavage. Microscopically this rock contains a cryprocrystaline matrix of quartz with

growths . . . / -

General Structure: It is recognised that the structure of the Gwanda Schist Belt is complex. There were probably three stages of folding separated by and finally followed by very considerable periods of erosion to produce the present outcrop pattern. However, it is considered beyond the scope of this paper to elucidate the structure of the Gwanda Schist Belt. Suffice it to consider only broadly the northwestern portion of the belt in which the Vubachikwe Mine lies.

In this area the rocks are considered to have been already folded before the development of the main syncline by earlier stages of tectonic disturbance (for detailed description, see Structure Section, Chapter Four). Subsequent to this earlier movement the main feature of the district, a syncline, was developed with an axis trending in a general northwest direction and pitching steeply to the northwest. The nose of this syncline relative to the quartz-schist-greenstone contact lies about a mile west of Gwanda township. This syncline is not a simple structure and is hence termed a "synform". It was considerably distorted by a later, comparatively minor, flexure. The two quartz-monzonite stocks were intruded just to the north of each limb of this synform. Many orebodies are found along its limbs and in its nose. The Vubachikwe Mine area falls about half way along the northern limb of the synform, and it will be shown how the orebodies in this vicinity all appear to have had their

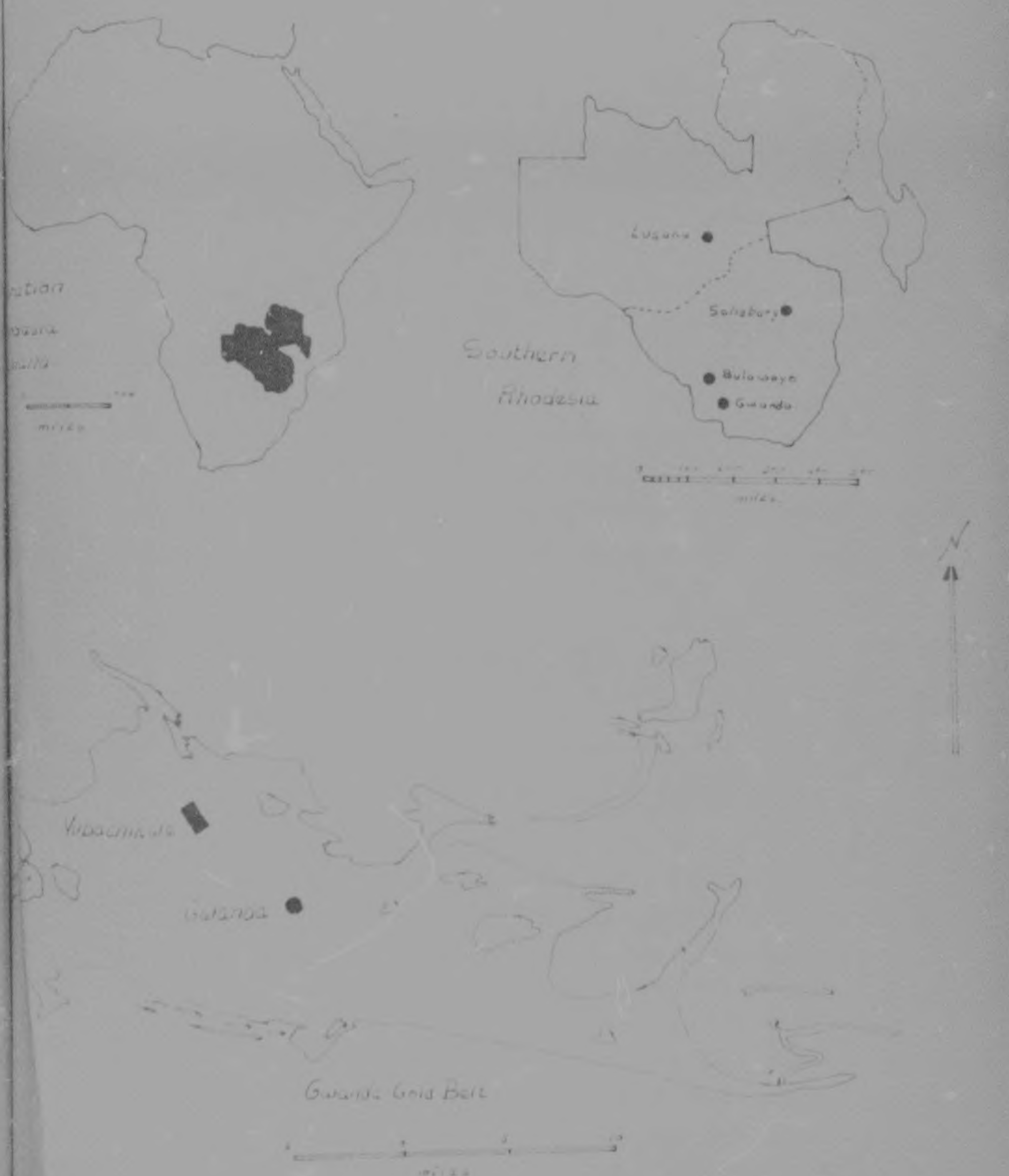
In levels 6, 7, 8 and 10, a more or less vertical dyke about thirty feet thick has been intersected in their southern ends. Due to its similar appearance to the main sill and, since no trace of its outcrop has been found on the surface south of the Long John quarries, it is believed that this dyke was a feed-fissure of the main sill.

The sill itself had very little effect on the orebodies or on the country rocks. It apparently intruded along a plane of weakness more or less parallel to the present surface. Its only major structural displacement is vertical. It causes a loss of ground for mining purposes. Since it cuts through all the rocks in the vicinity, it must be younger than all of them. There is no evidence available, either on the age of this sill nor is it known whether it is pre or post Karroo.

The interior of the sill is a coarse grained olive coloured gabbroic rock. Where intersected in the Cheque Shaft below the sixth level station, it is a coarse grained very fresh rock. (Slide K24, Plate 49). Twinned laths of labradorite-bytownite are abundant. Pale green granular ophitic augite is common. Also common are large fresh anhedral crystals of olivine with minute grains of iron ores present along the cracks. Associated to some extent with the iron ore particles, are flakes of biotite of apparently deuteric origin. The rock is a typical coarse grained olivine dolerite.

The bottom chill-zone of the sill near the seventh level station in the Cheque Shaft consists of

a blackish microcrystalline /-



Location of Vubachikwe Mine in the Gwanda Gold Belt

C O N T E N T S (Cont . .)

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PLATE NO. 6 : Common Hornblende Greenschist
Plane polarised x 50.

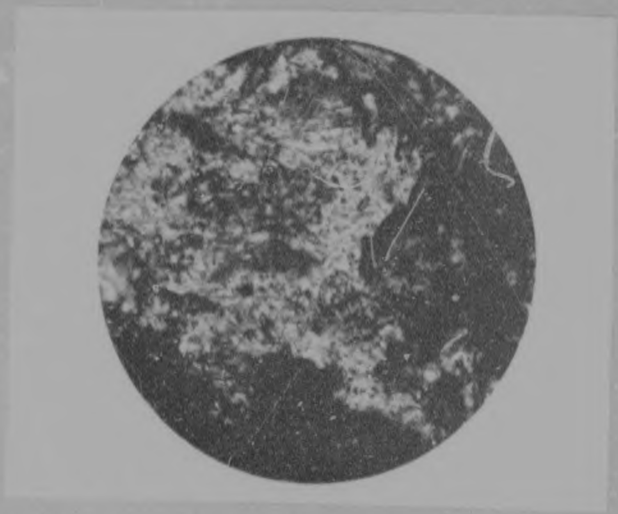

PLATE NO. 7 : Common Hornblende Greenschist.
Plane polarised x 200.

a blackish microcrystalline rock with labradorite phenocrysts up to 1 mm long. (Slide E25; Plates Nos. 47 and 48). Some recognizable clino pyroxene crystals are visible. This rock appears to contain very much more opaque material than the coarser grained varieties from within the sill. This is due either to the illusion caused by the fineness of texture, or else to the settling out of ore minerals at the base of the sill. Physically however, this chill zone is noticeably more magnetic than the interior of the sill; so the former probably applies.

The baking effect of local metamorphism on the country caused by the intrusion of the sill rocks is extremely slight - presumably because previous metamorphic effects are of a higher grade than those induced by the intrusion of the sill. Hence, although having a marked chill zone itself, it produced only a very local effect in the country rocks.

This type of sill is a rather common feature of Rhodesian schist-belt mines.

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emplacement controlled by the development of permeable zones resulting from the formation of this synform. These zones of greater permeability are mostly confined to the more brittle rocks - such as the jaspilites. Therefore, this folding acted as a major structural control on the mineralization of the area.

Subsequent to their formation, the orebodies have been subjected to a certain amount of distortion due to a later stage of folding.

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C H A P T E R   O N E

INTRODUCTION:

> "Now a miner, before he begins to mine the veins, must consider seven things, viz. situation, conditions, water, roads, climate, right of ownership and neighbours" (Agricola).

In the great expanse of bush that forms the plains of Wenlock and Insidi on the northern edge of the broken country round Gwanda, lies a prominent hill. It is rounded and elongated and has a "back like a hippopotamus". This is the Makaranka (local people) translation of Vumbashinkwe, which the conquering Matabele corrupted to Vubachikwe. Hence, Vubachikwe hill gives its name to the large farm on which it lies, and to the mine immediately to its west.

SITUATION:

Vubachikwe Mine lies approximately seven miles north-west of Gwanda at an elevation of roughly 3,400 feet above sea level. It is immediately to the west of the prominent Vubachikwe hill, the elevation of which is 3,911 feet above sea level, is 28° 53'E and 20° 53'S. Gwanda is a small mining and cattle town approximately eighty miles south-southeast of Bulawayo in Southern Rhodesia. The Mine is reached from Gwanda by a good motor-road which passes through the property. The nearest railway station is at Gwanda. (See Map No. 1)

C O N T E N T S

(Cont..)

growths of chlorite hornblende biotite and quartz. It probably represents a metamorphosed shale. See specimen K51.

Other examples of the mudstone-siltstone facies of these undifferentiated sediments are to be seen in specimens K21, 23, 27, 28, 29, 31, 34, 35, 38, 46.

<u>Jaspilite or Banded Ironstone</u>:

These rocks are generally part of the undifferentiated sedimentary group, but are important and distinctive enough to be mapped and described separately.

On the surface there occur long narrow continuous outcrops, and shorter "lenses" of banded ironstone. This rock has a peculiar jaspery brown appearance with more or less regular bands of reddish brown jasper and brownish chert. In rather rare examples, some limonitic boxwerks are found on the surface. More usually, this rock is very hard and compact.

On outcrop, jasper and chert appear to be the main constituent minerals of this rock, and hence it is named jaspilite. For the most part, the continuous outcrops of jaspilite lie in the tongue of sediments described above. Several lenses of jaspilite, however, are found isolated in the greenschist, and lie generally parallel to the regional cleavage. These were probably fairly brittle beds of jaspilite intercollated with the greenschists. When the rocks were folded these beds, or horizons of jaspilite, were forced apart and became "macro-boudins".

