THE GEOLOGY OF THE PICKSTONE GOLD MINE

HARTLEY DISTRICT

RHODESIA

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BY

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DECLARATION

I, Ronald Stanley Johnson, hereby declare that this thesis is my own work, and has not been submitted previously for any degree in any university.

R. S. Johnson.

Signed

I. ABSTRACT

The Pickstone Gold Mine is situated in the Concession Hill Mining Reserve, 20 miles east-northeast of the town of Gatooma, a mining and farming centre in the Midlands District of Rhodesia.

The Pickstone deposit is a sulphide replacement deposit in a banded jaspilite host rock and is situated on the steeply dipping southern limb of the Eastern Hartley synform. The banded jaspilite host rock is an interlayered sediment in the volcanic rocks of the Bulawayan System, early Precambrian in age, and is composed of narrow parallel and alternating bands of fine-grained siderite and cryptocrystalline quartz. The origin of this non-detrital rock is obscure, but the majority of hypotheses relating to these banded iron formations, favour a sedimentary origin by chemical precipitation.

Intrusion and updoming by the surrounding granitic batholiths subjected this relatively competent banded jaspilite to compressive forces resulting in the development of boudinage structure normal to the compressive stress. The tensile stress developed intensive fracturing in the relatively narrow zones (pinched zones) between the boudins, forming channelways for the mineralized fluids to permeate, the sulphides showing preferential replacement of the chemically favourable siderite bands in the jaspilite host rock. The close relationship between the structure of the banded jaspilite host rock, depicted by

isopachs at 5 feet intervals, and the ore shoots plotted on a vertical projection of the Pickstone Mine are clearly illustrated. The trends of these isopachs show the relationships of the non-mineralized boudins (swells) and the mineralized pinched zones, and this has proved a useful guide in predicting the trends of the ore shoots. Although the ore shoots are continuous in the vertical plane they fluctuate continuously within the broad host rock and to overcome the acute dilution problem encountered using underhand stoping, sub-level stoping was introduced below 10 level. Methods which have been used for the beneficiation of the ore are described including the present method of discarding about 10 per cent of the rock mined by hand sorting.

The rocks of the Pickstone Mine area are generally very fine-grained and have been altered by metamorphism. The banded jaspilite has narrow parallel bands of light and dark coloured material. The mineral composition of the dark bands was determined by X-ray Diffraction analysis and shown to be siderite. Observations of the light coloured bands under the microscope showed them to consist of cryptocrystalline quartz. Although macroscopically the contacts between these bands appear fairly sharp, mixing of the quartz and siderite grains was often observed under the microscope. Thin sections cut on mineralized specimens of banded jaspilite showed that there is preferential replacement of the siderite bands by the sulphides. The south wall-rock of the Pickstone orebody is a highly foliated and altered rock, which is considered to have been derived from the alteration of a closely associated felsite and quartz-porphyry. X-ray Diffraction analysis disclosed that this south wall-rock consists predominantly of pyrophyllite (basic aluminium silicate). The north wall-rock of the Pickstone orebody is a speckled chlorite schist presumably derived from the alteration of a basic igneous rock. Crushed relics of felspar altering to sericite, which are enveloped by chlorite, give this rock a speckled appearance.

The ore minerals identified from microscopic examination of polished sections were arsenopyrite, pyrite, chalcopyrite, sphalerite and gold. The predominant ore minerals are arsenopyrite and pyrite, and these two minerals generally display subhedral and euhedral crystal faces, the contacts between these crystal faces usually showing an interlocking of these two minerals with each other. Microscopic observations of these ore minerals suggest that the two minerals crystallized out more or less contemporaneously and that the amount of arsenopyrite slightly exceeds that of the pyrite. Gold is present in extremely fine form as irregular grains, usually from 15 - 50 microns in diameter as inclusions in and between interlocking crystals of the arsenopyrite and pyrite. Free gold was observed associated with the late milky vein-quartz gangue, but such occurrences are rare. The origin of the gold is considered to be related to the invading granitic bodies, the gold-bearing solutions presumably expelled under high pressure from below the developing hoods of the granitic batholiths.

Assay results of the fineness of the gold and silver in parts per thousand obtained from the sampling of gold bars together with the calculated impurities (iron, copper, and nickel), show that the fineness of the gold fluctuated strongly during certain periods, while the silver content remained relatively constant at all times, leading to the conclusion that there is an~~direct~~ inverse relationship between the fineness of the gold and the content of base metal in the ore.

The total gold recovered up to the end of 1966 was 242,373.38 ounces from 1,271,637 tons milled giving an average recovered grade of 3.81 pennyweights per ton milled.

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III. INTRODUCTION

The Pickstone Gold Deposit, although one of the earliest to be mined in Rhodesia, has only very recently achieved recognition as a major gold producer in this country. The reasons for this are the highly refractory nature of the sulphide ore below the oxidised zone, the difficulties of avoiding ore dilution during mining operations, and the introduction of beneficiation of the ore. No detailed geological investigations were conducted on this gold deposit prior to 1961, when an intensive geological study was undertaken involving a programme of diamond drilling to provide further information on the structure, continuity and mineral content of the orebody.

The results of the geological study further indicated the possibility of a substantially large tonnage of ore being present. From this study it became evident that the position of the ore shoots in this deposit was controlled by structural conditions and this proved a useful guide to ore in the subsequent development programme of the mine. Investigations into the beneficiation of the ore were conducted and at present upgrading of the ore is achieved by hand sorting of waste material.

IV. LOCATION AND GEOGRAPHY

Pickstone Mine is situated in the Concession Hill Mining Reserve, 16 miles south-southeast of the small town of Hartley, and 20 miles east-northeast of the town of Gatooma. The main Salisbury - Bulawayo railwayline and national road pass through these two towns. the mine is linked to both towns by good secondary roads (Figure 1).

At present, the majority of the major gold-producing mines in Rhodesia are clustered around Gatooma and Hartley, namely the Cam & Motor, Dalny, Pickstone, Patchway, Golden Valley and Giant Mines.

The Pickstone Mine is situated at an elevation of 3,900 feet above sea level. The surrounding country is generally fairly flat, with a number of low parallel ridges running in a general east-west direction and rising to a maximum elevation of 150 feet above the surroundings. These are formed by resistent inter-layered siliceous sediments and narrow grit bands in the more easily weathered metamorphosed basic, and ultrabasic lavas. Undifferentiated sediments on the northern side of the Pickstone Mine weather to form a very even surface consisting essentially of a clayey-type soil, and to the south there is an extensive region of weathered granite country of mature landscape. Six miles east of the Pickstone Mine is the world-renowned geological feature, the Great Dyke, which in this area forms a slightly elevated topographical feature. This surrounding country is described by L. C. King (1962) as a pediplain which forms part of the late - Cainozoic geomorphological surface.

The rainy season extends over the five months from November to March, with a mean annual rainfall for the period 1960 to 1967 of 25 inches.

The Mombi River, a tributary of the westerly flowing Umswewe River, was superimposed transgressively on the older formation of schists and granite consisting of ancient Precambrian rocks, from a younger covering of Karroo rocks, remnants of which are to be found east of the Great Dyke.

Savannah type vegetation includes the Mopani (Colophospermum Mopani), occupying the low granite country, with the Mfuti (Brachystegia Boehmii), and Msasa (Brachystegia Spiciformis), both relatively tall trees, growing on the low ridges of these ancient rocks. The last two trees mentioned are cut locally, and used as a cheap fuel for the Africans employed on the mines of the area.

Dry-cultivation farming is carried on in the region, the chief crops grown being maize, cotton and tobacco. Cattle ranching is gaining rapidly in importance, and contributes greatly to the farming industry. Secondary industries comprise cotton milling and textiles.


MAP OF RHODESIA
LOCALITY PLAN
Salisbury
Gatooma
Que Que
Bulawayo
Pickstone Mine
30° E
19° S
GEOLOGICAL MAP OF CENTRAL PORTION OF RHODESIA
LEGEND
Aeolian sands
Basalt
Grits, sandstones
Dolomites, slates, quartzites
Phyllites, slates, quartzites
Grits, arkose, slates
Metavolcanics, interbedded sediments
Amphibole schist, serpentine
Granites (various ages)
KALAHARI
KARROO
LOMAGUNDI
PIRIWIRI
SHAMVAIAN
BULAWAYAN
SEBAKWIAN
SYSTEM
FORMATION
IGNEOUS INTRUSIVES
Norite, gabbro
Pyroxenite, serpentine
GT. DYKE
— REFERENCE —
Railway
Towns
SALISBURY
HARTLEY
PICKSTONE MINE
GATOOMA
QUE QUE
Umfuli R.
Umswesve R.
Mombi R.
Umniati R.
18° S.
19° S.
30° E
31° E.
SCALE
10 0 10 20 Miles
TAKEN FROM PROVISIONAL GEOLOGICAL MAP OF SOUTHERN RHODESIA. GEOLOGICAL SURVEY 1961.

Fig. 1.

V. HISTORY OF THE PICKSTONE MINE

The original Pickstone Mine claims were pegged in 1905 on ancient workings, situated approximately 1,000 feet east of the Burnett Shaft, and north of the banded jaspilite ridge known as Duchess Hill (Figure 3). The ore deposit comprised narrow, branching lenses of vein-quartz in highly sheared greenstone lava, which dipped approximately 80° south, and converged on the banded jaspilite westwards along strike. According to A. E. Zealley (1918), the quartz reefs were phenomenally rich in places, with seams of gold up to one-eighth inch wide. Gold was first produced in 1907 when 544 tons of ore crushed gave 455 ounces of gold. Pyrite, mispickel and galena were present in small quantities.

In 1908, presumably with the spread of mining activities westwards to the banded jaspilite contact, a new orebody, known as the Pickstone West was discovered. No "ancient" workings existed on this orebody, which on outcrop was a large lense-shaped body of soft ferruginous gossan, with paint gold showings.

Mining operations on the Pickstone East, viz. the quartz reefs, had reached the 200 feet level by 1910, and it is recorded that gold values became erratic and poorer as the depth of the mine increased. By 1911 the Pickstone West, viz. the ferruginous gossan, was developed to the 100 feet level and a trial crushing that year of 500 tons gave an extraction of 7.0 dwts./ton. In November 1911, the property was taken over by the L. S. Syndicate, who acquired a ¾ interest from

C. Swarton and a ¼ interest from I. Minnaar.

The Pickstone Gold Mines Ltd. was registered in August 1912, with an authorised capital of £50,000. In 1914 it was reported that three orebodies had been developed. It is necessary at this stage to clarify the names of these orebodies and their relationships to the present-day orebodies or ore shoots. The original Pickstone East, comprising the vein-quartz reefs, ceased mining operations in 1915 due to poor values at depth. The Pickstone West, developed on the soft ferruginous gossan, are the surface showings of the present-day Pickstone East ore shoots. The third orebody, known as the Concession Hill East Extension, a continuation west of the ferruginous gossan, represents the present-day Venning Ore Shoots at surface level.

The plant consisted of ten stamps and two Chilian Mills with a capacity of 6,000 tons per month. With mining operations attaining greater depths, the semi-oxidised ore became increasingly refractory and gold recovery was only 63 percent. Mining operations were stopped between 1915 and 1918. The company relinquished the claims in 1926, as it was realised that an all-sliming plant was necessary to deal with the refractory sulphide ore.

The sands and slimes dumps were retreated by R. Sutherland from 1928 to 1940, and stopped with the onset of World War II.

In 1948, a syndicate of companies, including London and Rhodesia Mining and Land Company Ltd., acquired the Pickstone Mine and favourable results from five surface boreholes, covering a strike of 960 feet, led to the de-watering of the old Pickstone West. In January 1952 it became the property of the Cam and Motor Gold Mining Company (1919) Ltd.

Shaft sinking with subsequent underground development proved a considerable tonnage of payable ore, and construction of a reduction plant started in October, 1954. The plant, with a milling capacity of 7,000 tons per month, provided direct cyanidation of the finely ground arsenical concentrates, and came into operation in April, 1956. By 1958 both the Burnett and Southwell shafts were down to 7 level (950 feet below surface).

In 1959, the Rio Tinto Mining Group acquired the Cam and Motor Gold Mine, and the Pickstone Mine was included in the acquisition. No previous detailed geological mapping had been undertaken of the Pickstone Mine workings, and the underground surveying and sampling was administered by Cam and Motor Mine staff. Geological mapping of the Pickstone Mine was up to date by the middle of 1962, combining mapping of the main drives and the geological recording and assessment of the results of the programme of diamond drilling of the wide banded jaspilite host rock. Increased knowledge of the behaviour of the Pickstone ore shoots led to improved mining methods, upgrading of the ore, and the mine plant enlarged to mill approximately 15,000 tons per month.

At present the Pickstone Mine may be classified as a low grade, medium to high tonnage-range gold mine, and is one of the larger gold producing mines in Rhodesia.

VI. AN OUTLINE OF THE GEOLOGY OF THE EASTERN HARTLEY GOLD - BELT

(a) General

The Hartley area derives its name from the well-known elephant hunter Henry Hartley, who in the 1860's made frequent hunting trips to the north from his Transvaal farm. Having located extensive "ancient" workings, approximately eight miles east of the present town of Hartley and close to the western edge of the Great Dyke, Hartley invited Carl Mauch, a German geologist to investigate these workings. Mauch confirmed the presence of gold in these "ancient" workings, and they became known as the "Northern Goldfields". Mining only commenced in 1890, but soon moved to the richer goldfields discovered around Gatooma.

(b) Geology

The Basement Complex, which comprises the gold-belt schists and surrounding granites, is exposed over more than half of the total area of Rhodesia (Figure 2). Mapping of these geologically important gold-belts has disclosed a close resemblance in rock types, structures, and geological events. Dr. A. M. Macgregor, a former Director of the Geological Survey, established a geological subdivision for these Rhodesian gold-belts. In 1957, J. W. Wiles published a description of the Geology of the Eastern Hartley gold-belt, a summary of which is given below. He correlated the rocks in accordance with Dr. A. M. Macgregor's subdivision as follows.-

Upper Sedimentary Series	SHAMVAIAN SYSTEM
Upper Greenstone Series Middle Sedimentary Series	BULAWAYAN SYSTEM
Ultrabasic Intrusives Lower Greenstone Series Lower Sedimentary Series	SEBAKWIAN SYSTEM

SEBAKWIAN SYSTEM

Lower Sedimentary Series

The rocks are predominantly banded ironstones with minor pelitic sediments. Granite assimilation coupled with erosion have left only a few remnants of these rocks mainly in the southeast section of the goldbelt adjacent to the Great Dyke, and within the serpentine xenoliths in the granite south of the Pickstone Mine. These sediments are generally steeply dipping.

Lower Greenstone Series

The rocks are hornblende schists and epidiorite, and occur only as numerous small patches, approximately a mile south and southeast of the Pickstone Mine.

Ultrabasic Intrusives

These serpentinites and talc schists were derived from original ultrabasic dunites and peridotites, and envelope the sediments of the Lower Sedimentary Series and the Lower Greenstone Series. These intrusives extend as a narrow belt from approximately two miles southwest of the Pickstone Mine eastwards to the Great Dyke, and due to their unassimible nature remain as inclusions in the Rhodesdale Granite south of the Pickstone Mine.

BULAWAYAN SYSTEM

Middle Sedimentary Series

The rocks of the Middle Sedimentary Series are described by Wiles as consisting of quartzites, greywackes, grits, conglomerate, banded ironstone, quartz-hornblende schist and dolomitic limestone interlayered with epidiorite. These sedimentary rocks occur on the eastern extremity of the Eastern Hartley goldbelt on the eastern side of the Great Dyke, and do not resemble the interlayered sediments found on the western side of the Great Dyke, which in this area form part of the Upper Greenstone Series.

Upper Greenstone Series

The rocks of the Upper Greenstone Series consist predominantly of metamorphosed basic lavas with interlayered sediments. The metamorphosed basic lavas, generally known as greenstones, were derived from the alteration of rocks of basaltic, limburgitic and andesitic compositions. Metamorphism has eliminated all of the original pyroxene, the alteration products formed being chiefly chlorite and more rarely the mineral hornblende. The greenstone may by either schistose or massive, and in the latter case original textures and structures such as amygdaloidal, porphyritic and pillow structures, may be preserved. The greenstone on weathering gives a red clay soil.

Two closely related rocks termed felsite and quartz-porphyry form a narrow belt along the south-eastern limb of the major synformal structure of the Eastern Hartley gold-belt (as seen in Figure 3), and are conformable with the general strike of Bulawayan volcanic rocks. These rocks were described by Wiles as intrusives. There is much evidence in the Pickstone Mine area to support the view that these rocks are extrusive in origin, the reasons for which are discussed in detail in section VII headed THE GEOLOGY OF THE PICKSTONE MINE AREA. The felsite and quartz-porphyry would therefore be of Bulawayan age.

Minor belts of agglomerate and tuff outcrop adjacent to the Cam and Motor Mine 4 miles east of Gatooma. The sediments of the Cam and Motor "Complex" dip westwards from surface, steepen with depth and are easterly dipping on the deepest levels (46 level at a depth of 6,500 feet), suggesting a slightly overturned synclinal structure in this region of the gold-belt.

This sequence of rocks, the Upper Greenstone Series, besides being the most extensive, is also the most important economically, as it is in these rocks that the major gold producing mines occur.

SHAMWAIAN SYSTEM

Upper Sedimentary Series

This series is represented by an upper and lower group, separated by an unconformity.

The lower group of grits and quartzites forms narrow ridges along the outside edges of a northeast striking synclinal basin. The upper group of undifferentiated sediments consisting essentially of arkoses, greywacks, shale, slate, banded ironstone and conglomerate, fill the centre portion of the synclinal basin. These undifferentiated sediments are easily weathered giving rise to a large tract of clayey ground with very few exposures.

GRANITES

The Eastern Hartley gold-belt schists were invaded by two major granitic masses, recognised as the older post-Sebakwian Rhodesdale Granite (gneissic) in the south, and the younger Biri or Zwimba Granite in the north (Figure 2). Wiles mentions that the Biri Granite is intrusive into the Rhodesdale Granite and that the Biri Granite is also considered younger than the three Precambrian Systems. Wiles refers to the fact that the Biri Granite is gneissic along its contacts with the gold-belt schists and resembles the Rhodesdale Granite in colour and in mineral composition. Both granites are biotite-rich, the felspars are usually fresh microcline and turbid oligoclase. The quartz crystals often show undulose extinction and the accessory minerals are epidote, apatite, and sphene. Hornblende was reported by Wiles in these granites, but only in rock specimens which were contaminated by adjacent rock types.

A porphyritic granite cupola northeast of the Pickstone Mine is thought to be related to the Biri Granite batholith (Figure 2).

INTRUSIVE ROCKS

Felsite and Quartz-Porphyry

Besides the belt of felsite and quartz-porphyry, which occurs in the Pickstone Mine area and previously mentioned and considered by the writer as an extrusive phase of Bulawayan age, numerous other isolated and irregular shaped patches of these rock-types were mapped by Wiles in areas along the northeast, northwest, and westerly contacts of the porphyritic granite cupola northeast of the Pickstone Mine.

Serpentinite

These post-Bulawayan ultrabasic rocks were mapped in the area of the Giant Mine north of Hartley and extend eastwards to the Great Dyke. The presence of serpentine rocks in the Sebakwian System has already been mentioned and Wiles states that the conformable nature of these rocks casts certain doubts as to whether these rocks are intrusive in origin.

Great Dyke

The Great Dyke striking north to south, overlies the eastern portion of the Eastern Hartley gold-belt, and has a width of approximately 6 miles in this area. The predominant rock-type exposed is norite, which shows conspicuous spheroidal weathering, and on outcrop is well covered by trees. The pyroxenites, hartzburgites and serpentinites are poorly exposed and outcrop mainly along the eastern margin of the Great Dyke in this area. These ultrabasic rocks are weathered to considerable depths and produce depressions which are grass-covered.

The norite shows planes of igneous lamination which are produced by the plagioclase and to a lesser extent the pyroxenes, which show preferred orientation of their crystals. The steepest dip observed was 20 degrees, which occurs on the margin of the Great Dyke, and which flattens towards the centre of the Great Dyke. There appears to have been a number of igneous emplacements, each of which has undergone differentiation in-situ. Only minor outcroppings of gabbro were observed.

The pyroxenites which in the Great Dyke contain the "platinum reef" are poorly exposed in this area. A few thin chromitite seams are present in the ultrabasic marginal rocks, which outcrop on the eastern margin of the Great Dyke. The chromite seams dip inwards at approximately 15 degrees and are usually 2 to 3 inches thick.

Highly altered rocks classified by Wiles as ultrabasic hornfels, basic hornfels, hybrids and granite xenoliths have been identified as inclusions in the Great Dyke.

Dykes

Dolerite dykes and sills of various ages occur in the area. Thin, long dykes paralleling the strike of the Great Dyke are found in the Biri Granite north of the gold-belt, whereas sills predominate in the Rhodesdale Granite southeast of the belt. Numerous dolerite sills occur in the Great Dyke.

(c) Historical Geology

The synformal structure of the Eastern Hartley gold-belt, although Archean in age and of continental origin, may be compared with the growth of "younger" geosynclines formed on the edges of continents.

In "younger" geosynclines the pattern is generally that of a multiple geosyncline with the relatively shallower miogeosyncline adjacent to the continental edge, an intervening sub-surface geanticline of granite, and further out the deeper eugeosyncline. This deeper eugeosyncline is filled by great thicknesses of volcanic lava termed the ophiolite stage, whereas the miogeosyncline being shallower shows an absence of these volcanics, and is filled by sediments. Deep sedimentary conditions prevailed giving greywackes and shales, called the "greywacke suite" or flysch. Uplift, due to isostatic compensation gives rise to unconformities, and shallow water deposition of conglomerates, arkoses, grits, and quartzites, known as the Molasse Suite.

The intercontinental synform of the Eastern Hartley gold-belt resembles the eugeosyncline in its history, the ophiolite stage having its equivalents in the Sebakwian and Bulawayan volcanics, the flysch stage being poorly developed and possibly represented by the suite of sedimentary rocks of the Cam and Motor Mine "Complex" containing shales and greywackes, and having a thickness of the order of one thousand feet. The molasse suite of rocks corresponds with the shallow water sediments of the Shamvaian System.

These synformal rocks were subjected to two periods of granite intrusion. The first intrusion of "older granite" (Rhodesdale) took place in post-Sebakwian times, possibly even partly during Sebakwian times, resulting in folding and metamorphism of the Sebakwian rocks. The emplacement of this "older granite" must have continued in Bulawayan and post-Bulawayan times, in the form of updoming of the granite bodies to account for the very steep folding of the Bulawayan rocks and possibly even continued during Shamvaian times to account for their fairly steep dips.

The "younger granite" (Biri Granite and porphyritic granite) were probably intruded in post-Shamvaian times and caused the subsequent faulting and minor drag-folding in the rocks of the Eastern Hartley gold-belt.

There is also evidence to support the view that the volcanic rocks and minor interlayered sediments of the Sebakwian and Bulawayan Systems, originally formed part of an extensive covering of volcanic rocks which extended over a major part of the Rhodesian craton. The volcanic rocks possibly overlay a thin primordial crust of sialic material. Updoming of this thin crust together with down-folding around the peripheries of the domed areas took place. The thin sialic crust in the down-folded areas was probably re-mobilised and this material was intruded into the overlying volcanic rocks and minor sediments. The updomed subcrustal material crystallized to form granitic batholiths. The updoming of these granitic batholiths and overlying volcanic rocks were subjected to a long cycle of weathering and erosion, the detritus derived from this weathering flowing into the down folded areas to form the rocks of the Shamvaian System.

The reasons for the updoming of these surrounding granites are not certain, but numerous hypotheses have been put forward to try and explain this phenomena covering such topics as sub-crustal convection currents, magmatic stoping by ascending magma from a "reservoir" at some great depth, and diapiric intrusion as a result of inward and upward rheid flow (viscous solid).

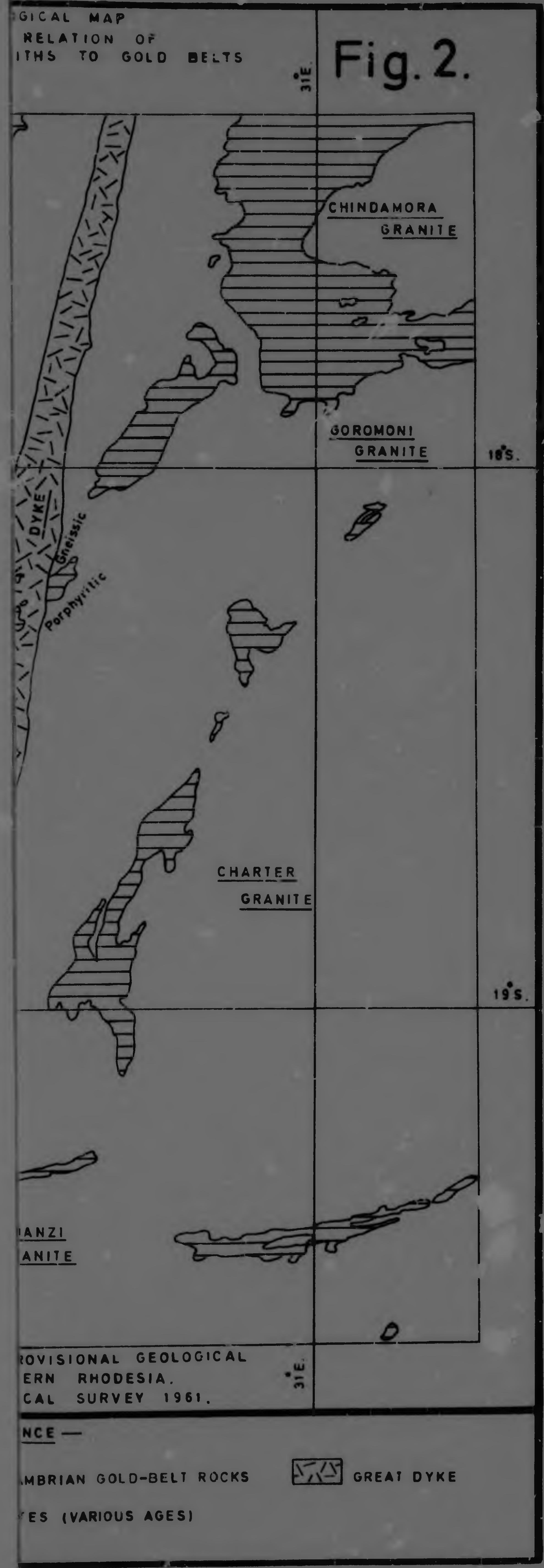
RELATION OF
TO GOLD BELTS
31°E.
CHINDAMORA GRANITE
GOROMONI GRANITE
18°S.
DYKE
Gneissic
Porphyritic
CHARTER GRANITE
19°S.
RHODESIA.
SURVEY 1961.
GOLD-BELT ROCKS
GREAT DYKE
(VARIOUS AGES)

Fig. 2.