Hand specimens of this rock show grey cherty bands alternating with buff coloured bands. The

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C O N T E N T S

(Cont ..)

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M A P S

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PHYSICAL GEOGRAPHY:

The area under discussion covers approximately one square mile and occupies the northern third of a property of 44 blocks of claims which covers a three mile strike. The whole area lies on Vubachikwe Farm. It forms portion of the eastern limb of a complex syncline pitching steeply northwest. The countryside is dominated by Vubachikwe Hill, a quartzite ridge immediately to the east of the mine. This hill is a portion of the same large syncline. The surrounding country is formed largely of greenstone which forms low lying hills with a north-south orientation. This orientation is accounted for by the presence of hard jaspilite intercallations in the greenstone. These hard bodies are orientated north-south and form the backbones of many of the hills.

In comparatively recent geological times, the watershed in this district between the Tuli and Mchabezi Rivers, was formed by the main Vubachikwe quartzite. However, due to the quartzite's open jointing and friability when weathered, (except on Vubachikwe Hill itself) the watershed has migrated westwards off the quartzite.. It now lies in a range of low greenstone hills a mile from the quartzite. It is peculiar to find a watershed dissociated from the major hill in the vicinity.

The resultant topography is a portion of the vast Prekarroo Peneplain of Rhodesia, which in this vicinity has been moderately rejuvenated. Because

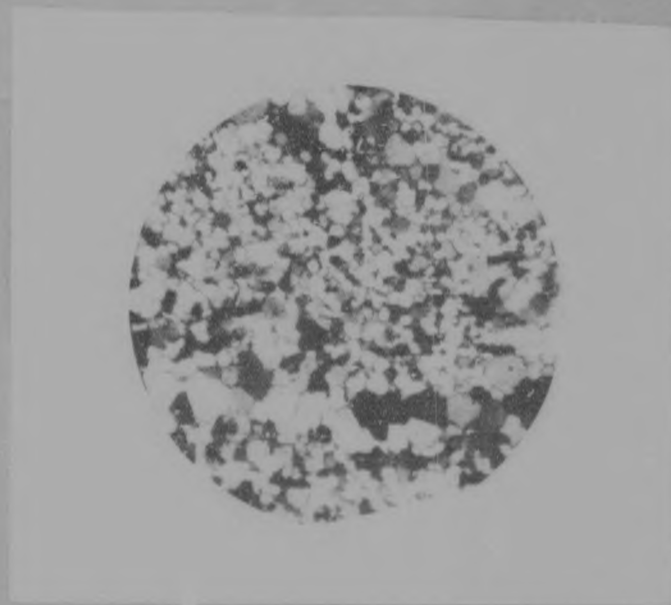

PLATE NO. 10 : Original Quartz as found in Jaspilite and altered Siltstone. Note tendency towards sorting. Minor amphibole needles present.

X nicols x 62

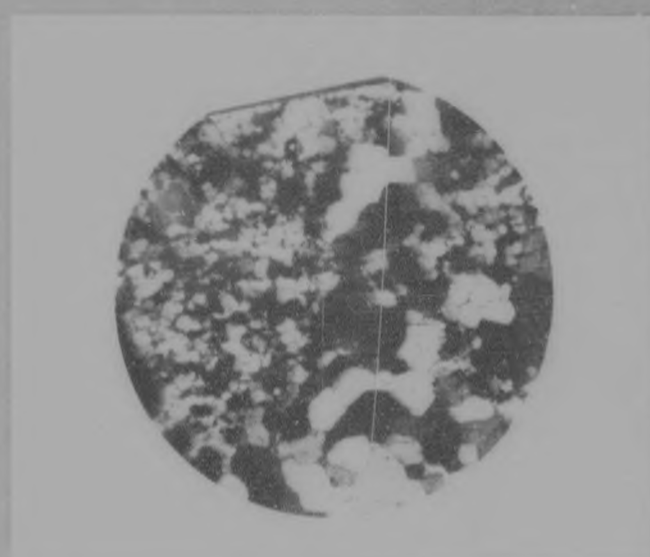

PLATE NO. 11 : Original Quartz as found in Altered Siltstones and Jaspilites. Note very appreciable sorting of grainsize.

X nicols x 62

C O N T E N T S (Cont..)

P H O T O M I C R O G R A P H S

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C H A P T E R   T H R E E

THE GEOLOGY OF THE ROCKS AROUND THE VUBACHIKWE MINE (See Map 3)

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TABLE OF ROCK TYPES:

Many of the rocks mentioned below are names in accordance with local mine practice and such names have been retained, although they may not be strictly correct petrological nomenclature.

Greenstone: or Amphibolite Schist	Greenschist (Hornblended)
	Greenschist (Mica)
	Actinolite Green Schist
	Silicified Green Schist
	Epidiorite
Undifferentiated Sediments :	Quartz Grunerite Schist
	Altered siltstone
	Altered Shale
	Jaspilite
	Slate
Tale Carbonate Schist	
Quartz Schist	
Dolerite.	

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GREENSTONE OR AMPHIBOLITE:

General Description . . / -

brownish bands carry abundant amphibole minerals. At irregular intervals there are small bands of magnetite, and from these bands felted amphibole needles radiate out into the quartz.

Below the zone of oxidation this rock is an irregularly banded quartz iron-rich amphibole rock. The rock is composed mostly of quartz, approximately 60%. (See Slides 20a and b, and Plates 10 and 11). This quartz is composed of grains of approximately equal grain size with a pavement-like mozaic effect. Scattered sparsely through the quartz is a fine black dust, presumably magnetite, which also occurs in larger grains. Associated with the finer bands of quartz are stellate aggregates of grunerite needles. The needles are generally very small and are approximately thirty times as long as they are wide. These needles, because of their peculiar wavy extinction under crossed nicols are probably aggregates or bundles of needles. (See Plates 15, 17, 18.)

The rock would thus appear to have been an iron rich, fine grained quartzite with considerable clay content. At a certain stage of the metamorphism, reaction between the clays and magnetite formed grunerite as a metamorphic constituent, which grew from iron rich centres into iron free areas.

The jaspilite has been the host rock for most of the ore minerals, giving rise to the economic gold deposits of the area. Thus, where the sulphide content of this rock is locally concentrated it is accompanied by gold, and hence forms ore. In a typical jaspilite specimen having a high iron content

the sulphides . . / -

of the synclinal structure, there is a very slight indication of peneplained cuesta type land surface.

HYDROLOGY:

Being close to a water divide, the drainage of the area is by small fast-flowing gulleys which flow only intermittently. For much of the year natural surface water is absent.

CLIMATE:

Erratic annual rainfall varying between nine and fortyfive inches per annum, and averaging about twenty inches per annum is the dominant climatic feature. With the absence of almost all surface water for most of the year, there is little malaria and the district is healthy. In early summer and, occasionally, in mid-winter, there are influxes of maritime air. These cause spells of cold, misty, cloudy weather, locally termed "guti". Regarding temperature, no systematic records have been kept on the mine. Frost has been known in low-lying places, but is exceptional. Temperatures described as "well over one hundred" are not uncommon in the pre-rain heat spells of October and November.

VEGETATION:

The gold-belt falls almost entirely within the classification of mopani-veld, i.e. savanah country with Colophospermum mopane as the dominant tree. However, considerable tracts have been cleared of virgin bush before the march of civilisation.

Around . . / -

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C H A P T E R F O U R

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T H E S T R U C T U R E

HISTORICAL GEOLOGY AND STRUCTURE OF
THE GWANDA SCHIST BELT

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ORIGINAL STRUCTURE
FIRST DEFORMATION
SECOND DEFORMATION
THIRD DEFORMATION

.... oOo ....

DETAILED STRUCTURE OF THE
WESTERN PORTION OF THE GWANDA SCHIST BELT

M I N O R S T R U C T U R E S

CLEAVAGE ON LOCAL FOLDS

First Deformation
Second Deformation

.... oOo ....

S U M M A R Y

Stereogram 1
Stereogram 2
Stereogram 3
Stereogram 4

A C K N O W L E D G E M E N T.

I would like to thank my Supervisor, Professor E. Mendelsohn of Witwatersrand University, for his many hours of kind help and attention during my work on this paper.

I also wish to thank Mr. H.C. Morris for his assistance on the Chapter on Structure; and Dr. W. van Biljon for his help in the Xray analyses work.

Special thanks are due to the Owners, Management and Staff of Vubachikwe Mine for all the kindly and courteous assistance rendered me during my many visits to the Property, and for making all the Mine Records available to me without restriction.

I wish to express my sincere gratitude to the Geological Survey of Southern Rhodesia, especially regarding the extended Library facilities granted me. Thanks are also due to Mr. A.E. Phaup, Director of the Survey, and Mr. I. Goldberg, Economic Geologist, for their advice and encouragement.

I am most obliged to Mrs. C. Lee for her many hours spent in typing this paper.

Last, but not least, I must thank my wife, Glenda, for without her constant nagging this thesis would never have reached completion.

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General Description:

Greenstone forms by far the bulk of the rocks in the area (See Map No. 3.) It varies greatly in composition and texture, but is generally very typical of greenstones common in the gold belts of Southern Rhodesia. Although this rock would appear to be conformable with the regional bedding of the sediments in the area, very little trace of original bedding is found. Instead, it is well cleaved and, in places, markedly sheared. The shear direction is oblique to the regional strike by about 20°. This shear cleavage is the schistose foliation of the rock and is a structural feature related to the synform. (See Structure, Chapter Four.)

The Greenstones in the area have been divided into two types which differ in appearance on outcrop, and could be mapped in separate units, viz. Greenschist and Greenstone (Epidiorite).

GREENSCHIST:

Greenschist or Chlorite-Hornblende Schist is by far the commonest variety of rock found in the vicinity of Vubachikwe property. It forms the low hills to the west of the mine and is also extensively developed to the east of the property. On the flanks of these hills are rocks of tomb-stone like slabs of greenschist outcropping in a rather sombre ruined cemetery manner. (See plates 2 & 3, Page Eleven).

On a petrological basis . . / -

Around the old open workings and in cleared, but unused parts of the area, ecological recession has resulted in the development of a thorn bush vegetation. The dominant trees in these localised places are knob thorn (Acacia Nigrescens) and "Wag 'n Bietjie" thorn (Ziziphus Abyssinica). The grasses are mostly of sweet variety, with the result that, at the present time with boreholes supplying perennial water, the whole district is ranch-land.

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PLATE NO. [illegible] : Actinolite Greenschist showing very well developed felted crystals of actinolite-tremolite. Groundmass is same mineral.

Plane polarised x 37·5.

PLATE NO. 9 : Actinolite Greenschist-chloritized.

Plane polarised x 250.

CHAPTER FOUR

THE STRUCTURE

It has been stated before that a complete elucidation of the structure of the Gwanda Schist Belt is beyond the scope of this treatise. However, to appreciate the concepts of the local structure of Vubachikwe Mine, some explanation of the regional structure is necessary.

From a study of Tyndale Biscoe's geological map of the district and from MacGregor's map of the Sabiwa area - as well as considerable mapping done personally, and visits to many parts of the schist belt, the following emerges:-

HISTORICAL GEOLOGY AND STRUCTURE OF THE GWANDA SCHIST BELT.

In Bulawayan times (i.e. early Precambrian), a succession of sediments derived from the weathering of basic igneous rocks was laid down. This succession was intercollated with basic lavas, tuffs and agglomerates. There were probably periods of considerable igneous activity, including lava flows, accompanied by tectonic movements and interspersed with periods of relative stability, during which erosion of the higher ground took place. There is no real evidence available to indicate whether or not the succession of lavas and sediments was formed

under marine . . / -

THE STRUCTURE AND MINERALIZATION OF

V U B A C H I K W E   M I N E ,

GWANDA, SOUTHERN RHODESIA.

By HECTOR ROGER KLEINOT. B.Sc.Hons. A.M.I.M.M.

Thesis for the degree of

MASTER OF SCIENCE

submitted to the

University of Witwatersrand,

Johannesburg.

J O H A N N E S B U R G   1 9 6 3

On a petrological basis the greenschist is subdivided into a major type and three variations, namely, Hornblende Greenschist; Mica-Hornblende Greenschist, Actinolite Greenschist and Silicified Greenschist.

1. <u>Normal Hornblende Greenschist</u>:

The ordinary greenschist is by far the commonest variety of greenstone in the area. It is of a generally coarser texture than the epidiorite, and usually has comparatively large bladed crystals of amphibole orientated parallel to the schistosity. Hand specimens show well developed cleavage along the schistosity and have rough broken ends. The rock has undergone considerable propylitization and very numerous lenses and bands of carbonate occur in the rock. These carbonate concentrations vary in dimension from microscopic lenticles to bands several feet across. They all lie parallel to the schistosity.

The constituents of this rock are amphibole, chlorite, carbonates, quartz, felspar and biotite, with magnetite as the main accessory mineral. Generally, the amphibole in the greenschist is hornblende very pleochroic from pale- to yellow-green. The crystals of amphibole may be anything up to several millimetres long in a mass of finer crystals of felspar, amphibole and carbonates. Some quartz is also commonly present. In hand specimens this rock is usually even textured but microscopically there is often a suggestion of a porphyroblastic texture with larger ragged amphibole crystals. The rock has an olive black colour on fresh surfaces. See Slides K32, 33, 36, 39, 40, 44: Plates Nos. 6 and 7.

2. Mica-Hornblende Greenschist../ -

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C H A P T E R   T W O

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General Outline of the Geology of the North West
Gwanda Schist (Gold) Belt.

Table of Geological Formations found in the Vicinity
of VUBACHIKWE MINE.

BULAWAYAN SYSTEM

Greenstones
Greenschist
Jaspilite
Quartz Schist

SHAMVIAN SYSTEM

Gneiss Granite
Quartz Monzonite
General Structure

* * * * * * * * * * * * *

the sulphides seem to be associated with the quartzitic rather than the gruneritic portions of the rock. (Slide K9. See also Ore Minerology.) In some areas the magnetite content is sufficiently high to render the rock magnetic. Slides examined of this rock include Nos. K1-6 - K8-13 and 18, 19 and 20. (See Plates Nos. 19, 24 and 26.)

On the surface, scree and rubble from the jaspilite bodies is very misleading since it gives the impression of having been derived from bodies of greater width than are actually present.

Slate:

This rock is relatively uncommon on surface, probably because it occurs as narrow discontinuous bands. It is noticed on the surface, particularly in the valley, south of the main tailings dump about 600 feet south of the mill, and also about 400 feet south of Vuba shaft. The strike is parallel to the strike of the jaspilite body and is associated with it. It is relatively common underground.

The rock is called slate because it is very fine grained and darkly coloured, although it often has only a poorly developed slaty cleavage. In different parts of the mine several variations of slate occur in narrow bands between one and seven feet thick, but more usually only between one and two feet thick. The commonest type is almost black, very fine grained, not very markedly banded, and with a cherty subconcoidal fracture and a slight to moderate slaty cleavage. It often contains pyrrhotite and chalcopyrite, sometimes as smears on partings. When near orebodies, it

usually has . . / -

Buried at some considerable depth, these rocks were involved in a period of orogenesis and were highly folded. They were probably subjected to considerable heat at the same time and metamorphism of constituent minerals, as well as granitization of the surrounding rocks began. The granitization probably took up a very long period of time, and may represent an extreme phase of the metamorphism to which the schist belt was subjected. Evidence for this granitization is led by Tyndale Biscoe in his section on Contact Rocks*. Whilst he considered most of the granites to be magnetic the evidence also supports the granitization theory.

For a long time the rocks remained in this state, while erosion removed their roofing material and granitization process corroded their edges.

SECOND DEFORMATION:

These contorted - probably isoclinally folded - rocks were subjected to another orogenesis, as a result of which they were folded in a direction very nearly at right angles to the original direction of folding. This flexure was not as severe as that produced by the first deformation.

A period of igneous activity might have followed this orogenesis resulting in the formation of bosses of

quartz-monzonite. / -

*p.45 Bull. 36; Geol. Surv. of S.R.

DECLARATION

I hereby declare that this thesis entitled "The Structure and Mineralization of Vubachikwe Mine, Gwanda, Southern Rhodesia" is my own work, and that it has not been submitted elsewhere for another degree by myself.

H. R. KLEINOT.

2. <u>Mica-Hornblende Greenschist:</u>

Essentially similar to the Hornblende Greenschist is a variety which has a very noticeable amount of biotite. Hard specimens have a distinctly brown sheen compared with the dull olive colour of the common type. This brown colour is due to the presence of a considerable amount of biotite in the rock. The mica often surrounds small magnetite grains which occur as an accessory mineral in the rock. The biotite flakes are large but very ragged and may be a deuteric mineral developed from an interaction of silica with magnetite and clay minerals. This rock type grades into the common greenschist without an obvious contact. See Slides K30.

3. <u>Actinolite Greenschist:</u>

A few miles to the north of Vubachikwe property, actinolite schist is very common. On the Mine area however, it has only been observed in a small quarry some two hundred feet east of the Middle-shaft, and also in the valley to the east of the Magsno Section. This rock consists of tremolite-actinolite needles up to four millimetres in length, and, apart from carbonate, is composed almost exclusively of amphiboles. No sharp contact with surrounding hornblende greenschist is apparent, the contact being gradational. In places this rock has been largely altered into a chlorite schist, possibly as a result of weathering. (See Slide and Plates 8 and 9).

4. <u>Silicified Greenschist:</u>

In several places . . / -

C H A P T E R T W O

GENERAL OUTLINE OF THE GEOLOGY OF THE NORTH WEST GWANDA SCHIST (GOLD) BELT

This section is largely condensed from the description of the Gwanda Gold Belt Bulletin 36 (Tyndale-Biscoe 1940), but has been slightly modified by personal observation (See Map No. 2)

TABLE OF GEOLOGICAL FORMATIONS FOUND IN THE VICINITY OF VUBACHIKWE MINE

Archaen Schists	Shamvian System	(Greywacke (Paragneiss
	Bulawayan System	(Quartz Schist (Jaspilite (Greenstones.
	Intrusive	Monzonite Gneiss and Granite.

The northwest Gwanda Schist Belt consists of a highly metamorphosed and folded mass of schists surrounded by gneissic rocks. The composition of the schists varies from ultrabasic to highly siliceous. The oldest rocks present are greenstones with interbedded quartz schists and banded jaspilites. These rocks form part of the Bulawayan System.

quartz-monzonite. There may have been hydrothermal solutions associated with these intrusions. These may have been intruded into the rocks along planes of weakness created by the folding and accompanying fracturing, which deposited various minerals in the rocks thus forming ore-bodies.

THIRD DEFORMATION:

The last stage of regional distortion resulted in the development of gently undulating broad folds superimposed on the previous folding.

At about this stage, a large dolerite sill was intruded. It is not known, however, whether this sill was indtruded horizontally and was deformed by the third deformation to its present rolling attitude; or whether it was intruded along a plane of weakness formed by the third deformation and hence assumed its undulating attitude directly.

Subsequent erosion led to the present outcrop pattern of the rocks in the area.

DETAILED STRUCTURE OF THE WESTERN PORTION OF THE GWANDA SCHIST BELT.

The area in which the Vubachikwe Orebody occurs is this Western portion of the schist belt.

A horizontal succession of volcanics and sediments derived from basic rocks, and containing a major

sandstone horizon, / -

usually has a significant proportion of pyrrhotite. Since it is commonly associated with jasper, and it often extends in the sediments and jaspilites beyond the limits of orebodies, it has been used as a rough indication of the presence of ore in the vicinity. However, these slaty bands are not sufficiently persistent, nor are they uniform enough for them to be valuable marker horizons, but only vague indications. Two types of slate may be distinguished,

a) Common slate;

b) Garnetiferous slate.

****

i) Common slate:

The commonest type of slate is a dark grey-black, very compact uniform rock with a faint trace of banding. The slide shows it to contain a dominant proportion of quartz, very fine grained and somewhat intergrown. In it are parallel bands or lenses of opaque graphite material giving rise to schistose texture. Parallel to the schistosity are growths of biotite crystals around small magnetite grains. The biotite would appear to be a secondary mineral formed from silica-clay reaction with magnetite. (Specimen K22 and 26)

ii) Garnet Slate:

Some varieties of this slate bear speciol mention. One variety occurs as a slaty band on 9 level south, Long John Section, and is a garnet "Knofenschiefer". Under the microscope it has an almost opaque matrix due, apparently, to a considerable graphite content. In this black matrix, which is probably largely quartz from

its hardness . . / -

A B S T R A C T.

In several places, greenstones containing large amounts of quartz are found. The quartz is present as lenses and lenticles which are orientated parallel to the schistosity of the greenstone. The ferro magnesian mineral present is largely hornblende. In some instances, the quartz forms part of the major part of the rock and may be developed to such a degree as to form veins or stockworks with inclusions of country rock. These inclusions are occasionally recrystallized giving rise to tremolite needles up to three cms. long. The quartz is usually milky in colour with a pronounced vitreous appearance. These zones of quartz with associated amphiboles are often up to several hundred feet long. They resist erosion more than the ordinary greenstone and hence generally form the crests of small ridges. See slide No. K37 and Plate 12.

ORIGIN OF THE GREENSCHIST:

In mineral composition as observed under the microscope, the greenschist is similar to the propylitized altered phyllites occurring in the sediments. (See below) Since the overall chemical composition of a pelitic sediment and a basaltic lava are similar, certain conditions of metamorphism of the area was the possible result in similar rock types being formed. The regional metamorphism of the area was probably of a retrograde nature with stress rather than temperature as the major influence. (See Structural Section). Thus, although the greenschist was originally, most likely, a basaltic volcanic lava, with the actinolitic and micaceous

Somewhat younger is the greywacke-paragneiss group which is part of the Shamvian System, and is separated from the Bulawayan System by an unconformity.