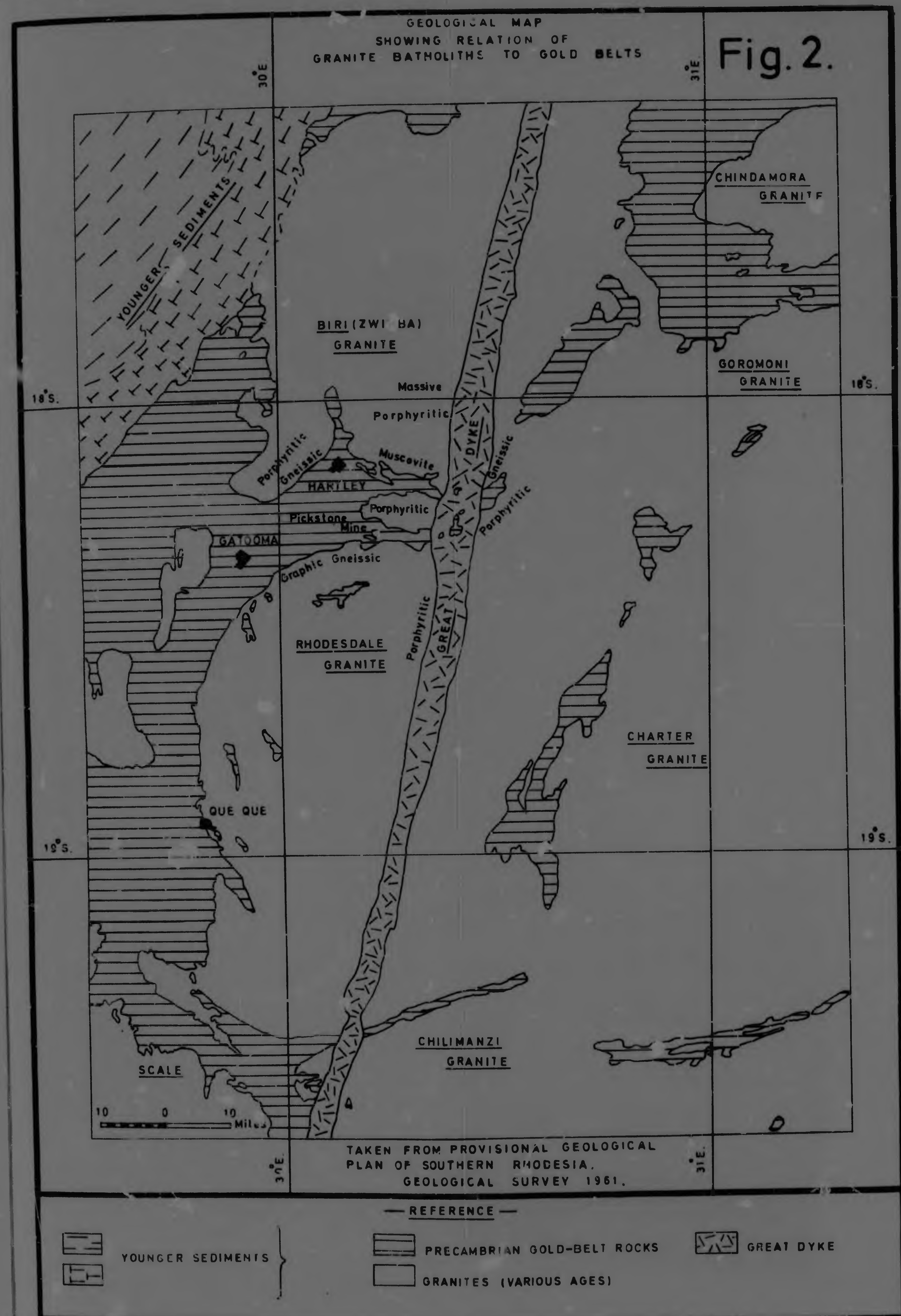
GEOLOGICAL MAP
SHOWING RELATION OF
GRANITE BATHOLITHS TO GOLD BELTS
30°E
31°E
18°S.
19°S.
YOUNGER SEDIMENTS
BIRI (ZWI BA)
GRANITE
Massive
Porphyritic
Porphyritic
Gneissic
Muscovite
HARTLEY
Porphyritic
Pickstone
Mine
GATOOMA
Graphic
Gneissic
GREAT DYKE
Gneissic
Porphyritic
Porphyritic
RHODESDALE
GRANITE
CHINDAMORA
GRANITE
GOROMONI
GRANITE
CHARTER
GRANITE
QUE QUE
CHILIMANZI
GRANITE
SCALE
10 0 10 Miles
TAKEN FROM PROVISIONAL GEOLOGICAL
PLAN OF SOUTHERN RHODESIA.
GEOLOGICAL SURVEY 1961.
— REFERENCE —
YOUNGER SEDIMENTS
PRECAMBRIAN GOLD-BELT ROCKS
GRANITES (VARIOUS AGES)
GREAT DYKE

Fig. 2.

VII. THE GEOLOGY OF THE PICKSTONE MINE AREA

(a) Introduction

Geological mapping of the area around the Pickstone Mine was carried out using aerial photographs on a scale of 1:10,000. Detailed mapping of the flat area along the cherty and shaly limestone outcrop, which is the host rock to the Peerless Mine orebodies, was on a scale of 1:2,000. This latter plan was compiled from a surveyed baseline adjacent and parallel to this limestone outcrop, and measuring was by compass and tape taken at right angles to this baseline. The data from this plan, which included diamond drill borehole locations and geological information obtained from trenching along the strike of the Peerless limestone outcrop, have been added to the map showing the geology of the area around the Pickstone Mine (Figure 3).

(b) Stratigraphy

The strata occurring in the area around the Pickstone Mine are situated on the southern limb of the Eastern Hartley synform, having a general strike direction slightly south of east and dipping very steeply towards the north.

The oldest rock in this area is represented by a hornblende schist of the Sebakwian System. Exposures of this rock-type are poor, the only fresh specimens obtained for petrographic analysis were from a prospect diamond drill borehole, drilled close to the homestead on Stewartonia Farm. Weathering of this rock produces a reddish-brown soil, and proved useful in delineating the contact with the Rhodesdale Granite. The hornblende schist occurs as a narrow belt approximately 1,300 feet wide in the area 2 miles west of the Pickstone Mine, but widens considerably on Stewartonia Farm south of the Pickstone Mine. Along its southern margin the hornblende schist is intruded by the main body of the Rhodesdale Granite and also by a stock-like body of the granite within the schist in the southern central part of the area shown in Figure 3. The south contact between the granite stock and hornblende schist was observed in a shallow prospect, known as Dan's Luck, where the two rock-types are separated by a vertically dipping, four feet wide vein-quartz reef, suggesting a fault contact.

The Rhodesdale Granite is poorly exposed in this area and was identified on surface mainly by the light coloured sandy soil, derived from the weathering of this granite, and the abundant tall anthills occurring within the granite country. The Rhodesdale Granite has a slightly gneissic texture which is concordant with the strike of the hornblende schist on Ranwick Farm, and the contact with the schist turns sharply south after crossing the Mombi River.

The granite stock protruding through the overlying hornblende schist, although massive in texture, microscopically closely resembles the main body of the

Rhodesdale Granite, and is classified as such in the mapping of this area. The granite stock, which is oval in shape outcrops approximately 4,000 feet south of the Pickstone Mine. The long axis of the granite stock trends south of east, and is approximately 7,500 feet in length. The short axis has a length of approximately 1,200 feet.

Overlying the hornblende schist on what appears to be a conformable contact, are rocks of the Bulawayan System, which, in order to simplify the stratigraphic description are divided into two units. The lower unit which is a speckled chlorite schist, derived from the alteration of basic lava flows, contains interlayered siliceous sediments together with the controversial extrusive felsite and quartz-porphyry. The upper unit comprises an extensive flow or series of flows of pillow lava. The speckled chlorite schist and related rocks are approximately 3,500 feet thick in the west and central regions of the area mapped, attaining a thickness in excess of 4,000 feet in the eastern region. The speckled chlorite schist, which macroscopically shows thin whitish-grey streaks of altered felspar, giving it a speckled appearance, forms the north and south wall-rocks of the Peerless siliceous limestone, which is host rock to the Peerless orebody. The speckled chlorite schist also forms the north wall-rock of the Pickstone banded jaspilite, which is host rock to the Pickstone orebody. Diamond drilling, both from surface, and in the underground workings of those two mines, shows a noteable zone of shearing developed in the speckled chlorite schist close to the contacts with these interlayered siliceous sedimentary host rocks, suggesting that these relatively competent interlayered sediments have acted as gliding planes along which regional stresses were released. Thin sinuous sedimentary beds of banded jaspilite usually 30 - 40 feet thick occur within the speckled chlorite schist, on the contact between the speckled chlorite schist and the felsite and quartz-porphyry extrusive, as well as interlayered within the latter east of the oblique-dip fault, which occurs in the centre of the area mapped. Prospects that have been investigated for gold mineraliz tion by diamond drilling are the Ranvik, Revenue, and the Pacific. The dips of the banded jaspilites are approximately vertical. The banded jaspilite of the Ranvik Prospect stopped at a vertical depth of 320 feet due to faulting.

In the area mapped the felsite and quartz-porphyry maintains an even thickness of approximately 1,000 feet along its strike and pinches out approximately two miles east of the Pi tone Mine. These rocks are strongly foliated, the dip of foliation being very steeply to the north. On outcrop large slabs of these foliated rocks lie haphazardly slumped against each other (Plate III, Figure 5). These leucocratic rocks are thought to have originated as extrusives, their original mineral composition consisting essentially of fine-grained quartz and felspar. The quartz-porphyry occurs in much lesser amount than the felsite in which it is present as isolated patches.

These rocks are strongly sheared along their entire strike and it is thought that the regional stresses which caused the shearing, were due to the intrusion and emplacement of the "older granite" (Rhodesdale) and the "younger" granite cupola northeast of the Pickstone Mine (see Figure 2).

These fine-grained rocks are considered to be of an extrusive nature for the following reasons: They outcrop as a narrow belt for a distance of 20 miles on the southern limb of the Eastern Hartley synform and are conformable with the general strike of rock types in the area. The contact between the felsite and quartz-porphyry and the banded jaspilite of the Pickstone Mine, as observed in the underground workings, shows no sign of any intrusive effects. The felsite and quartz-porphyry does not extend into the banded jaspilite as short apophyses and there is no recrystallization of the banded jaspilite along the contact between these two rock-types. Diamond drill borehole N. 8 on the Revenue Prospect passed through the contact between the felsite and quartz-porphyry and the speckled chlorite schist of the Bulawayan System showing an even, sharp contact (Figure 3). Furthermore, felsite and quartz-porphyry outcrop as narrow belts in relatively similar positions, both in sequence and on strike on the opposing limbs of the Eastern Hartley synform and suggests that these rocks cover an extensive area.

Wiles (1957) states that banded ironstone xenoliths were observed in the felsite and quartz-porphyry along the boundary of Bexhill and Tiverton Farms (approximately) 4 miles west of the Pickstone Mine. The writer considers these banded ironstones are interlayered sediments, similar to those occurring in the speckled chlorite schists of the Bulawayan System and were formed during periods of quiescence between phases of volcanic activity.

Approximately 100 feet south of the contact between the speckled chlorite schist and the pillow lavas, are two bands of interlayered cherty and shaly limestone, ranging in thickness from 60 - 80 feet, and dipping steeply to the north. The one band occurs in the north-west of the area mapped, and has numerous old-workings along its strike, the most noteable being the St. Kilda Prospect. The second band is in the central region of the mapped area, and has a strike exceeding 10,000 feet. The section of this band west of the oblique-dip fault has been extensively investigated using both surface and underground diamond drilling as well as surface trenching. These interlayered sediments, known locally as the Peerless Band, have two facies of rocks developed, the southern portion of the band consisting of shales and shaly limestone, and the northern portion being a cherty limestone. It is in the relatively competent cherty limestone that secondary fracturing has taken place, providing the permeability that gave rise to the numerous sub-economic, sulphide replacement ore shoots, similar in many respects to the ore shoots developed on the Pickstone Mine banded jaspilite. A partial chemical analysis of the cherty limestone carried out by the Cam and Motor Mine assay laboratory was as follows:

Chemical Analysis

$CaCO_3$ - 36.85%	Silica - 30.03%
$MgCO_3$ - 15.44%	Al.Fe. - 12.70%
Specific gravity - 2.94	

The upper unit of the Bulawayan System in this area is a pale-green, fine-grained pillow lava. Pillow lavas, showing pillow structures were intersected in all the diamond drill boreholes, drilled on the northern side of the Peerless limestone. The pillow lava structures are outlined by a distinctive dark-green layer, approximately half an inch to an inch in thickness, which presumably represents the chilled margins of the pillows. The pillow lava structures generally range in size from 18 to 30 inches. Later vein-quartz and carbonate, approximately half an inch to two inches thick, usually surround the pillow structures. Intersections of this vein-quartz and carbonate obtained from diamond drill borehole cores were sampled and assayed for gold, but the values seldom exceeded half a pennyweight per ton of gold.

The pillow lava covers a large proportion of the northern region, outcropping approximately 100 feet north of the Peerless limestone, and also exposed between the overlying Shamvaian sediments, which form the limbs of the easterly plunging anticline.