The gneissic rocks surrounding the schist belt comprise mainly granite gneiss, varying greatly in texture foliation and composition.

The schist belt is rather complex, containing a large number of dykes and sills of various compositions in addition to quartz veins. In many places there are great enclaves of gneiss within the schist. At the contact of the schist and gneiss there is often developed a complex zone of migmatites.

The following is a summarised description of the formations mentioned.

__BULAWAYAN SYSTEM:__

__Greenstones:__ The greenstones are the commonest rocks in the area and are characterised by two dominant types.

(a) Greenstone. This rock is a massive epidiorite which is a fine grained dark rock composed mainly of hornblende and felspar. It usually shows spheroidal weathering. It was probably formed from the alteration of original basaltic lavas.

(b) Greenschist. Chlorite-hornblende Schist. This rock is an amphibolite schist which weathers into peculiar slab-like boulders

giving a macabre . . / -

sandstone horizon, was subjected at depth to the orogenic movement described above under "First Deformation". This produced a recumbent isoclinal fold in a more or less horizontal attitude with the axis of the fold lying approximately horizontal, striking about N 50° E, and lying across the northwest end of the schist belt. (See Map no. 2)

This succession of metamorphosed rocks was then subjected to movements described in "Second Deformation" which folded the rocks synformally. The structural nose of this synform is seen in the outcrop patterns of the jaspilites and greenstones about two miles west of Gwanda township. This axis is plunging at about 52° in a direction approximately N 70° W (See below) suggests a fold axis for the third deformation. This axis is orientated about N 50° E. (See Stereogram 4) The conjugated folds lie in the quartz schist about 100 yards above the Mchabezi bridge one mile west of Gwanda. It is appreciated that this is very limited evidence, but it does support the other data.

Thus, in it s simplest form, only three movements are required to have produced the complex outcrop pattern of the rocks.

The exact nature of the first deformation is unknown and the suggestion provided is hypothetical. There is no field evidence to provide a more substantial solution and, moreover, it is quite likely that the initial movement(s) was(were) considerably more complex than is suggested above. For example, according to Tyndale Biscoe's Map (1958), there is a suggestion that the quartz Schist forming Vubachikwe Hill may be

a tight . . / -

its hardness and fracture, there is present a little biotite and fairly numerous growths of garnet up to five millimetres in diameter. (See Slide K22, Plate 22.)

iii) Shear Fills:

Falling into a similar category as the slaty rocks are the shear fills, because of their similar appearance underground. The shear fills are usually mylonites or silicified mylonite. Where the shears pass through Phyllitic sediments and greenschist, they are generally closed cracks and contain no gouge material of any consequence. However, where they pass through the hard competent rocks (i.e. slate and jaspilite), they form mylonitized zones up to twelve inches wide. The mylonite is usually very platy and shows slickensides due to the last movement. It is often lustrous black in colour due to a considerable admixture of graphite. However, by far the greatest proportion of the shear rock is quartz. Slides cut from this rock are virtually opaque and no photographs are available.

Graphite:

The intensely black opaque substance often found in the slate rocks is almost certainly graphite. It probably originated from some early form of life. Although atmospheric conditions may well have been very different in Precambrian times, the possibility of early types of proterozoic life existing in favourable swamps, in which would accumulate the muds and

iron rich . . . / -

ABSTRACT

Vubachikwe Gold Mine is situated seven miles northwest of Gwanda in Southern Rhodesia. It lies at the foot of Vubachikwe hill about two thirds along the strike length of the northwest Gwanda gold-belt. This gold-belt is a great synformal structure composed of Bulawayan greenstones and altered mixed sediments. It has been intruded by the Insindi and Sizeze monzonite stocks as well as by numerous dykes and sills of dolerite. The whole gold-belt lies as a roof pendant in gneissic granite, of which a large proportion is believed to have been formed by granitization processes. This process also resulted in considerable migmatization of the goldbelt's contact zones.

The present outcrop pattern of the gold-belt is apparently the result of three stages of folding. The second stage, which folded the northwest portion into a complex syncline or synform, produced as a consequence, the folds and shears which provided channelways for mineralizing solutions. The channelways are fold axial planes and shears which are shown stereographically to be related to the second deformation or fold period. The third deformation or final fold period was of minor magnitude and served only to complicate and disaligne the constant pattern produced structurally to the second deformation. Generally, it can be stated that all mineralization at Vubachikwe mine is found in competent jaspilites striking just west of north and dipping westwards at about 65°

with folds . . . /

variations a manifestation of original volcanic facies variation, it may have been a pelitic sediment of somewhat variable facies.

GREENSTONE EPIDIORITE:

Although this rock is very common in the schist belt, it is comparatively rare in the area of Vubachikwe property. It is a dark olive coloured fine grained rock which weathers into sphoreoidal boulders and, generally, forms low lying country with deep reddish-brown soil cover. It is composed of hornblende, sodic felspar in very insignificant amounts, and carbonates. The rock is not as well cleaved as the green-schist variety and may be the alteration product of basic lavas, dykes and sills. Since this rock type is insignificant on Vubachikwe property and has nowhere been observed in the mine workings, this description is based largely on Tyndale Biscoe's observations.

UNDIFFERENTIATED SEDIMENTS:

Striking about N. 20^{0} W, and dipping at 70^{o} W, is a tongue of metamorphosed sedimentary rocks occupying the central portion of Vubachikwe property. Virtually all the mine workings of any importance are contained within these sediments.

Within the group of Undifferentiated Sediments are varieties of quartz grunerite schist, altered siltstone and shale and slate jaspilite. These slates and jaspilites are however described separately since they are important and distinctive enough in character to be mapped as separate entities.

Except for . . / -

a tight overturned fold. This is interpreted from the map which shows minor folds on the northwest contact between the quartz-schist and greenstone.* (See Map No.2). The axes of these folds are so orientated as to suggest the quartz schist is overturned on this contact.

It is recognised that if this quartz schist is an overturned fold, then an entirely different interpretation must be given to the initial movements. However, other field evidence does not support this supposition, and furthermore, the initial deformation(s) apparently did not influence the development of ore-bodies to any extent.

The nature of the second deformation is, by comparison, clear. A study of the map No. 2 shows the whole of the relevant portion of this schist belt to be synformal about an axis plunging at 52° in a direction N 70° W. The attitude of the many jaspilite bands, particularly in the area of parasitic folding, readily reveals this structure.

If, however, the folding producing the synform was the last deformation to have taken place, then the outcrops of the limbs of the synform would tend to be straight provided there was no marked relief. The outcrop of the northern limb trends 65° W at about the position of Vubachikwe Hill. This 30° swing could only have resulted from a further flexure. By comparison with the first and second deformation

this flexure . . / -

*Ref. Map, Bull. 36; Geol. Surv. of S.R.

PLATE NO.2 : Greenschist outcrop. Note slablike boulders giving macabre ruined cemetery effect. Boulders are up to four feet tall.

PLATE NO.3 : Greenschist slab on outcrop. Note ruined tombstone effect. Approximately three feet tall.

iron rich precipitates which would form these slates, is very probable. There are definite organic remains in the rocks of the Bulawayan System (algal remains in the Huntsman Limestone*) and, since these rocks are of Bulawayan age, the graphite rocks in them probably contain original organic carbon. Graphite in the rocks of the Bulawayan System is far too common for it all to have originated from volcanic gases.

TALC CARBONATE SCHIST:

At several localities in the area shown in Map No. 3, bodies of talc-carbonate schist occur. The rock is schistose in texture, has a soapy talc-chlorite feel, and is considerably carbonated. The largest of these bodies outcrops about 1,500 feet south-southeast of the main shaft. It weathers with a brown colour since the carbonates become a decided brown, while the talc retains an olive colour. The proportion of talc to carbonate varies considerably from place to place. In the stream at the north end of the outcrop, small veins of calcite and siderite were found cutting through the rock.

Over a large part of the southern section of the mine, a body of talcose rock occurs immediately in the footwall of the ore zone; and a similar situation was found in the Black Jack Section. The talcose body in the South is traceable for 800 feet and is apparently conformable with the sediments in which it lies. Its dip is approximately 70° W, and its strike varies between

N 50° W and N 25° W . ./ -

*Ref: A.M. Mac Gregor, 1941.

this flexure was gentle. Assuming an axis approximately parallel to that of the first deformation, the whole schist belt was bent downwards about 15^{o} in the form of a bow about an axis approximately a mile east of Gwanda. Subsequent erosion gave the present outcrop pattern. (See Map. No. 2.)

MINOR STRUCTURES.

CLEAVAGE ON LOCAL FOLDS:

First Deformation: Doubtless a strong cleavage system was produced by as pronounced a movement as the first deformation. However, due to subsequent movements, the original cleavage is not observed in the field. Having been subjected to repeated deformation, it has probably come to lie very nearly parallel to the original bedding planes, and is hence not evident.

Second Deformation: This produced a very marked cleavage in the rocks. It is reasonably clear from Tyndale Biscoe's Map that at the time the map was drawn (1938), no clear distinction was made between bedding and cleavage. This is due largely to the bedding having been obscured by cleavage - particularly in the greenschist areas.

In the vicinity of Vubachikwe Mine this cleavage has been carefully mapped. It occurs as a series of strong fracture planes parallel

to the schistosity . . / -

to the schistosity of the greenschist. Indeed the schistosity of the greenschist is a manifestation of this cleavage. On cleavage faces, striations or lineations pointing steeply downwards in a northwesterly direction are found. Cleavage is a known feature produced by folding, and its orientation is very definitely controlled by that folding. This is particularly noticeable in the talc-carbonate in the footwall of the main Vubachikwe orebodies.

Field evidence shows that this cleavage is all nearly parallel, and when plotted on a stereogram (See Stereogram 1, Page 53) forms a close enough cluster of poles to suggest a common relationship. The average orientation of this cleavage near Vubachikwe Mine is about N 40° W dipping at 70° to the southwest. In the field this cleavage suggests a relationship to the large local folds found in the banded jaspilite outcrops. These local folds are quite common to the southeast of Vubachikwe property. On plotting the axes of these local folds, it is apparent that they are definitely related to the cleavage. (See stereogram 2, Page 54). On examination of the regional map, confirmed by field evidence, it is seen that these local folds are common on the limbs of the regional synform, particularly near its nose, dying out on its limbs away from there. It is thus reasonably apparent that cleavage and local folds are related to the regional synform, and that they were in fact produced by the same stress. On plotting the fold axis of the regional synform (Stereogram 3, Page 55), it is found that the axis plunges at 52° in a

direction . . / -

direction N 72° W. However, the axis plotted on the stereogram lies very close to the plane of cleavage. This means, that within the limits of field mapping and available data, the cleavage plane contains the fold axis. If they are related, then this is a structural requirement. Furthermore, if the local or minor folds are related to the main fold, then their fold axes must be parallel to each other. This is not the case. However, these fold axes are related in that they are all contained in the cleavage plane although plunging in different directions. (See Stereogram 2, Page 54) This occurs when a set of related folds are subjected to a stress which superimposes a different set of folds in a new direction. Instead of all the dependent fold axes being parallel to the major fold axis, they are spread out on the great circle trace of the cleavage; that is to say that, although still in a common plane, they are no longer parallel to each other.

*** *** *** ***

S U M M A R Y

If the effects of the third deformation are removed, then:-

1) The outcrops of the limbs of the synform become straight relative to the topographic surface which is nearly a plain. The northern limb, in particular, near Vubachikwe Hill would be orientated about 30° south of its present direction.

2) The Cleavage . . / -

2) The Cleavage in the vicinity of Vubachikwe Mine similarly rotates 30° southwards and the lineations on the cleavage plunge at an angle about 15° less than the present amount.

3) The axes of the local or minor folds would all be nearly parallel.

In fact, all the lineations would then lie in the cleavage plane with their axes parallel to the axis of the second deformation.

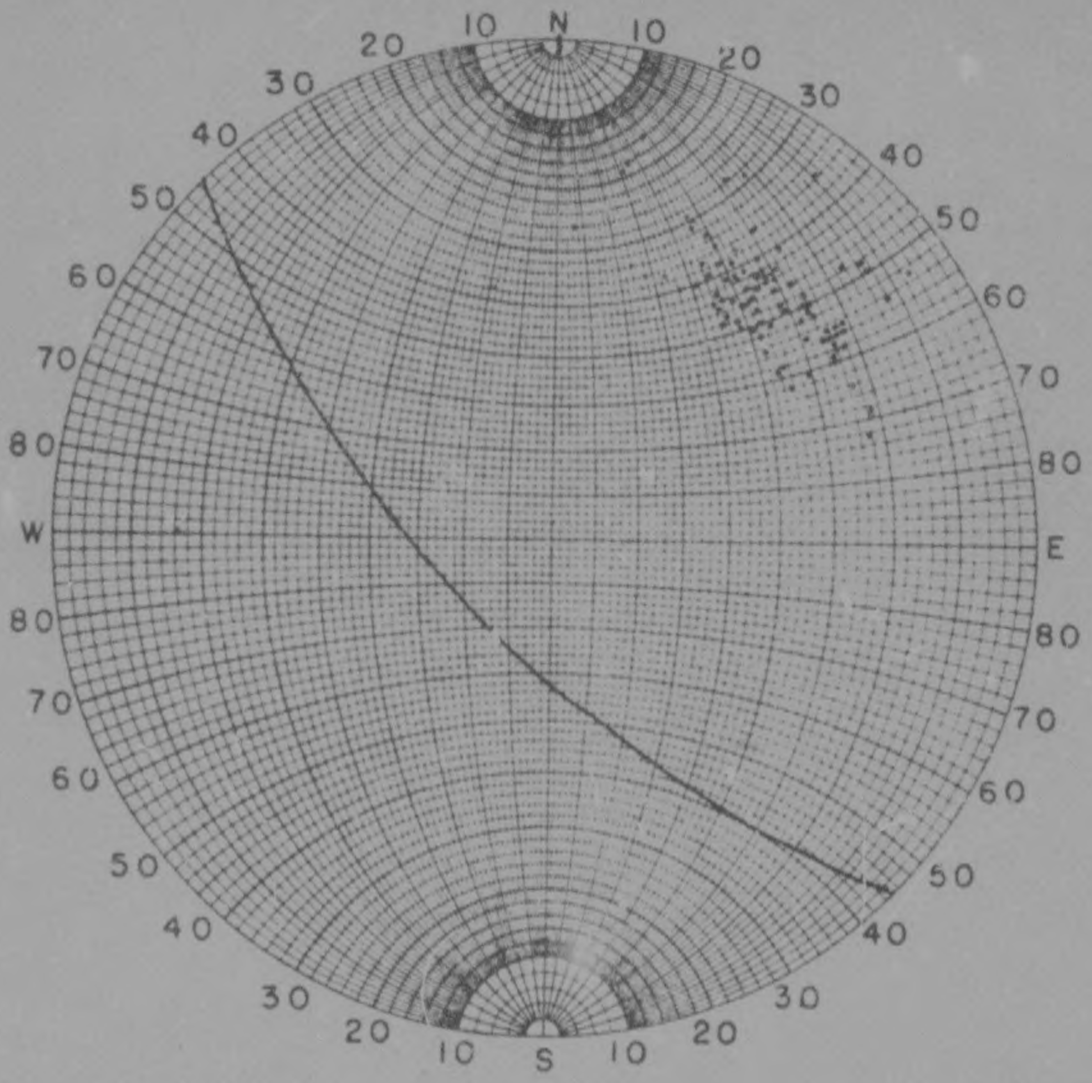
It would seem that the actual effect of the third deformation was to irregularly depress the northern section of the schist belt about the axis described above. This had the effect of locally steepening the cleavage lineations through about 15° and "rotating" the outcrops of the northern limb northwards by about 30°.

To recapitulate: removal of the third deformation effects leaves a clear picture of a synform with a strong axial plane cleavage. Various lineations and folds along its limbs are parallel to the major fold axis and tend approximately N 70° W, plunging northwest at approximately 50°.

* * * * * *

Stereogram 1

CLEAVAGE IN THE VICINITY OF VUBACHIKWE MINE

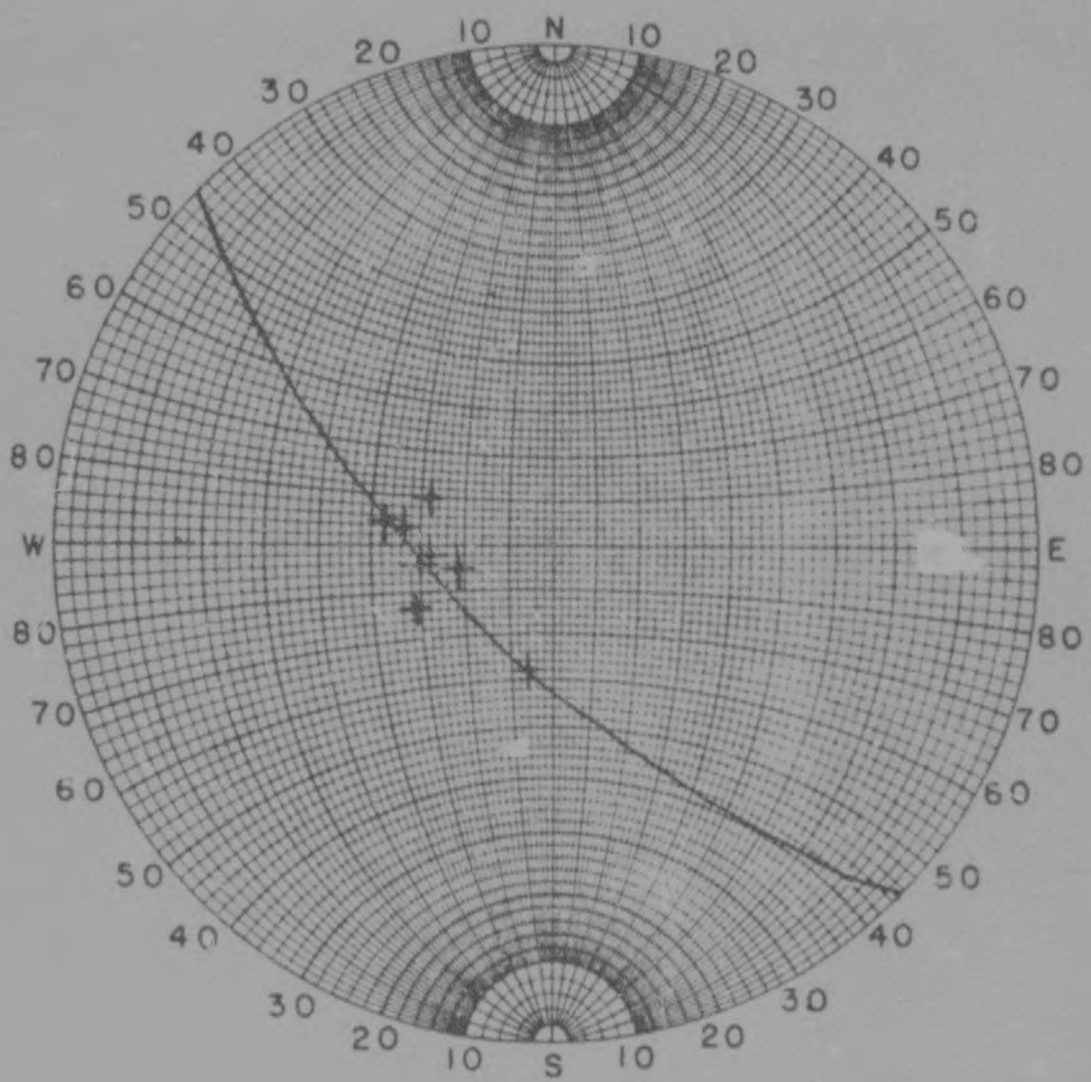


Stereographic plot of Poles of Cleavages along a three mile strike from Cheque Section southwards.

The cyclographic trace is the average plane of cleavage in the district, and is the axial plane of the stage of deformation producing that cleavage.

Stereogram 2

AXES OF MINOR FOLDS IN VICINITY OF VUBACHIKWE MINE
Shown with Cleavage Trace Superimposed