The Shamvaian sediments lie unconformably on the Bulawayan pillow lavas. These sediments extend from west to east as two belts across the northern region of the area mapped, converging in the northeast to form the nose of an easterly plunging anticline. The rocks exposed are massive, greyish-white grits, which give rise to long, narrow ridges. Tight folding of the grits on the southern limb of the anticline west of the oblique-dip fault, accounts for the wide distribution on outcrop of these grits in this area. (Plate I, Figure 1). It is difficult to establish the attitude of these sediments as they show even-grading of their ditrital quartz grains, lack of bedding-planes, and a complete absence of any form of lineation. The reasons for assuming that these sediments are steeply dipping are as follows: Erosion along the course of the Momoi River, which transgresses these sediments at right-angles to their strike, shows that the directions of the contacts between these sediments and the pillow lava do not change, as would be the case if the sediments dipped at low angles. Diamond drill boreholes N.4 and N.7. intersected numerous narrow bands (approximately 10 feet wide) of quartz grit directly below the small outcrop of grit approximately 800 feet north of the Peerless Mine, suggesting that the grits, although wider on outcrop, persist in depth and are almost vertically dipping (Figure 3).

(c) Petrographic Description of the Rock-Types

Rocks of the Sebakwian System

Hornblende Schist

This fine-grained rock is light green in colour and sometimes exhibits banding as a result of segregate bands of amphibole and quartz.

In thin section the rock consists essentially of distinctly pleochroic hornblende and quartz. Pleochroism of the hornblende is as follows -

X	Y	Z
pale green	green	dark green

The maximum extinction angle c∧Z of the hornblende was 22 degrees, the mean extinction angle from the readings was 18 degrees. When banded, porphyroblasts of hornblende generally range in length from 0.25 to 0.75 millimetres and show an interlaced arrangement semi-aligned along their long axes, the quartz bands being much finer-grained and usually associated with minor amounts of poorly developed hornblende. These two minerals are usually intimately associated giving poeciloblastic texture (Plate VI Figure 10).

Massive Granite (Stock)

Fresh granite specimens were obtained from a dump of granite at a small abandoned mine, known as the Cormandia, on the southern side of the granite stock south of the Pickstone Mine. The granite is massive in texture fine-to medium-grained and usually pinkish-white in colour. Dark-green biotite is macroscopically visible disseminated throughout the rock.

Large crystals of orthoclase, which generally range from 1.0 to 2.25 millimetres in length, form one of the major constituents of this leucocratic rock. It usually shows Carlsbad twins as well as occassional zoned crystals. The orthoclase is always turbid and shows alteration to sericite preferentially in the interior portions of the crystals (Plate VI, Figure 11). Fresh quartz and microcline make up the remainder of the leucocratic minerals present. The microcline, showing grid-iron texture is fairly abundant, and the grains of microcline are generally smaller in size than the grains of the orthoclase and quartz.

Flakes of green, pleochroic biotite are abundant and often occur associated with irregular, yellowish-green grains of epidote (Plate VII, Figure 12). A few columnar aggregates of clinozoisite were observed.

Rocks of the Bulawayan System

Speckled Chlorite Schist

The speckled chlorite schist outcrops over an extensive area and also forms the northern wall-rock of the orebody on the Pickstone Mine. Macroscopically this rock is fine-grained and dark-green in colour. Minute whitish-grey lenticules usually of the order of 0.25 to 0.5 millimetres in length give this rock a speckled appearance.

Chlorite is the principle mineral present in this rock. The chlorite is very pale green in colour and generally shows faint pleochroism. The chlorite is in the form of lenticules which envelope crushed relics of felspar. The felspar, which sometimes exhibits faint twinning, is in an advanced stage of crushing and rolling out, and is in the process of altering to the lower-grade metamorphic mineral, sericite. Seritization of the original felspars to form lenticules of sericite (Plate VIII, Figure 14), represents a mineralogical reversal and is mentioned by Harker (1956) as an example of retrograde metamorphism. The lenticules of sericite, which often show felspar relics are responsible for the specks in this chlorite schist (Plate VII, Figure 13).

Magnetite is present and generally conforms with the lenticular pattern present in these rocks. Minor amounts of carbonate was observed, usually as fillings in minor fracture planes.

Felsite and Quartz-Porphyry

These rocks have a yellowish-green colour in the fresh state but weather to a glistening whitish-brown colour on surface. The macroscopically visible phenocrysts are grains of vitreous quartz ranging from 0.5 to 2.0 millimetres in size.

Due to the extremely fine-grained nature of these rocks, a powdered sample from rock specimen x 10014 taken from the south wall-rock of the Venning Ore Body was tested using the X-ray Diffraction technique. This disclosed that these rocks had been recrystallized to form a rock consisting dominantly of the basic aluminium silicate mineral pyrophyllite $Al_2Si_2O_{10}(OH)_2$ together with minor amounts of quartz. Details of the X-ray Diffraction analysis are given in Table 1.

Table 1. X-RAY DATA ON PYROPHYLLITE TAKEN FROM SOUTH WALL-ROCK OF THE VENNING ORE BODY

Rock Sample Number X10014		A.S.T.M. Card Number 12-203	
d(Å)	Io	d(Å)	I/Io
9.22	80	9.21	60
4.59	80	4.58	50
4.45	30	4.40	20
4.19	5	4.17	15
3.07	100	3.08	100
2.96	5	2.97	2
-	-	2.59	5
2.55	5	2.55	10
-	-	2.44	15
2.30	10	2.31	5
-	-	2.17	5
2.09	5	2.09	5
2.07	5	2.07	5
-	-	1.895	2
1.84	20	1.848	15
-	-	1.692	5
1.650	5	1.650	10
-	-	1.542	5
1.492	5	1.492	10
-	-	1.475	2
-	-	1.437	2
1.38	5	1.388	10
1.37	5	1.373	10

The discrepancies between the intensities obtained from the rock specimen X10014 and the A.S.T.M. (American Society for Testing and Materials) Card may be attributed to the preferred orientation of this flaky mineral, and that no attempt was made to alter the entrance and exit slits of the X-ray Diffractometer during scanning, resulting in lower relative intensities of the reflections in the higher angle regions.

Under the microscope it was observed that the matrix of these rocks is a cryptocrystalline mass of pyrophyllite showing strong birefringence, in which minute irregular grains of quartz are present (Plate VIII, Figure 15). A little kaolinite is also possibly present. Micro-augen textures were observed in which it was found that the augens consisted of lenses of slightly coarser material than the pyrophyllite, but too fine-grained for identification. The phenocrysts of quartz are nearly always cracked or sheared, the cracks being filled by the highly birefringent pyrophyllite (Plate IX, Figure 16). "Strain-Shadows" shown up by the irregular extinction between crossed nicols are present in most of these quartz phenocrysts.

Banded Jaspilite (Pickstone Mine Host Rock)

This important rock-type is extremely fine-grained, and as the name implies, the rock consists of alternating, parallel bands of light and dark material. The alternating, parallel bands range in size from very thin hair-line widths to approximately an inch in width.

The colour of the rock when fresh, is generally grey, but patches of red and maroon jasper are fairly common. On surface, as a result of oxidation, these banded jaspilites show differential weathering due to the hard jasper bands and softer darker bands so that these rocks take on a "sandwich" appearance. In order to determine the mineral composition of the dark bands of this banded jaspilite an X-ray Diffraction analysis was carried out on the material comprising the dark bands. The results of the X-ray Diffraction analysis showed that the dark bands consist of siderite (chalybite) $FeCO_3$. The results of this analysis are given in the Table 2.

Table 2. X-RAY DATA ON SIDERITE FROM BANDED JASPILITE HOST ROCK OF THE PICKSTONE MINE

Rock Sample number X10012		A.S.T.M. Card Number 12-531	
d(Å)	Io	d(Å)	I/Io
3.59	25	3.59	25
2.79	100	2.79	100
2.34	15	2.34	20
2.13	20	2.13	25
1.96	15	1.96	30
1.79	10	1.79	16
1.73	25	1.74	35
1.73	25	1.73	45
1.50	10	1.51	20
1.43	5	1.43	16

Lower relative intensities in the higher angle regions for the test sample, compared with the values given by the A.S.T.M. card, are probably due to not altering the settings of the entrance and exit slits of the X-ray Diffractometer during scanning.

Under the microscope the siderite bands consist of irregular, fine-grained grains of siderite, which show fairly high relief, and extreme birefringence. Occasionally minute rhombs of siderite were observed (Plate X, Figure 19). The jasper bands are predominantly cryptocrystalline quartz. The siderite and jasper bands usually show a fairly sharp contact in the hand-specimen, but under the microscope there is a slight mixing of siderite grains with the quartz grains in the jasper bands.

Slides cut on mineralized specimens of the Pickstone Mine ore showed numerous interesting relationships between the sulphides and the banded jaspilite host rock.

The subhedral and euhedral crystals of arsenopyrite and pyrite show preferential replacement of the siderite bands (Plate X, Figure 18). When occasional scattered crystals of these sulphides occur within the jasper bands, the cryptocrystalline quartz surrounding these crystals has been recrystallized to form impressive looking "flame quartz" (Plate XI, Figure 20) and (Plate XI, Figure 21). The "flame quartz" crystallized as elongate grains adjacent to one another, and with their long axes perpendicular to the crystal faces of the arsenopyrite and pyrite, around which they have formed. The shape of the recrystallized quartz, as well as the undulatory extinction present in the quartz, are responsible for the flame-like appearance that is produced by the recrystallized quartz grains. Veins of later quartz associated with the hydrothermal mineralization cut across the banded jaspilite, and vary in size from minute veinlets only observed under the microscope up to 6 inches thick. Under the microscope the veinlets consist of an intergrowth of quartz grains which are approximately 0.1 millimetres in size. A thin section cut from a thick vein of hydrothermal quartz showed the general size of the quartz grains as 1.5 millimetres.

Pillow Lavas

These very fine-grained, pale-green rocks form a major portion of the volcanic rocks of the Bulawayan System both in the Pickstone Mine area and in the Eastern Hartley gold-belt. The pillow lavas are characterised by the presence of pillow structures. A description of these pillows was given in the section which is sub-titled Stratigraphy in Chapter VII of this thesis.

Micro-crystalline chlorite is the chief mineral constituent. The chlorite is very pale-green in colour and is faintly pleochroic. Viewed under crossed nicols, the chlorite often shows "Berlin Blue" interference colours. Minute, slender, laths of plagioclase are present (Plate XII, Figure 22). The plagioclase laths vary in size from 0.25 to 0.5 millimetres in length and are generally poorly developed (Plate XII, Figure 23). Twinning is present in the plagioclase, the extinction of the twins being almost parallel, classifying the plagioclase as a soda-rich variety. Micro-structures resembling amygdales were observed, but it was impossible to identify the cryptocrystalline whitish-brown material, of which the possible amygdales are composed. The amygdales varied from 1.0 to 2.0 millimetres in length (Plate XIII, Figure 24).

Rocks of the Shamvaian System

The grits forming part of the Shamvaian System are greyish-white in colour in this area and are almost entirely composed of ditrital grains of semi-translucent, milky-grey quartz. The quartz grains are usually in the size range of two to three millimetres in diameter, but occassionally they exceed six millimetres. These grains are cemented by finer interlocking quartz material.

Microscopic examination shows that these grits co[illegible]f sub-angular to angular grains of quartz, the larger grains sometimes show slight rounding but practically all the smaller grains are angular. These quartz grains are nearly always cracked and show slight strained extinction (Plate XIII, Figure 25). The matrix consists of microcrystalline interlocking quartz grains, usually associated with small amounts of birefringent sericite (Plate XIV, Figure 26). When very little interstitial matrix material is present, the quartz grains have a mosaic arrangement giving a granulitic micro-texture. Rock specimens taken close to the contact of the grits and pillow lavas, showed an infiltration of secondary red iron oxides or hydrated iron oxides filling cracks in the quartz grains, and associated with the fine quartz matrix. Pleochroic flakes of light-green biotite are also rare constituents of these rocks.

Intrusive Rocks

Dolerite (Sill)

A compact, fine-grained, dark-green rock occurs as an intrusive sill at a depth of approximately 600 feet on the Pickstone Mine (Figure 4). It has produced a contact metamorphic effect on the banded jaspilite over a narrow zone along the contacts between these two rocks. The metamorphic effect seldom extends further than 5 feet into the banded jaspilite. The banded jaspilite in this zone is recrystallized, the dark coloured siderite and lighter coloured, cryptocrystalline quartz being mixed to form a dark-grey massive rock. Short apophyses of sill material extend into the banded jaspilite.

Due to the simultaneous crystallization of plagioclase and pyroxene, typical sub-ophitic texture is present often showing a radiating pattern (Plate XIV, Figure 27).

The pyroxene is augite and is almost colourless under the microscope. The maximum extinction angle $c \wedge Z$ measured was 43 degrees, most of the measured sections showing wavy extinction known as hourglass structure. Plagioclase is present as the mineral andesine and the mean extinction angle Z∧(010) measured from twenty four readings was 23 degrees. The larger laths of andesine show slight alteration of their centres to sericite. Abundant magnetite is present, mainly as an alteration product of the augite.

The mineral composition of this fine-grained rock, which consists essentially of augite and andesine together with the distinctive sub-ophitic texture present, classifies the rock as a dolerite.

(d) Structure

The Pickstone Mine is situated on the steeply-dipping, southern limb of the Eastern Hartley synform.

There appears to have been two periods during which structural deformation of these synformal rocks took place. The southern Rhodesdale Granite and northern Biri Granite were intruded and updomed, and the rocks forming the Eastern Hartley gold-belt were downfolded, and compressed between these two granites. As a result of this compression the gold-belt rocks were tilted into their near-vertical attitude. The Rhodesdale Granite is intrusive into rocks of the Sebakwian System and on this basis the first period of structural deformation is dated as post-Sebakwian in age. The compressive forces which resulted from the intrusion and updoming of the granites, acted on the relatively competent banded jaspilite which occurs in adjacent and relatively incompetent rocks, resulting in the development of boudinage or pinch and swell structure in the banded jaspilite

The second period of structural deformation, which affected the steeply dipping Shamvaian grits and older rocks north of the Pickstone Mine, is post-Shamvaian in age. The "younger" porphyritic granite cupola northeast of the Pickstone Mine is an intermediate (depth) cupola forming part of the roof portion of the Biri Granite batholith, and as a result of the cupola forming at this depth, it probably solidified later than the upper portions of the Biri Granite batholith. The intrusion and updoming of the porphyritic granite cupola produced forces which acted from the east on the vertically dipping gold-belt rocks. These forces caused the steeply dipping Shamvaian grits on the southern limb of the easterly plunging anticline, just north of the Pickstone Mine, to develop minor folds in the form of drag-folds forming minor synclinal and anticlinal structures. Similar drag-folds were mapped by Wiles (1957) occurring along the interlayered sediments of the Bulawayan and Shamvaian Systems of the Eastern Hartley gold-belt. Further signs of the effect of these easterly forces are the numerous strike faults along the banded jaspilite and the strong shearing in the adjacent country rocks as a result of the gliding action produced along this interlayered sediment. The strong shearing and development of foliation in the original felsite and quartz-porphyry extrusive, in which its fine-grained felspathic-quartz constituents were recrystallized to form the mineral pyrophyllite and minor amounts of quartz, is also thought to have been a result of the action of these easterly forces.

A small granite stock, southeast of the Pickstone Mine, is considered by the writer to be the surface showing of a trough cupola forming part of the roof portion of the Rhodesdale Granite batholith at depth. The oblique-dip fault east of the Pickstone Mine, appears to originate from the eastern side of this granite stock, and the position of the oblique-dip fault was possibly determined by the updoming of this granite stock, as a solid body. The oblique-dip fault has displaced rocks of the Bulawayan and Shamvaian Systems giving a relative horizontal displacement of approximately five hundred feet. The grits of the Shamvaian System in this area had been drag-folded before the oblique-dip fault was developed.

(e) Metamorphism

The gold-belt rocks in the Pickstone Mine area were altered by low-grade metamorphism. The grits of the Shamvaian System show almost negligible metamorphism. The widespread volcanic rocks of the Bulawayan System were subjected to low-grade metamorphism resulting in the development of the greenschist facies. In the greenschist facies, the original ferromagnesian minerals of the basalts and andesites were recrystallized to form the predominant metamorphic mineral chlorite, and the original felspars were partly altered to sericite, as in the case of the speckled chlorite schist. This reversion of the felspar to the lower metamorphic mineral sericite is an example of retrograde metamorphism (Harker).

Metamorphism of a slightly higher degree occurs in the rocks of the Sebakwian System with the development of a hornblende schist close to the contact of the Rhodesdale Granite, and is due to the intrusion of the Rhodesdale Granite into the Sebakwian rocks.

The formation of the stress mineral pyrophyllite in the original felsite and quartz-porphyry extrusive is thought to be connected with the high degree of shearing imparted onto these rocks, and caused by the later easterly acting forces, resulting from the intrusion of the porphyritic granite cupola to the east of the area mapped.

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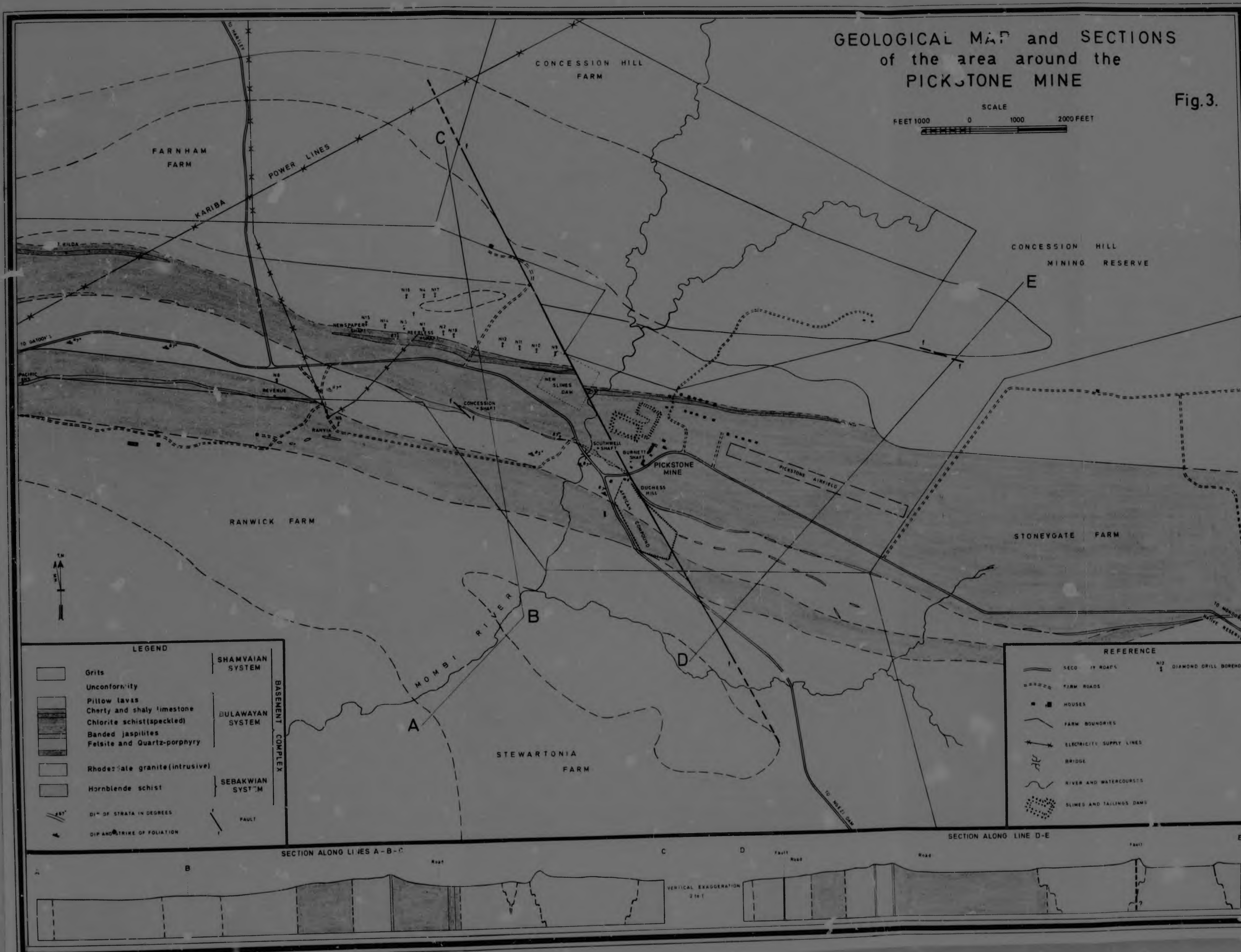
GEOLOGICAL MAP and SECTIONS
of the area around the
PICKSTONE MINE
Fig.3.
SCALE
FEET 1000 0 1000 2000 FEET
CONCESSION HILL
FARM
FARNHAM
FARM
KARIBA POWER LINES
CONCESSION HILL
MINING RESERVE
NEWSPAPER SHAFT
PEERLESS
REVENUE
CONCESSION SHAFT
NEW SLIMES DAM
SOUTHWELL SHAFT
BURNETT SHAFT
PICKSTONE MINE
DUCHESS HILL
PICKSTONE AIRFIELD
RANWICK FARM
STONEYGATE FARM
MOMBI RIVER
STEWARTONIA
FARM
A
B
C
D
E
LEGEND
Grits
Unconformity
Pillow lavas
Cherty and shaly limestone
Chlorite schist(speckled)
Banded jaspilites
Felsite and Quartz-porphyry
Hornblende schist
SHAMVAIAN SYSTEM
BULAWAYAN SYSTEM
SEBAKWIAN SYSTEM
BASEMENT COMPLEX
FAULT
REFERENCE
FARM ROADS
HOUSES
FARM BOUNDARIES
ELECTRICITY SUPPLY LINES
BRIDGE
RIVER AND WATERCOURSES
SLIMES AND TAILINGS DAMS
DIAMOND DRILL BOREHOLE
SECTION ALONG LINES A-B-C
SECTION ALONG LINE D-E
Road
Fault
VERTICAL EXAGGERATION 2 to 1

VIII. GOLD MINERALIZATION

The Pickstone gold deposit is a sulphide replacement deposit in a host rock of banded jaspilite. The Pickstone deposit consists of three wide and steeply dipping ore zones, which occur along a 3,500 feet strike of steeply dipping banded jaspilite, situated on the western side of the Pickstone oblique-dip fault.

(a) Host Rock

The banded jaspilite host rock, as previously described under the petrographic description of the rock-types, is composed of alternating and parallel bands of siderite and cryptocrystalline quartz, generally with widths of the order of half an inch.

The mean width of the banded jaspilite on the Pickstone Mine is approximately 30 feet, ranging to a maximum width of 100 feet, this maximum width occurring in a cross-cut on the east side of the Concession ore shoots on 4 level main drive (Figure 7). Underground workings extend for a distance of 3,800 feet on strike and show an elimination of this host rock of approximately 200 feet on the east side of the Venning ore shoots resulting from strike faulting (Figure 12).

The banded jaspilite has acted as a congenial host rock for gold deposition due mainly to the combination of physical and chemical characteristics possessed by this rock-type. The banded jaspilite is relatively competent compared with the speckled chlorite schist, and the felsite and quartz-porphyry (now mainly pyrophyllite) wall-rocks. Compressive forces acting on this brittle rock resulted in the formation of boudinage structure, and the development of zones of intense fracturing within the relatively narrow "necks" between the boudins. These highly fractured "necks" or pinched zones have provided this extremely compact rock with interconnected channel-ways along which the mineralized solutions could permeate. Preferential replacement of the chemically favourable siderite bands by the sulphides arsenopyrite and pyrite with associated gold within these zones of intense fracturing led to the formation of this hydrothermal gold deposit.

The origin of these Precambrian banded iron formations is as yet not clearly understood. A noteable difference exists between the early to middle Pre brian iron formations of predominantly nonditrit , low alumina conten. and the late Precambrian iron formations of dominantly detrital and high alumina content, Lepp and Goldwich (1964). These differences are ascribed to a change in environmental factors presumably as a result in the changeover from a primitive reducing atmosphere, which may have contained large amounts of carbon dioxide gas, to an atmosphere in which oxygen was beginning to be introduced by primitive plant life.

It is intended to give only brief summaries of some of the more widely accepted hypotheses that have been advocated to account for the formation of these banded iron formations. G. L. Laberge (1966) carried out intensive studies on the later Precambrian iron formations occurring in the Hammersley Range in Western Australia and the iron formations overlying the massive Dolomite formation of the Transvaal System in South Africa. Volcanic activity contemporaneous with the deposition of iron formations appears to have taken place in many other parts of the world in which these Precambrian iron formations occur. In these areas massive black stilpnomelane (iron silicate) rocks with interlayered bands of considerable magnetite and siderite contained axiolitic shard structures. The stilpnomelane layers with appreciable amounts of siderite or chert generally were devoid of these shard structures, but as these rocks were found to grade into the shard-bearing rocks, Laberge suggests that these iron formations are derived from the alteration of pyroclastic rocks and are exogenetic.

Recent discoveries have been made of primitive life-forms dating as far back as plus 3 billion years, Pflug (1966), in rocks of the Fig Tree Series of the Swaziland System in the area around Barberton (North-Eastern Transvaal). Structured remains of microfossils were revealed preserved in the cherts and shales and it has been suggested that structures resembling primitive algae were capable of precipitating metal salts by the action of their life process (Pflug), and could have played an important part in the formation of these early Precambrian sedimentary iron formations.

Silica is present in natural waters in true solution as monosilicic acid H_2SiO_4 and not as colloidal silica, and earlier theories proposing removal by coagulation of colloidal silica by electrolytes in sea water have been proved incorrect. Iron is dissolved as ferric hydroxide complex or ferric sulphate. It has been established that in natural waters where the concentration and quantity of iron is not necessarily excessive, that two basic controls governing precipitation, namely pH (hydrogen ion concentration), and Eh (oxidation-reduction) potentials may determine the type of mineral precipitated, Pettijohn (1957). A delicate change in these potentials usually linked with seasonal changes could account for the rythmic banding of the iron and silica.