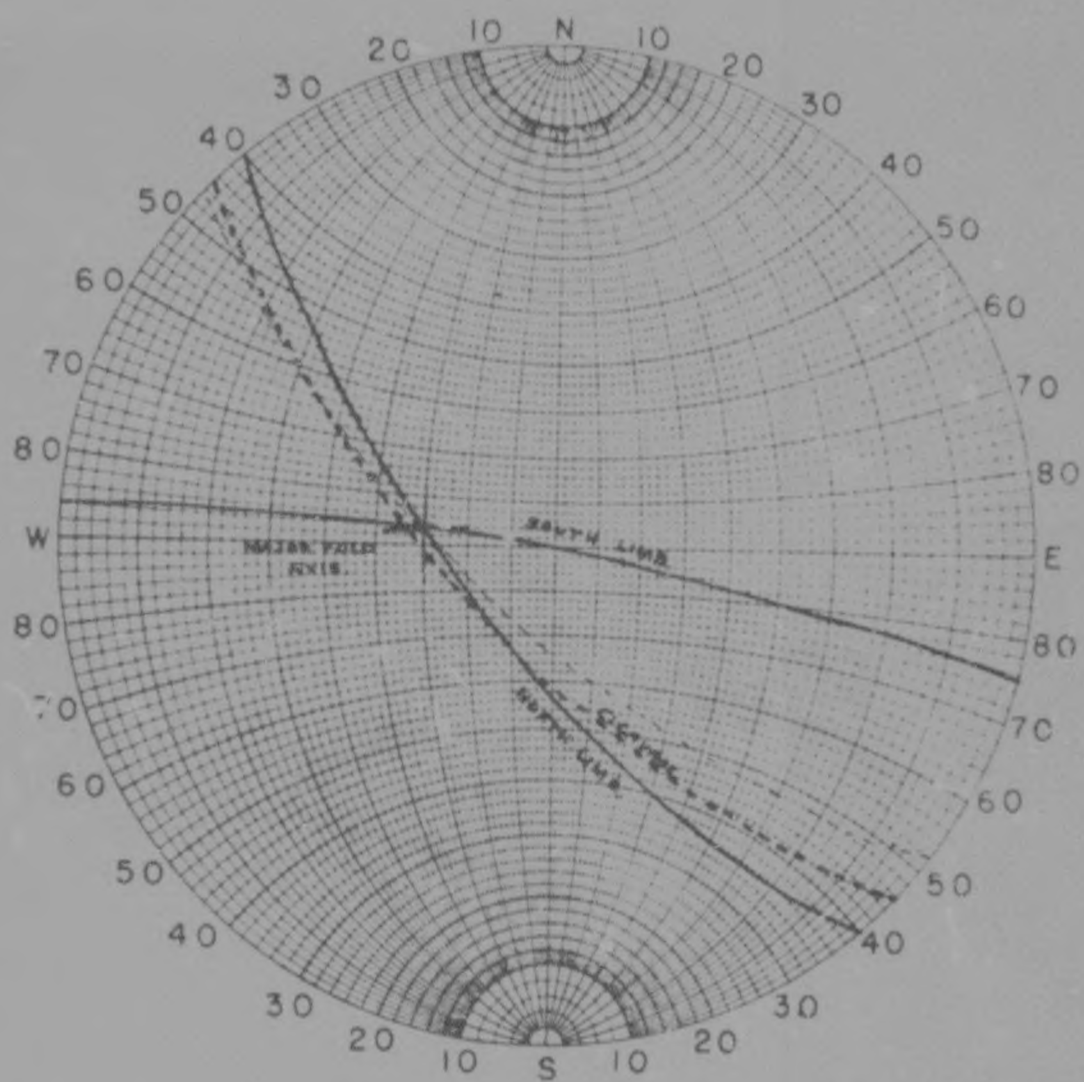
Stereographic plot of Poles of Fold Axes of minor folds within one mile south of Magano Section.

Superimposed on fold axes is the cyclographic trace of the cleavage plane.

Axes of minor folds lie in the axial plane cleavage and hence were produced by the same deformation.

Stereogram 3

FOLD AXIS OF THE REGIONAL SYNFORM
plunging at 52^{o} in a direction 72^{o} west of north, produced by second deformation



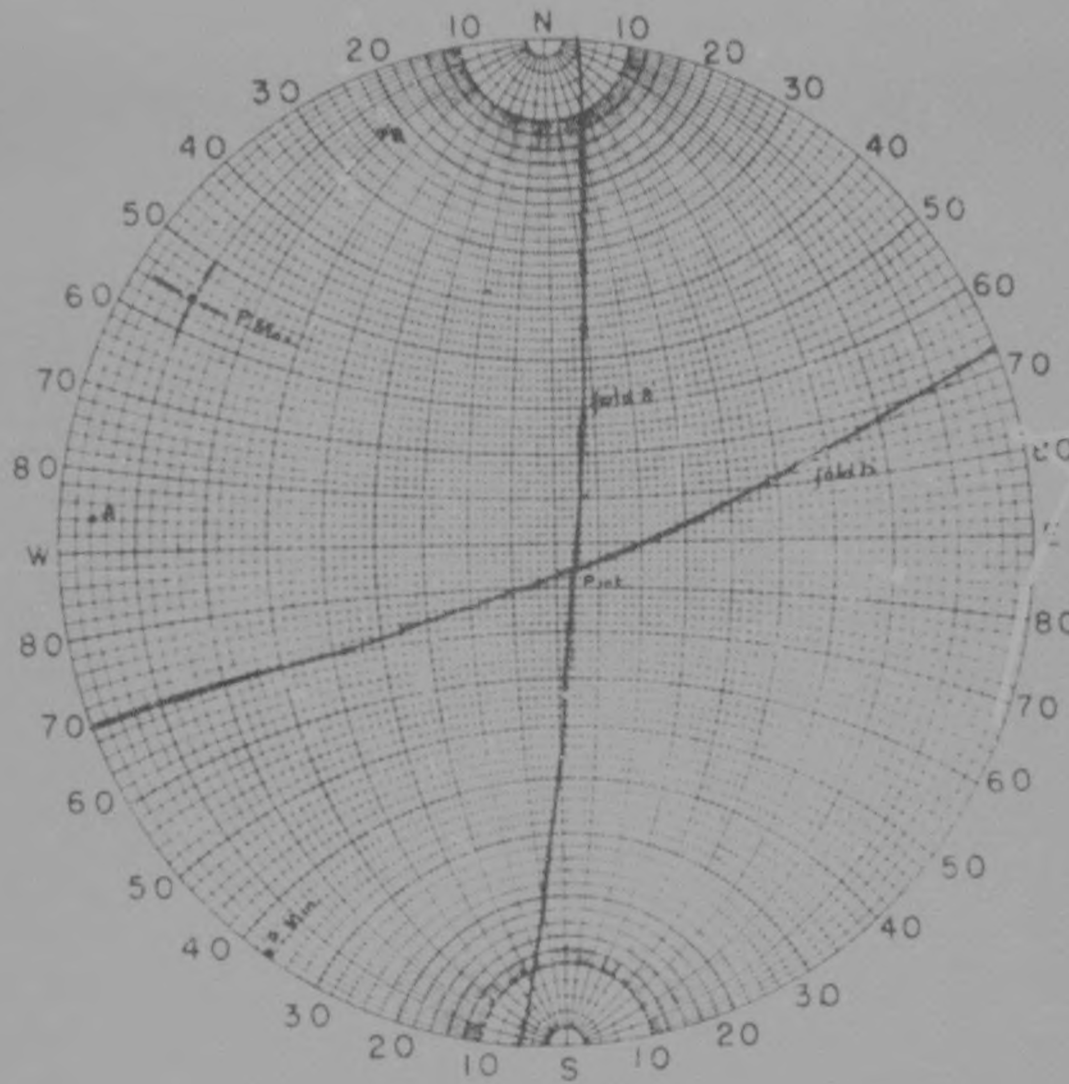
Stereographic plot of the limbs of the regional synform to show the attitude of the axis of folding.

This axis is shown to lie very close to the cleavage derived on Stereogram 1 which is the axial plane cleavage of this synform. The discrepancy arises through the third deformation (see text), and the limits of field observations.

Stereogram 4

CONJUGATE FOLDS OF THE THIRD DEFORMATION

With probable axis of fold about 55° East



Stereographic plot of axis of conjugate folds of the final deformation in quartz schist in Mchabezi River approximately one mile west of Gwanda.

The direction of the maximum strain produced - i.e. P.Max is parallel to the axis of the fold. Thus the axis of the third (final) deformation strikes about 55° East. (H.C. Norris)

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C H A P T E R   F I V E

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THE NATURE OF THE OREBODIES

******

ORE BODIES OR ORE SHOOTS OF THE NORTHERN LIMB OF THE SYNFORM

******

PROBABLE CONDITIONS FOR OREBODY EMPLACEMENT

******

C H A P T E R   F I V E

THE NATURE OF THE OREBODIES:

Solutions permeating the earth's crust tend to follow routes offering least resistance to their flow. They commonly follow openings produced along fault planes and similar lines of weakness. It would appear that the lines of weakness followed by the mineralizing solutions in the north-west Gwanda area were features formed by the second deformation, as discussed above. It is considered that the channelways followed by the hydrothermal solutions were all aligned in the cleavage plane of the regional synforms and from these channelways spread out along bedding planes. Moreover, these channelways were all parallel to the regional fold axis, and were best developed in the competent rocks which contain open cleavage fractures. These open fractures are in contrast to the crystalline lineations of flow cleavage formed in the plastic rocks. Furthermore, minerals would only be precipitated from the solutions in areas of chemical and physical suitability. The ferruginous rocks of the undifferentiated sediments seem to have provided all these conditions.

Possibly the solutions were derived from the magmatic source which gave rise to the intrusion of the quartz-monzonite stocks (See Map 2) and permeated the whole succession of rocks. These solutions only precipitated minerals where the most suitable local conditions existed. These conditions vary considerably along the limbs of the synform and hence the nature of the orebodies changes. Had there been a suitable horizon, e.g. a banded jaspilite body evenly grained and fractured, with similar conditions all along the north limb of the synform, then it is likely that a single, very evenly mineralized - probably very low grade - gold deposit would have resulted.

However, the host horizon was not uniform, therefore minerals were precipitated in localized areas only and left other areas comparatively barren. Hence there was a development of ore-shoots.

OREBODIES OR ORE-SHOOTS OF THE NORTHERN LIMB OF THE SYNFORM.

The following is a brief description of orebodies along the northern limb of the synform. They are dealt with in order from the nose of the fold westwards. The southern limb of the synform is almost a mirror-image of the northern limb, several orebodies being associated with it. However, it is not relevant to discuss it here.

In the nose of the synform, about two miles west of Gwanda, many parasitic folds give rise to saddle reef deposits with short strike and comparatively great depth extent. (e.g. Roper and Bar 20 Mines, 100' strike, 900' deep). However, due to the occurrence of a number of jaspilite bands in the area, there was a considerable volume of rock for the solutions to permeate. Thus the solutions were spread out and the resultant mineral precipitates are more sparsely disseminated than would be expected in an area where high values might be anticipated. No rich orebodies occur here.

Further westwards from the nose, along the northern limb, oreshoots are found as saddle reefs in the noses of many local folds. Where there is a well developed fold in a narrow jaspilite body, accompanied by the development of fracture cleavage in the rock, comparatively rich deposits of gold have been found. Owing to their refractory nature of the ore in the sulphide zone, most of these oreshoots are at present not being mined: althoug some of the richer shoots have been mined for well over 1,000 feet down dip.

Westwards along the north limb are the Bullion, Lady Lina Susanna and Yellow Aster mines. All are associated with local folding. It is noticed that these folds become less obvious westwards. (See Map No.2) The last oreshoot situated on a very obvious local fold, is the Magano Mine. Thence westwards the folds die away and the tongue of undifferentiated sediments becomes narrower and finally fingers out north of the Cheque Section of Vubachikwe Mine. From the Magano Mine northwestwards to the last mine along this line of mineralisation (the Smiler Mine) some four miles away, the oreshoots are apparently controlled by very gentle folds and shears, the Sabiwa Mine being the only tightly folded exception.

Thus the eastern oreshoots or orebodies on the northern limb between the nose of the synform and the Magano Mine are controlled by tight folding and have short strikes, while the orebodies westwards from the Magano Mine are controlled by gentle folding and shears and correspondingly have longer strikes; also their tenor of mineralisation is more even. There is a tendency for a decrease in the grade southeast to northwest.