Recent research work on the geochemistry of iron and its probable paleogeochemistry indicate that a primary accumulation of this element cannot arise in a marine environment. G. J. Govett (1966) has recently put forward a hypothesis on the origin of Precambrian iron formations, suggesting that they were formed in closed-basins or lacustrine environments, and known limnological processes are invoked to provide a mechanism for the common rythmic banding of iron and silica. Govett describes the annual cycle in monomitic lakes in which there is a period when the waters become stratified forming an upper, warmer, and less dense epilimnion layer, and a cooler, more dense, hypolimnion layer, and a period during which circulation of the water in the lake occurs, and the oxygenated waters are brought down to the lower levels, thus giving rythmic precipitation of silica and iron on the basis of cyclical oxidation and reduction. In the summer when the waters become stratified reduction takes place in the hypolimnion and ferric hydroxide and ferric sulphate in the uppermost sediment layer will be reduced and go into solution. Any silica held as ferric silicate will first be released and then goes into solution until the limiting solubility of 100-150 parts per million is reached. As a result of this process the excess silica may leave a layer of silica in the topmost sediment. When circulation commences and the oxygenated waters are brought down into the hypolimnion the iron in solution is oxidised and sedimented and forms a microzone at the sediment-water interface. Siderite requires a reducing environment for precipitation, but Govett suggests that the siderite is diagenetic and formed by the rearrangement of materials in a supersaturated or colloidal state in the unconsolidated sediment on the floor of the lake or basin.

Lepp and Goldwich (1964) suggested a lateritic weathering process to explain the origin of the Precambrian iron formations. They suggest that the source region should remain stable in order to minimise mechanical erosion and have a moderate relief so that there is a rapid removal of silica as H_4SiO_4 and soluble elements from the weathered source rock. The atmosphere at this early stage would be lacking in oxygen. Leaching of the source rocks produces residual deposits of alumina, phosphorous and titanium oxides and hydroxides. The solutions draining the source area into a shallow basin would deposit primary carbonates such as siderite and calcite (Lepp and Goldwich, 1964). Diagenetic changes of these primary carbonates by the soluble elements present result in the formation of dolomite, chert, stilpnomelane, ankerite, quartz, magnetite and hematite. With the introduction of oxygen into the atmosphere approximately 1,200 million years ago the development of cherty iron formations was effectively curtailed (Lepp and Goldwich, 1964)

(b) Microscopic Relationships of the Ore Minerals

The ore minerals identified as being present in the Pickstone orebody were arsenopyrite, pyrite, chalcopyrite, sphalerite and gold. From examination of polished sections of the ore it was concluded that the predominant ore minerals are arsenopyrite and pyrite and that the amount of arsenopyrite slightly exceeds that of the pyrite. These minerals display subhedral to euhedral crystal faces, and have a general size range between 0.25 millimetres and 2.0 millimetres, but occasionally some of the larger crystals exceed 5.0 millimetres. A noticeable feature is that the subhedral crystals of arsenopyrite and pyrite along the boundary of the late milky vein-quartz, which is present as fillings in the fractures in the banded jaspilite, are fine-grained and larger crystals are developed further from the vein-quartz (Plate XVII, Figure 32). Another noteable feature is that the crystals of arsenopyrite are generally larger than those of the pyrite. The arsenopyrite crystallized as prisms, pyramids, and combinations of prisms and domes or pinacoids (Plate XV,

Figure 28), the pyrite crystallizing only in cube form. Under the microscope the colour of the arsenopyrite is white, and when tested for hardness using a needle, the mineral was scratched with difficulty. A microchemical test using HNO_3, 1:1, was found to etch the arsenopyrite (Plate XV, Figure 29). Under the microscope the pyrite is isotropic and pale yellow in colour. The pyrite often shows triangular pitting of its polished surface (Plate XV, Figure 29). Microscopic relationships observed showed crystals of arsenopyrite enclosed in massive pyrite (Plate XV, Figure 29), and vice versa (Plate XVI, Figure 30). Crystals of these two ore minerals are often intergrown with each other, the two minerals growing together giving irregular interlocking contacts (Plate XVI, Figure 31). Microscopic examination of these two predominant ore minerals showed no instances of one of these minerals replacing the other or of veinlets of one of these minerals cutting through the other. The textural relationships observed between these two minerals suggests that the arsenopyrite and pyrite crystallized more or less contemporaneously.

Minor amounts of chalcopyrite were observed along the interlocking contacts between arsenopyrite crystals (Plate XVII, Figure 33) and between the interlocking contacts of arsenopyrite and pyrite crystals. The chalcopyrite also occurs as fillings in fractures in these two ore minerals (Plate XVIII, Figure 34). The chalcopyrite is brass-yellow in colour and easily scratched by a needle.

The gold is present in extremely small grains being approximately 15-50 microns in diameter, visible under high power usually as irregular grains included in the arsenopyrite (Plate XVIII, Figure 34), and pyrite crystals. Gold also occurs along the interlocking faces of these two ore minerals (Plate XVIII, Figure 34). A polished section in which free gold is present in milky vein-quartz showed this late gold surrounding grains of arsenopyrite (Plate XIX, Figure 36).

Sphalerite is not a common mineral and was only observed on a single occasion as massive sphalerite in a vein-quartz fracture-filling in the banded jaspilite host rock exposed during the development of the 11 level main haulage east. Microscopic examinations of specimens from this occurrence showed the sphalerite to be irregular and massive, usually enclosing crystals of arsenopyrite, and occasionally as fillings in fractures in the arsenopyrite crystals (Plate XIX, Figure 37).

The mineral sequence or paragenesis based on these observed microscopic relationships is that the first minerals formed and presumed to have formed contemporaneously were arsenopyrite, pyrite, and the extremely small grains of gold that occurs as inclusions in these minerals. Later gold and minor amounts of chalcopyrite formed along the irregular, interlocking contacts of the arsenopyrite and pyrite. During the final stage of deposition minor sphalerite and free gold associated with the late milky vein-quartz gangue were formed.

An oxidised ore specimen from old surface workings on the Venning ore shoots was examined both microscopically and using the X-ray Diffraction technique. Pseudomorphs of arsenopyrite and pyrite were present, these minerals having altered to hematite and hydrated iron oxide (Plate XX, Figure 38). X-ray Diffraction results showed the presence of hematite, but the ratio of the heights of the intensities checked against a known specimen of hematite were estimated as 0.37 to 1, and as these intensity peaks also appeared broader than those of the known specimen, it is presumed that the remainder of the material is amorphous hydrated iron oxide.

(c) Origin of the Gold Mineralization

As there is a strong geographical relationship between the lode systems in the gold-belt rocks and the intrusive granitic masses in Rhodesia, it is reasonable to infer that they were formed by mineralized fluids expelled from such masses. Emmons (19[illegible]) described the mechanism of the deposition of metalliferous lode systems associated with granitic batholiths, the facts of which bear a very close resemblance to those that exist in the Eastern Hartley gold-belt. The writer, in discussing the origin of the gold mineralization of the Pickstone deposit, uses Emmons's findings and relates them to similar findings that are present in the area of the Pickstone Mine.

When these large batholithic bodies of granite invaded the overlying or roof rocks, upward bulges in the form of cupolas were formed at varying levels along the roofs of these batholiths, the uppermost cupolas being termed summit cupolas ranging downwards through intermediate cupolas to the deepest or trough cupolas, which project upwards from the lower portions of the batholiths. This granitic material on coming into contact with the roof rocks begins to cool and crystallize forming a magma shell or hood. It is assumed that the summit cupolas are solidified before the deeper trough cupolas, which may explain the different ages of granites found in the Basement Complex of Rhodesia. Progressive cooling continues below the thickening hood resulting in further crystallization and leading to the development of high pressure in the residual solutions. It has been proved by laboratory tests that when a wet magma cools with crystallization, the volatile (water) pressure increases as more silicate crystallizes. If the crust is fractured, possibly due to major faulting, for example the oblique-dip fault on the eastern side of the Pickstone Mine or is otherwise unable to withstand these pressures, the mobile constituents of the magma are expelled. In the early stages of crystallization, the metals in the "rest magma" are carried to the top of these batholiths and accumulate in the hood and roof rocks as lodes. At this early stage nearly all of the various types of metals are present in these expelled fluids, the chief metals being gold and silver, copper, lead and zinc, mercury, antimony, bismuth, and molybdenum.

As downward crystallization of the granite batholith continues and later periods of fracturing of the hood occur, a later stage of mineralization comprising only metals such as gold, copper and zinc are given off, as the magma has been depleted of certain metals, and these metals accumulate around the deeper trough cupolas which presumably crystallize at a later stage than the summit cupolas. The Pickstone mineralization is probably related to this type of mineralization namely, related to cupola formation associated with batholithic granite intrusion. Mineralization of the granite hood, namely the zone of granite close to the contact of the gold-belt schists may also take place and this is well substantiated in the Eastern Hartley gold-belt by such mines as the Thistle Etna, Inez, Shepherds Reef, Sid and Seigneury Mines. All of these mines are situated in the granite approximately one mile from the contact with the gold-belt rocks.

During the later stages of the development of these intrusive batholiths further crystallization then gives rise to the barren core, which may also fracture with final differentiates resulting in the deposition of barren quartz-pyrite veins and pegmatitic bodies in the core.

Following the total crystallization of these batholiths, a stage is reached when as a result of prolonged erosion the full batholithic profile through various classified stages is reached and the erosion line penetrates the barren granite core. The Eastern Hartley gold-belt rocks and associated batholiths are at present in the endobatholithic stage, namely the rim of the intrusive constitutes the border frame of the batholith and portions of the roof rocks that remain in the central regions of the batholith form roof pendants. It may therefore be assumed that the widespread gold mineralization found in the Basement Complex of Rhodesia is derived from mineralized fluids or hydrothermal solutions formed below the crystallizing hoods of the granitic intrusions, and were expelled under high pressure into the hoods and roof rocks. These invading hydrothermal solutions on penetrating these upper rocks, complied with the structural controls present in these roof rocks, which in the case of the Pickstone gold deposit were zones of maximum fracturing within the competent banded jaspilite host rock, and on deposition gave rise to this economical gold deposit.

IX. STRUCTURE-CONTROLLED ORE SHOOTS

(a) Introduction

The general structural pattern of the banded jaspilite host rock strongly resembles boudinage structures (pinch and swell structures), which form due to compressional forces acting on relatively competent rocks in adjacent and relatively incompetent rocks. The boudins formed are similar to the lenticular boudins described by H. Ramberg (1955), whereby rigid or competent rocks under a confining pressure and stress, decrease in competency and increases in plasticity, causing complete "necking down" during elongation, and may even reach an advanced stage in which complete rupture takes place between the boudins. The intrusion and updoming of the Rhodesdale and Biri Granites resulted in compressional forces which acted on the banded jaspilite. The compressional forces acted in a direction perpendicular to the strike of the banded jaspilite and formed pinch and swell structures as well as causing elongation along the strike of the banded jaspilite. During the process of "necking down" to form the narrow or pinch zones, tensional stresses occurred in these zones as a result of the elongation of the banded jaspilite along its strike. The tensional stresses caused the fracturing of the banded jaspilite in these narrow or pinch zones. In the text which deals with the description of the structure - controlled ore shoots, these narrow or pinch zones in which "necking down" and fracturing has occurred, will be referred to as pinched zones. Other significant points favouring this interpretation are that boudinage structures are known to only occur in areas strongly compressed and usually associated with steep or isoclinal folding, and that the fractures developed are not generally parallel to the direction of strike of the boudins. The development of boudinage structure is related to the intrusion and updoming of the Rhodesdale and Biri Granites, which compressed the gold-belt rocks between these two granites, and tilted them into their near-vertical attitudes. It is interesting to note that Swift (1961) in describing the folding and earth movements of the Basement Complex in Rhodesia uses the term "compression" in describing the structural formation of the gold-belts. Swift mentions that there is evidence of movement at various times during the formation of the Basement Complex and that much of the folding present in gold-belt rocks is due to compressive forces. He also mentions that these movements do not by themselves explain the arcuate strikes around the granitic intrusions.

The "younger" porphyritic granite cupola to the east of the ''ckstone Mine, as previously described, appears to be responsible for the regional minor drag-folding of these steeply dipping gold-belt rocks in this area, as well as the gliding action along the interlayered banded jaspilite. This gliding action is represented by strike faults along the length of the banded jaspilite and was superimposed on the existing boudinage structure.

These strike faults are responsible for the partial elimination of banded jaspilite along strike, the fault-traces often showing small remnants of crushed banded jaspilite, and the minor slip-movements within the boudins. Although the structural pattern developed in the banded jaspilite strongly resembles boudinage structure an alternative explanation for the development of this structural pattern may be suggested. It is possible that the intrusion and updoming of the "younger" porphyritic granite cupola produced easterly forces which resulted in a gliding action along the interlayered banded jaspilite, the strong shearing developed in the wall-rocks adjacent to the banded jaspilite and the strike faulting along the banded jaspilite is evidence of this movement. This gliding action may also be interpreted as the result of a rotational strain in which the north and south wall-rocks of the jaspilite moved westwards and eastwards respectively. The thicker portions of the banded jaspilite possibly acted as buffers during this movement and the narrower portions between these buffers suffered fracturing. In both explanations it is the narrow zones in the banded jaspilite which are strongly fractured, and the fractures have enabled the gold-bearing hydrothermal solutions to penetrate this compact host rock, giving rise to structure-controlled ore shoots.

Along the length of the Pickstone Orebody there are distinct zones which contain ore shoots which have been named from west to east, the Concession, Venning and Pickstone East ore shoots (Figure 12). In Figure 12 the close relationship existing between the structure of the banded jaspilite host rock, which is depicted using isopachs at 5 feet intervals plotted on a vertical projection of the Pickstone Mine, and the ore shoots, is clearly illustrated. Figure 4 is an East-West Vertical Projection of the Pickstone Mine underground workings with development and stoping as at the 31st May, 1967.

The most important ore zone of the Pickstone deposit contains the Venning ore shoots, and as the major proportion of ore is obtained from this ore zone, these structure-controlled ore shoots are described first. The Concession ore shoots of the western ore zone on the Pickstone Mine are similar in nature to those of the Venning ore shoots, as similar structural controls are present, and for this reason the description of the Concession ore shoots follows that of the Venning ore shoots. The eastern ore zone contains the Pickstone East ore shoots, but besides having the same structural controls as the Venning and Concession ore shoots, the structural controls of the Pickstone East ore shoots have been complicated by the additional control of step-faulting. The step faulting is a result of the relative drag-movement on the banded jaspilite resulting from the major oblique-dip fault which occurred to the east of the Pickstone Mine. Due to this added structural control the Pickstone East ore shoots are the last to be described.

(b) Venning Ore Shoots

The broad zone in which the Venning ore shoots are concentrated plunges steeply to the west and increases in strike length from 700 feet on 6 level to approximately 1,150 feet on 11 level (Figure 12). This broad zone is subdivided for descriptive purposes into western, central and eastern portions between 6 level and 11 level, where detailed geological mapping and sampling were carried out, as well as an upper portion comprising the old underground workings between surface and 6 level. Plans of the levels and sub-levels showing the structure, geology, and payable zones are illustrated in Figures 5 and 6.

In the western portion the ore shoots are confined to the pinched zone having a general strike length of approximately 300 feet. This pinched zone is bounded on its western side by a lenticular boudin that decreases in width with depth between 6 and 10 levels (Figure 12). The eastern side is bounded by two boudins occupying positions between 7 and 9 levels and between the 1460 sub-level and 11 level (Figure 12). Between these two boudins, namely from 9 level to the 1460 sub-level, another pinched zone is developed resulting in the ore shoots of this western portion extending eastwards, and joining the ore shoots of the central portion (Figure 12).

The ore shoots of the central portion have short strike lengths and occupy the relatively narrower pinched zones between the numerous boudins. Although these ore shoots are continuous in the vertical plane, the payable ore zones within the banded jaspilite show a fluctuating pattern, which is largely responsible for the dilution of this ore during mining operations. These relatively narrow pinched zones may attain widths that exceed 40 feet (Figure 6, 1580 sub-level), and their erratic nature is due to the relative intensity and the attitude of the fracturing. The fractures in these relatively wide pinched zones between the boudins generally strike obliquely (north-west-southeast) across the banded jaspilite, which has a strike direction approximately west to east, and the fractures dip southwest at angles between 50 - 60 degrees. The fractures in the banded jaspilite are recognised by the milky vein-quartz fillings which seldom exceed 6 inches in width.

The structural pattern of the eastern zone is complicated by the banded jaspilite splitting into two, giving rise to the locally named "north band", and the main band (Figure 5). In Figure 12 only the isopachs related to the main band were plotted. This splitting of the banded jaspilite probably contributed to the fracturing in this eastern zone, this "north band" having produced a considerable amount of high-grade ore between 6 and 10 levels. The swing to the east of the contact between the banded jaspilite, and the area in which the banded jaspilite was eliminated due to strike faulting between 10 and 11 levels, extended the narrow pinched zone eastwards with the introduction of additional ore shoots (Figure 12 and Figure 6).

In the upper portion of the Venning ore shoots sulphide mineralization has spread into the area in which strike faulting has eliminated the banded jaspilite (Figure 12). The sulphides and associated gold were deposited along the contact between the speckled chlorite schist and felsite and quartz-porphyry, which is a contact along which there has been intense shearing, forming a heavily mineralized zone approximately 5 feet wide and extending along strike for approximately 300 feet. This mineralized zone carries high gold values (approximately 10-15 pennyweights) and a major portion of this ore was mined out in the initial mining operations on the Pickstone ore deposit (Figure 4). Because of the high shearing of the speckled chlorite schist and felsite and quartz-porphyry rocks in this zone, these rocks tend to slab-off making mining operations hazardous. In the early stages of the mining of this zone water also proved problematical. The possible reason for the development of this mineralization along the sheared contact in the area in which the banded jaspilite is eliminated, is that the Venning and Pickstone East ore zones merge together above 4 level (Figure 12), resulting in sufficient mineral being available to fill this sheared zone. On surface the mineralized zone produces a narrow oxidised gossan, which is dark reddish-brown and often contains showings of flake-gold. A specimen from the oxidised gossan was polished and examined under the microscope and was also investigated by the X-ray Diffraction technique, the results of which were described under the sub-title Microscopic Relationships of the Ore Minerals.

(c) Concession Ore Shoots

The structure-controlled ore shoots of the Venning and Concession ore zones have similar structural relationships. The broad zone incorporating the Concession ore shoots plunges steeply to the west and has a mean strike length of approximately 500 feet. The ore zone may be conveniently classified into west and east portions (Figure 12).

The ore shoots of the west portion show clearly the extent to which the ore shoots are controlled by the boudinage structure. The ore shoot on 4 level has a strike of 150 feet, and in its short upward trend, is practically terminated against a large boudin which extends downwards from 2 level to approximately 60 feet above 4 level (Figure 12 and Figure 7). A large boudin with a thickness which exceeds 70 feet on 3 level, extends downwards from 2 level to approximately 100 feet above the dolerite sill and separates the ore shoots of the west portion from the ore shoots of the east portion (Figure 12). The west ore shoots extend eastwards and join with the east ore shoots in the pinched zone that exists approximately 100 above and 60 feet below the dolerite sill (Figure 12). The west ore shoots with a strike length of 350 feet on 6 level, shorten rapidly in strike length down to the 7 level, where their strike length is 80 feet (Figure 12). The banded jaspilite between 7 and 10 levels remains narrow in width (approximately 10 feet wide) along the total strike length below the west and east ore shoots of the Concession ore zone. In the area below 6 level the ore shoots of the west and east portions are poorly developed. The reason for the poor development of the ore shoots is attributed to the fact that below 6 level boudinage structure has not been developed. The development of swell relationships. The broad zone incorporating the Concession ore shoots plunges steeply to the west and has a mean strike length of approximately 500 feet. The ore zone may be conveniently classified into west and east portions (Figure 12).

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The ore shoots of the east portion are contained in the pinched zone which is bounded on its eastern side by an extremely large boudin which attains a width of 100 feet on 4 level decreasing in width to approximately 45 feet on 6 level (Figure 7 and Figure 12). On the western side of the east ore shoots above 4 level a wide boudin is present, which as previously described, separates the west ore shoots from the east ore shoots. The east ore shoots extend down to 6 level where they have a strike length of 230 feet but due to the lack of development of boudinage structure between 6 and 10 levels these ore shoots show very poor development in this area.

Numerous old open workings are situated along the strike of the banded jaspilite outcrop on the western side of the Concession Shaft but does not appear to form part of the Concession ore zone (Figure 12).

(d) Pickstone East Ore Shoots

The complex nature of the Pickstone East ore shoots is due to a further set of structural controls being combined with the boudinage structure and strike faulting, and in this east ore zone all of these structural controls have played a part in determining the position and persistence of the ore shoots. This additional control is due to the relative drag-movement on the banded jaspilite in this area, resulting from the major oblique-dip fault, which is present east of the Pickstone Mine (Figure 3). East of the Southwell Shaft, the banded jaspilite curves towards the southeast for a distance of approximately 800 feet (Figure 9 and Figure 11), the movement in this competent rock being taken up by the development of numerous minor step-faults along the strike of the banded jaspilite. East of the oblique-dip fault in the area of Duchess Hill the strike of the banded jaspilite resumes its south of east strike direction (Figure 3).

The Pickstone East ore zone dips steeply to the east and in the area above the dolerite sill the west ore shoots of the Pickstone East ore zone join with ore shoots of the Venning ore zone. The ore shoots in this upper section, extend from the large area in which the banded jaspilite was eliminated by strike faulting, eastwards to the Burnett Shaft, a strike length of approximately 1,150 feet (Figure 12). In the area above the dolerite sill the position of the ore shoots were plotted using the areas in which stoping had taken place (Figure 4 and Figure 12).

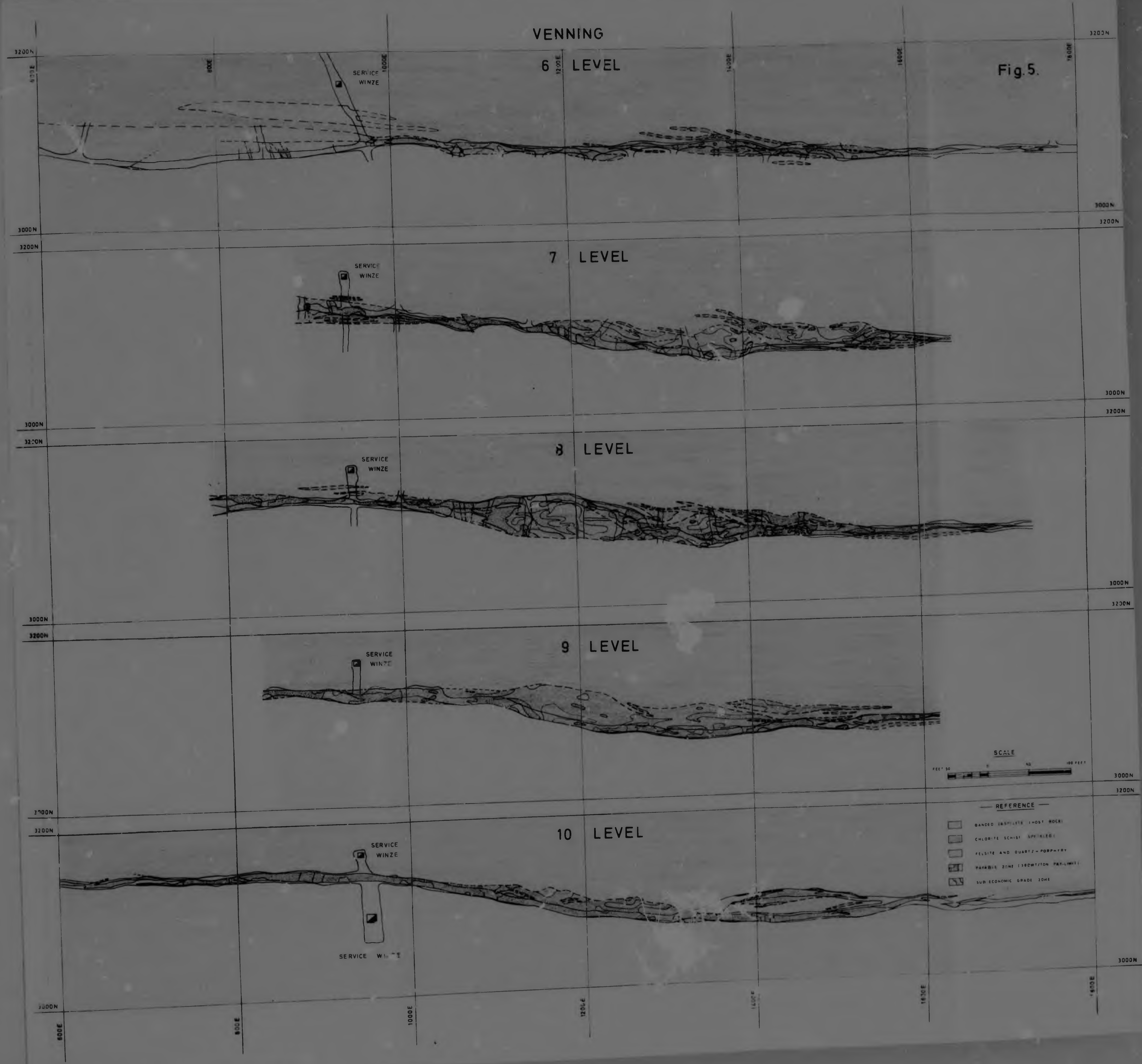
In the area below the dolerite sill detailed geological mapping and sampling were carried out.

The ore shoots of the east portion of the ore zone on 6 level occur on either side of the small area in which the banded jaspilite was eliminated due to strike faulting (Figure 9), and have a strike length of 325 feet. The ore shoots in this area are contained in a pinched zone which suffered strike faulting before the mineralized fluids were introduced. The area in which the banded jaspilite was eliminated by strike faulting on 6 level closes off before reaching 7 level (Figure 9). The pinched zone is bounded on its west and east sides by boudins on 6 and 7 levels (Figure 9), but the pinched zone of the banded jaspilite increases in width with depth and on 8 level the banded jaspilite is almost uniform in width along its strike length. The mineralization on 8 level was controlled mainly by the minor step-faults present along the strike of the banded jaspilite (Figure 10). The presence of two large boudins directly below the development of the ore shoots on 8 level resulted in the ore shoots following the pinched zone in which strike faulting has occurred along the eastern edge of the eastern boudin between 8 and 9 levels (Figure 12 and Figure 10). On 9 level the mineralization was controlled by a minor step-fault on the western side of the ore shoot and a strike fault in the pinched zone (Figure 10). Below 9 level the strike length of the ore shoot shortens considerably and is only 10 feet long on 10 level on the eastern side of the Burnett Shaft (Figure 12).

granite cupola to the east of the Pickstone Mine, appears to be a cupola of intermediate depth, and to have produced forces directed from the east which resulted in the strike faulting of the banded jaspilite after the compressional forces had tilted the banded jaspilite into its vertical position. The strike faulting is mainly associated with the weak pinched zones and is later in age than the boudinage structure. The position of the oblique-dip fault on the eastern side of the Pickstone Mine was possibly determined by the presence of the granite stock, already a solid body, or that the updoming of this stock, as a solid body, gave rise to the forces which produced the fault. The drag-movement of the banded jaspilite on the western side of the oblique-dip fault resulted in step-faulting in the banded jaspilite in this area and occurred after the imposition of the boudinage structure and the strike faulting.