On introduction of the hydrothermal solution it is considered that zones of greater permeability, due to a greater degree of fracturing, became the more favourable areas for mineral deposition. Near the nose of the synform conditions were favourable for a concentrated deposition of minerals from solutions hence forming small, comparatively rich orebodies. Further along the limbs, owing to decreased permeability, lesser quantities of hydrothermal solutions were introduced, and hence the amount of gold deposition was largely below present economic grades. This is borne out by the following figures of the amounts of ore mined from deposits in area northwestwards from the Susanna Mine, which contained a small oreshoot in a highly disturbed area:

MINE	TONS PRODUCED (Approx.)	YIELD: dwt/ton.
Susanna Mine	30,000	19·0
Vubachikwe Mine	1,000,000	4·0
Blanket Mine	250,000	5·0

****

Tonnage potentials on the Vubachikwe and Blanket Mines are large compared with the Susanna Mine, because the oreshoots of the former are not controlled by intense local disruptions as is the case of the latter. Thus the Vubachikwe and Blanket oreshoots are much larger than those of the Susanna.

Lying between the Vubachikwe and Blanket Mines

is the Sabiwa Mine . . / -

is the Sabiwa Mine. This property is an exception to the local type. The oreshoots in this mine are saddle reef bodies associated with intense folding and the accompanying fracturing, which is confined to the area of this property. This is in contrast to the gentle folding developed in this part of the synform. Being in a zone providing favourable channelways for solutions, the grade is markedly higher than the average for this stretch of the limb, and is approximately 6 dwts/ton compared with the usual 3 - 4 dwt/ton.

PROBABLE CONDITIONS FOR OREBODY EMPLACEMENT:

For the northern limb of the synform, the following conditions seem reasonably established:-

1) The area was invaded by mineralizing solutions of uniform composition.

2) Deposition from this solution resulted in valuable concentration of sulphides accompany gold and other minerals, which were dependent on the physical conditions existing at the time.

3) The physical conditions depended on the nature of the ore channelways which were controlled by folding and the accompanying fracturing of the rocks.

4) Short rich oreshoots were developed in association with tight local folds near the nose of the synform.

5) Long wide disseminated oreshoots were developed in association with shears and gentle folds

further away . . / -

further away from the nose of the synform.

6) Exceptions to this general pattern do occur, where some large lowgrade oreshoots lie near the nose of the synform and some rich short saddle reefs occur some distance away.

On the whole it is true that zones of sulphide concentrated become larger and of lower grade proceeding away from the nose of the synform.

* * * * * *

PLATE NO. 12 : Introduced quartz. Vein-quartz type as seen in Silicified Greenschist and shattered "healed" jaspilite. X nicols. partial extinction x 62.

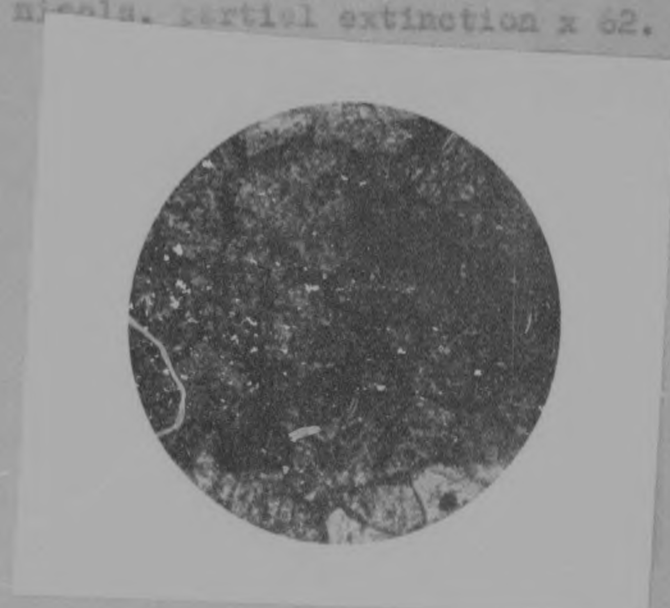

PLATE NO. 13 : Carbonate in Greenschist. Typical calcite-siderite as found in lenses and veinlets throughout the rocks of the area. Plane polarised x 250.

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C H A P T E R   S I X

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VUBACHIKWE MINE OREBODIES

THE LONG JOHN REEF

THE VUBA REEF

NATURE OF THE ORESHOOTS

LOCAL ORE CONTROLS

ORESHOOT CHARACTERISTICS

* * * * * * * * * * * * * * .

C H A P T E R   S I X

VUBACHIKWE MINE OREBODIES:

The Vubachikwe Mine orebodies - also called Payshoots and Oreshoots - lie on the northern limb of the regional synform about seven miles from its nose in an area comparatively free of intense local folding. There are two main ore zones: they are roughly parallel and follow the trend of local schistosity. On outcrop these "horizons" occur as banded jaspilite and show mineralization along their whole length which can be followed in the local area. These two ore zones are locally named the Long John and Vuba reefs. (See Map No. 5) However, each ore zone does not form ore in its entirety. Mineralisation is concentrated into eight oreshoots occurring at intervals along the strike of the two parallel reefs. For convenience these eight oreshoots are numbered 1 to 8 from south to north (see Longitudinal Section Map numbers 5 N and 5 S). They strike just west of north and dip at about 65° to the west.

THE LONG JOHN REEF:

The Long John Reef has always been considered the main reef of the property. It extends over a length of nearly a mile, of which 2,000 feet lies south of the Main Shaft and 2,400 feet to the north. Towards each end of the reef, the jaspilite and accompanying mineralisation thins out and eventually terminates. On the surface the reef consists of a mineralised, banded, jaspilite rock and, except where it is obscured by mine-dumps, it is readily traceable over the whole strike length. On the . . / -

On the surface the body appears to be continuous and of consistent character. However, underground the body is not homogenous, but grades from a jaspilite inot an unmineralized form of altered siltstone similar to the country rock. This occurs along the strike and on the hanging wall contact with the undifferentiated sediments. There is a well defined footwall contact with talc-carbonate rock along the central portions of the orebody, although this only becomes apparent underground owing to a lack of talc carbonate outcrops on the surface.

Six oreshoots are known to occur along the strike of this reef. These are shown in the Longitudinal Section of the Mine Workings (See Map No. 5S). There are five oreshoots in the southern section of the mine and one oreshoot - called the Black Jack Section in the northern section. This Black Jack oreshoot is shown on the section in dotted lines (Map 5 N.)

The outlines of the oreshoots, numbered 1 to 6 from south to north, as stated before, were determined from mine records and detailed sampling undertaken in 1958 during a detailed valuation of the property. It must be admitted that the oreshoot outlines in the upper levels are somewhat arbitrary, as old assay records are scanty and most working places in the upper levels are now inaccessible.

The southern-most oreshoot was never located on the surface but was discovered by underground development. It is only now (1961) being developed south of the dolerite dyke (See Section No. 6 S.) Between the

Battery Shaft . . / -

Battery Shaft and the Black Jack Section (oreshoot number 7), a distance of a thousand feet, considerable surface work has failed to reveal any payable oreshoot. Gold values, although persisting in this area, are all well below economic grade. Some surface work on the southern end of this jaspilite body has also not shown the presence of any oreshoots.

THE VUBA REEF:

About 300 feet to the west of the Long John Reef lies a similar parallel body of jaspilite. Although this body appears smaller and somewhat discontinuous compared to the main body it may, in fact, be a continuation of the very large Hegano jaspilite body some distance to the south. However, the surface between the Vuba Reef and the northern-most outcrop of the Hegano body is totally obscured by mine dumps. Hence it is not possible to determine the relationship between these two portions. The northern end of the Vuba mineralized jaspilite contains two oreshoots: the Vuba and the Cheque (Maps N 5 and N 6). Insufficient prospecting has been done in the southern section of this reef to prove the presence of any ore, but there are indications from surface sampling that there are probably oreshoots present.

NATURE OF THE ORESHOOTS:

The oreshoots are in places irregular, branching, splitting and reforming. Hence there are minor changes in strike in portions of the shoots at times giving rise to two distinct bodies. In shape they are a symetrical (See Maps 5N, 5S and 7.) Nevertheless, the oreshoots have the following general common features;)

1. They are all contained within the banded jaspilites;
2. They dip approximately 70° W;
3. The pitch is approximately 70° N.

These eight oreshoots have the following features:- (See Maps 4N, 4S, 5N and 5S.)

ORESHOOT:	AVERAGE: LENGTH: (STRIKE)	AVERAGE: WIDTH:	AVERAGE: GRADE:
1	80 feet	60 inches	6•2 dwts/ton
2	200 "	80 "	5•8 "
3	200 "	60 "	6•0 "
4	70 "	40 "	7•7 "
5	175 "	75 "	7•0 "
6	150 "	70 "	5•4 "
7	150 "	60 "	4•5 "
8	300 "	60 "	4•5 "

Thus on a very broad basis it may be said that the smallest oreshoot is the rich[illegible] and the largest is the poorest. Furthermore, th[illegible] a vague tendency for the oreshoots to increase in size,

relative ... /

relative to the grade, in a northerly direction. That is, in a general pattern the oreshoots increase in size and decrease in grade northwards. There are exceptions. Number four oreshoot is the richest and smallest and is nearly in the middle of the sequence. It must be borne in mind that there is a gap of nearly a thousand feet between the orebodies of the southern and northern sections. There may well be oreshoots within this length which are not evident on the surface: for instance, No. 1 oreshoot does not outcrop. This is especially true when considering the Vuba Reef, since very little is known about it south of oreshoot number 6 (See Map 3.)

It can thus be surmised that the Vuba and Long John Reefs are incompletely explored sections of the larger regional system. As such, what is known of them conforms to the regional pattern.

It must be indicated here that the margins of the oreshoots, where observed, are not sharp, but form a transition zone over several feet in which the intensity of the mineralization drops very considerably, and values decrease from a regular economic level, to averages of below one dwt/ton. However, erratic high values do occur and these are misleading and cause considerable over-mining.

LOCAL ORE CONTROLS:

Since only relatively small sections of the Long John and Vuba Reefs are exposed underground, it is difficult to elucidate the local ore controls precisely.

There are . . / -

There are, however, indications which suggest that the following factors may be relevant.

The jaspilite bodies do not lie in a plane but are somewhat contorted. Theoretically, axial plane cleavage does lie in a plane. Relative to surrounding rocks the jaspilite beds are competent. In areas where, through slight folding or bending, the jaspilite lies parallel to the axial plane cleavage, prominent shear zones were formed in it. The surrounding plastic greenschists did not form a fracture pattern, but developed a schistosity parallel to the axial plane cleavage when subjected to the stress of the second deformation. Fracture patterns developed in all the competent rocks, but were most prominent in the jaspilites which are parallel to the axial plane cleavage.

Thus it might be said that oreshoots may be found wherever the jaspilite is parallel to the axial plane cleavage.

It is considered an important feature that lineations on the cleavage planes of the talc-carbonate schist footwall to the Long John Reef are all parallel to each other, and plunge northwards at about 70°. This is parallel to the trend of the oreshoots and, moreover, parallel to the fold axis of the second deformation if the effects of the third deformation are removed. (See hand specimen showing lineations in collection.)

Mineralising solutions were introduced into the jaspilite by way of the fracture pattern. Thus in areas where the fracture pattern was best developed, greater volumes of solution were able to have minerals precipitated from them. In this manner, oreshoots

were formed ...../

were formed in the rocks with the greatest amount of fracturing. The oreshoots themselves are not regular, even-textured bodies. They are composed of aggregates of mineralised jaspilite which, in turn, are aggregates of ore mineral concentrations and gangue. The whole ore zone is an association of sulphide and gangue mineral grains which together form minute "ore pods". These in turn are the unit of rich and poor patches which together form minable oreshoots. On any given scale - macro or micro - the pattern would be similar.

A possible reason for the gaps between the oreshoots, in what might otherwise have been suitable rocks for mineralization, may be attributed to an unevenness in texture or composition of the host jaspilite. The rock is not uniform throughout, and mineralization probably had an affinity for the more iron rich sections of the jaspilite.

The system of shears and fractures which follows the banded jaspilites, is not uniform. Where a shear actually occurs in jaspilite, it takes the form of a well-marked fault, up to two feet wide, and has principally a gouge filling. These fractures occasionally contain quartz veins, but more usually just fault gouge. In the amphibolitic quartzites, this structure is discernible only as a scarcely traceable hairline fracture.

The main joint system is orientated in a plane which lies approximately at right angles to the axial plane cleavage - that is, it is striking about

N 50° E and dipping . . / -

N 50° E, and dipping 20° south. This evidence is inconclusive as the rocks are poorly jointed. It is possible that these joints may be related to the first or third deformations which folded the region (see Structure - Chapter Four). The joints have no apparent influence on the localisation of ore (See Maps 4N, 4S, particularly joints in 10 Level, main drive.)

ORESHOOT CHARACTERISTICS:

The individual oreshoots - or lodes - are all very similar to one another. Over a reasonable period, ore mined from any one stope is indistinguishable from that obtained from the others. It is true that, during short periods, ore from a particular stope may be recognised by textural characteristics by mine employees. However, in any one stope the textural characteristics never persist.

The ore texture varies and, as a rule, higher gold values are associated with fine grained arsenopyrite mineralisation. This is a common feature in many mines in Southern Rhodesia and will be discussed further in the section dealing with mineralisation. The oreshoots have been mined to a vertical depth of about 1,200 feet. (See Stope Sections; Maps 6N and 6S, and Plans; Maps 4N and 4S.)

* * * * *

F.G. Smith (1949) suggested that tourmaline forms at temperatures above 450° - 500° C. This is of the same order of temperature of formation as the other ore minerals comprising this suite. The general association of this tourmaline suggests a high temperature hydrothermal origin. Similar occurrences of tourmaline have been noted in mines to the south of Vubachikwe Mine by Tyndale Biscoe (1940). The tourmaline is a minor constituent of the ore. (See Plates Nos. 20, 21 and 25.)

CARBON: (GRAPHITE)

Carbon occurs in the slatey rocks and also in the fault gouges (see Slate - Local Geology). Since the slate is usually thin, it is often mined together with the ore and hence carbon is included as a gangue mineral. The nature and origin of the carbon has already been discussed under the section on slates. It is only necessary to add that, although present in only small amounts, the carbon in the ore does tend to upset the flotation and cyanidation processes in milling the ore, necessitating rather larger amounts of conditioning reagents than is usual in the treatment of such an ore. (See Plate No. 22).

GARNET:

Occurring as a metamorphic mineral in the slaty inclusions in the ore is a variety of garnet. There is only a very minor amount of this garnet. It is a

brownish-red, . . / -

grains examined from the concentrates have been distorted during milling (see Plate No. 39). In the original polished ore, small grains of gold varying between 1 and 8 microns in size, have been positively identified, associated with arsenopyrite and gangue. (See Plates Nos. 48 and 49). These small grains were found after careful examination of polished sections of rich ore carrying upwards of 3 ozs. gold/ton. Other small grains of a yellow mineral have been seen enclosed in arsenopyrite, but these are too small for identification, and may be chalcopyrite. Gold, with inclusions of tiny grains of pyrrhotite, has been seen. See Plates Nos. 41 and 42.

On Vubachikwe Mine it has been found that the major part of the gold is extremely finely divided and is held in the finer grained arsenopyrite. Assaying during metallurgical experiments on the mine have shown that over 90% of the fine gold is associated with the arsenopyrite; and under 10% with pyrrhotite. All coarse gold was first removed from these samples by panning before assay.

If samples of concentrates of -200 mesh size from the mill are panned, (see mill flow-sheet), almost no gold is seen. However, if similar amounts of concentrates from the regrind circuit, -325 mesh (see flow sheet) are panned, then a considerable amount of reddish tinged gold is seen - so fine, that a portion of it floats on the water during panning. Assay results for the -325 and -200 samples give very similar results, yet physically the gold is only seen in the finely ground portion. Hence it is concluded that the gold is chemically free, but is physically

finely divided . . ./-

PLATE NO. 14 : Grunerite (Amphibole) growing from magnetite to quartz. Typical in quartz rich Grunerite Schist and in Jaspilite. X nicols x 50.

PLATE NO. 15 : Felted Grunerite needles in Jaspilite. Also found similar in quartz grunerite schist. Plane polarised x 250.

brownish-red, isotropic, vitreous mineral in poorly formed aggregates or crystal growths up to 5 millimetres across. From its association the mineral is probably almandine, although no analytical work has been done on it since specimens of reasonable purity are not available. The garnet is of no metallurgical interest (see Plate No. 22).

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O R E   M I N E R A L S.

MAGNETITE:

Magnetite occurs as an original constituent in this deposit. It was most likely formed by the reduction of original sedimentary iron oxides under metamorphic conditions. Thus the magnetite is an original constituent of the host rock and not an introduced mineral.

Ideally, the banded jaspilite would consist of silica bands and iron oxide bands. However, the rock has been considered metamorphosed. The siliceous portion of the rock was probably not very pure, and when the area was carbonated, probably some magnesium and calcium were introduced into the ironstone. The reaction between calcium, magnesium, iron and silica resulted in the formation of amphiboles. Thus magnetite is rarely seen as discreet euhedral crystals, but almost invariably as scattered, irregular grains partially replaced by

amphiboles . . / -

finely divided and contained in the arsenopyrite. A rather extreme degree of grinding is necessary to free it.

Gold was probably the last mineral to crystallise in this suite. It came in at a late stage and was finely distributed in the arsenopyrite by partially replacing it. (See Plates Nos. 43 and 45) The "visible" gold is seen to occur in the ore as an interstitial replacement between quartz grains and filling micro fractures. (See Plates Nos. 41, 42 and 45.)

The fineness of the gold recovered from Vubachikwe Mine is comparatively low compared with the figures given for many of the Gwanda gold mines.* The fineness averages approximately 790/1,000 with a silver content of 95/1,000. This accounts for only 885/1,000 of Vubachikwe Mine bullion. The remaining 115/1,000 is unknown since a total bullion analysis has never been carried out. However, considering the presence of chalcopyrite in the ore, this unknown impurity would very likely be mostly copper.

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O R E P A R A G E N E S I S

A mineralising solution at comparatively high temperature was injected along a system of pre-existing

*[illegible]oles, 1960.

fractures . . / -

* *

C H A P T E R   S E V E N

* *

M I N E R A L I Z A T I O N

OXIDIZED ZONE * SULPHIDE ZONE * GANGUE MINERALS

* Q U A R T Z *

ORIGINAL QUARTZ * INTRODUCED QUARTZ

* CARBONATES * AMPHIBOLES * TOURMALINE *

CARBON (GRAPHITE) * GARNET

O R E   M I N E R A L S

MAGNETITE * ARSENOPYRITE - LOLLINGITE

PYRRHOTITE * CHALCOPYRITE * GOLD

O R E   P A R A G E N E S I S

PARAGENETIC CHART

FEATURES OF THE ORE SOLUTION

ORIGIN OF THE MINERALIZING SOLUTION

a) CUPOLA ORIGIN

b) LATERAL SECRETION

** * ** * ** * ** * **

amphiboles (grunerite). See section on Jaspilites, Local Geology.

All the magnetite present is intensely magnetic. Under the microscope, thin sections show it to be quite opaque. However, its association with gangue minerals becomes apparent in that, (as noted above) it is often seen partially replaced by grunerite. Polished sections containing magnetite show it to be a dull greyish mineral, standing out in relief above the gangue minerals. It is isotropic under reflected polarised light. The texture usually seen is either of very small isolated grains of magnetite in gangue, or of larger aggregates of grains revealing a typical replacement pattern. In cases, a modified form of the "exploded bomb" texture is noticed. The grain size varies from sub-microscopic to about 0·5 millimetres across, whilst the aggregates may have been grains or crystals of over 1 millimetre. Examples of Vubachikwe Mine ore show aggregates of magnetite partially replaced by amphibole while small grains of arsenopyrite were enclosed. This is interpreted as an early stage of the replacement of magnetite by early sulphides. In many instances of the ore examined, sulphides are concentrated in the iron-rich amphibolitic portions of the rock rather than in the siliceous portions. Owing to the chemical composition, the iron-rich portion of the rock is more reactive to mineralising solutions, and hence the concentration of hydrothermal minerals - such as arsenopyrite - tends to be concentrated in the iron-rich bands. Thus magnetite is an important constituent, since it acted as a form of chemical control, influencing the emplacement of sulphides and hence affecting the localisation of ore minerals. (See Plates Nos. 14, 17, 18 and 23.)

fractures into the rocks of Vubachikwe Mine. There, certain minerals crystallised from the solution in favourable localities. Possibly contemperaneous with this deposition, but more likely after it, the rocks were subjected to tectonic movements. This movement, described in the section dealing with Structure as the "Third Deformation", had no appreciable effect on the ore paragenesis.

The first mineral to crystallise was quartz - since the next mineral, arsenopyrite, is seen in quartz as a replacement. (See Plate No. 24). Quartz crystallised over a very wide range; Arsenopyrite was formed next - at first slowly in perfect crystals (see Plate No. 29) and, as the critical temperature was reached, more quickly - hence the mutual growth interference of crystals (see Plate No. 27). At the lower range of the crystallisation of arsenopyrite, tourmaline was formed and pyrrhotite began to crystallise out of the solution contemporaneously with a considerable amount of quartz (see Plates Nos. 25 and 34). The remnants followed - these were minor amounts of chalcopyrite, which replaced portions of the extremities of pyrrhotite veinlets, and gold which was very finely disseminated in fine grained arsenopyrite, and occurs as the usual veinlets in minute fractures in gangue.

The range of temperatures of crystallisation of these minerals is so great and overlapping that an accurate chart showing the temperature of formation of minerals is not possible. However, some attempt has been made at correlating the temperatures of formation with the paragenesis. (See Paragenetic Chart)

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