The Pickstone banded jaspilite affords an extremely good example of the development of boudinage structure or pinch and swell structure. The development of boudinage structure, strike faulting and step-faulting resulted in secondary fractures being formed in the banded jaspilite host rock and produced structurally controlled channelways along which the gold-bearing hydrothermal solutions could penetrate and deposit there valuable mineral content.

Fig. 4.
EAST-WEST VERTICAL PROJECTION
CONCESSION HILL S.W.P. CLAIMS
VENNING (7862) CLAIMS
PICKSTONE T.W. CLAIMS
WEST
EAST
CONCESSION SHAFT
SOUTHWELL SHAFT
BURNETT SHAFT
DUCHESE HILL
ROAD PILLAR
MOMBI RIVER
ZERO
-500
-1000
-1500
-2000
2000 W
1000 W
00
1000 E
2000 E
3000 E
4000 E
5000 E
1460 Sub-level
1520 Sub-level
1580 Sub-level
1640 Sub-level
PICKSTONE MINE
SCALE
PLAN OF UNDERGROUND WORKINGS
AS AT
31st MAY 1967
Reference
AREAS STOPED
DOLERITE SILL


VENNING
Fig.5.
6 LEVEL
7 LEVEL
8 LEVEL
9 LEVEL
10 LEVEL
SERVICE WINZE
SCALE
REFERENCE
3200N
3000N
800E
1000E
1200E
1400E
1600E

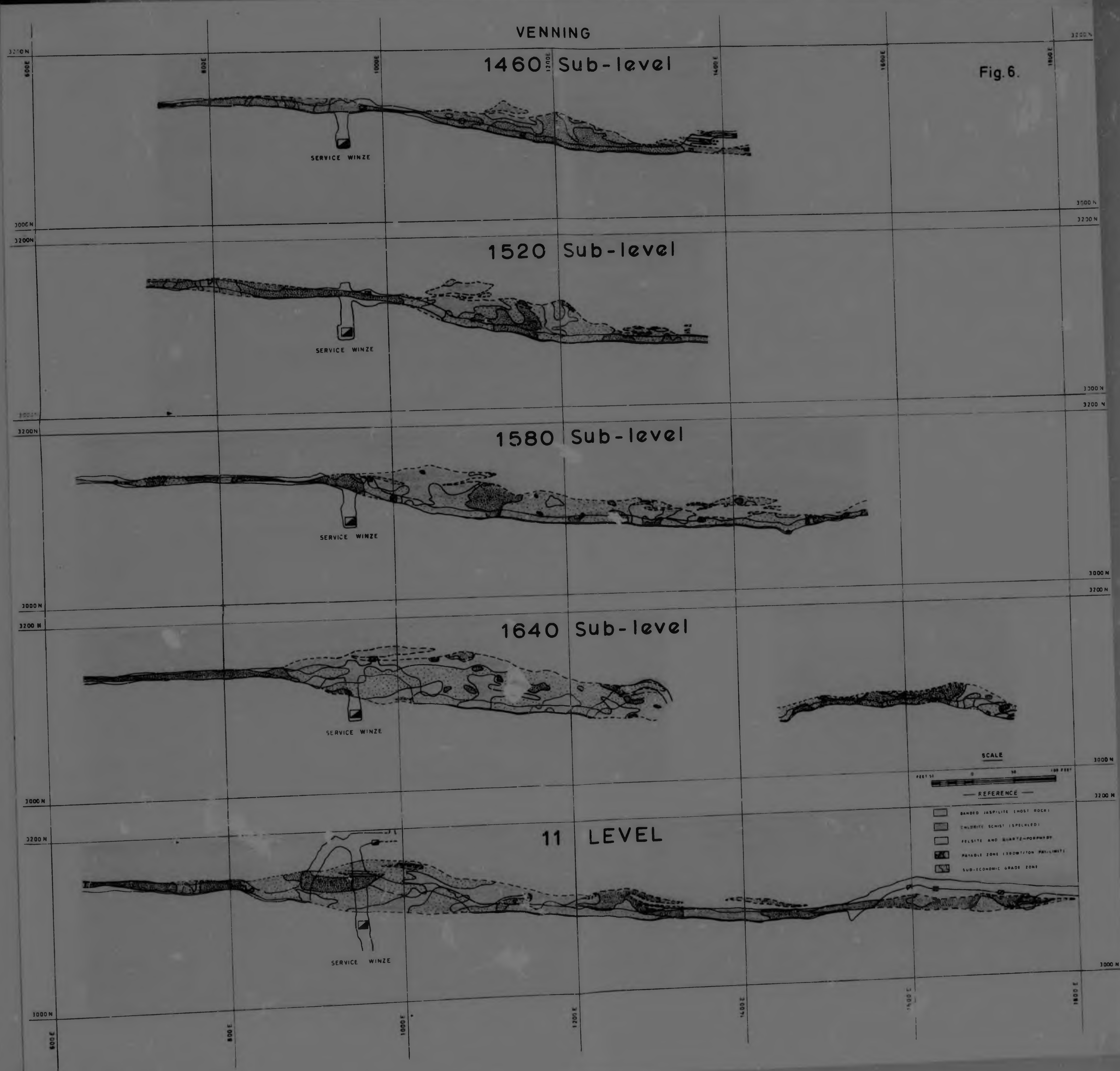

VENNING
1460 Sub-level
1520 Sub-level
1580 Sub-level
1640 Sub-level
11 LEVEL
SERVICE WINZE
SCALE
REFERENCE
BANDED JASPILITE (HOST ROCK)
CHLORITE SCHIST (SPECKLED)
FELSITE AND QUARTZ-PORPHYRY
SUB-ECONOMIC GRADE ZONE
3000 N
3200 N
600 E
800 E
1000 E
1200 E
1400 E

Fig. 6.

Fig. 7.

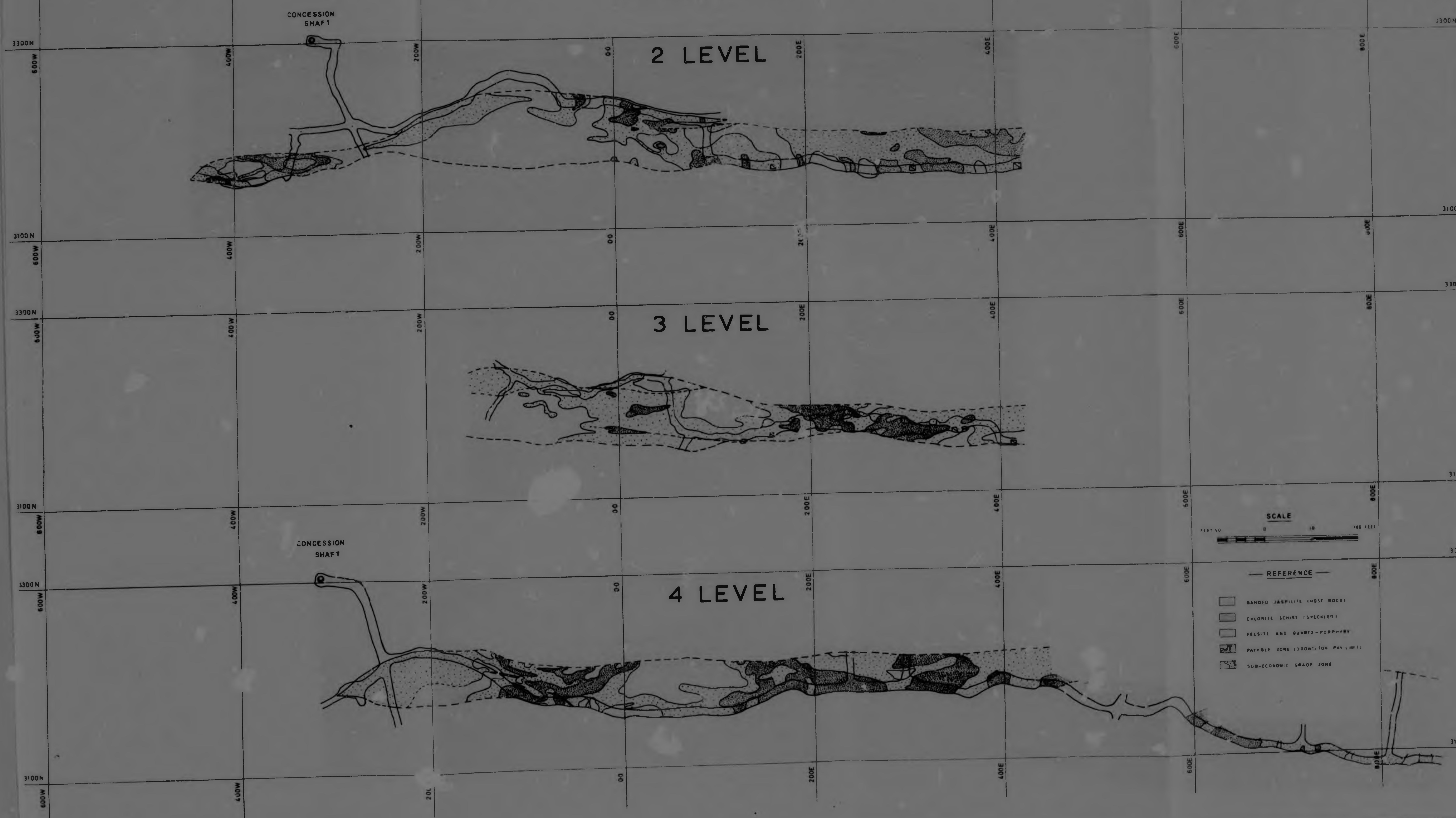
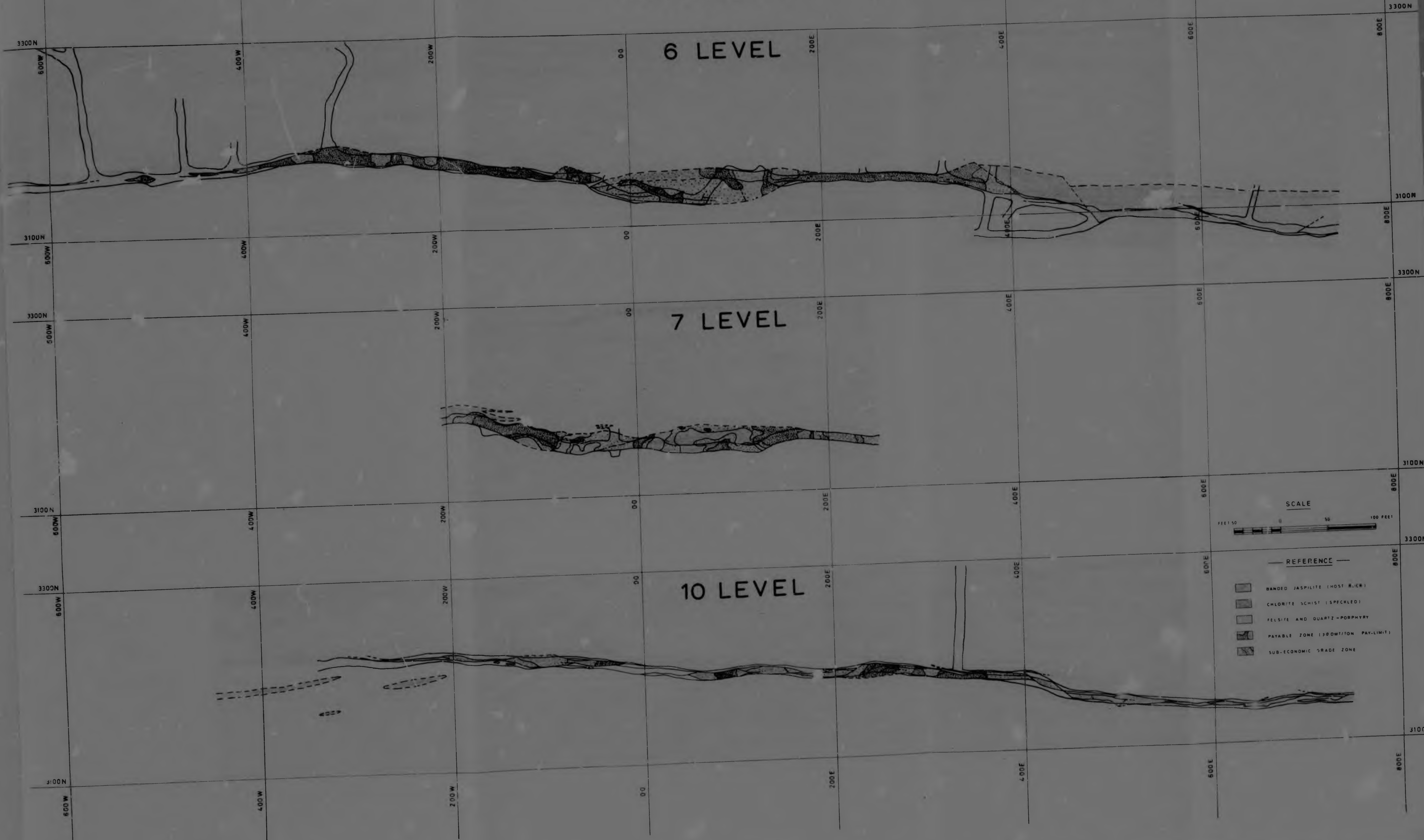
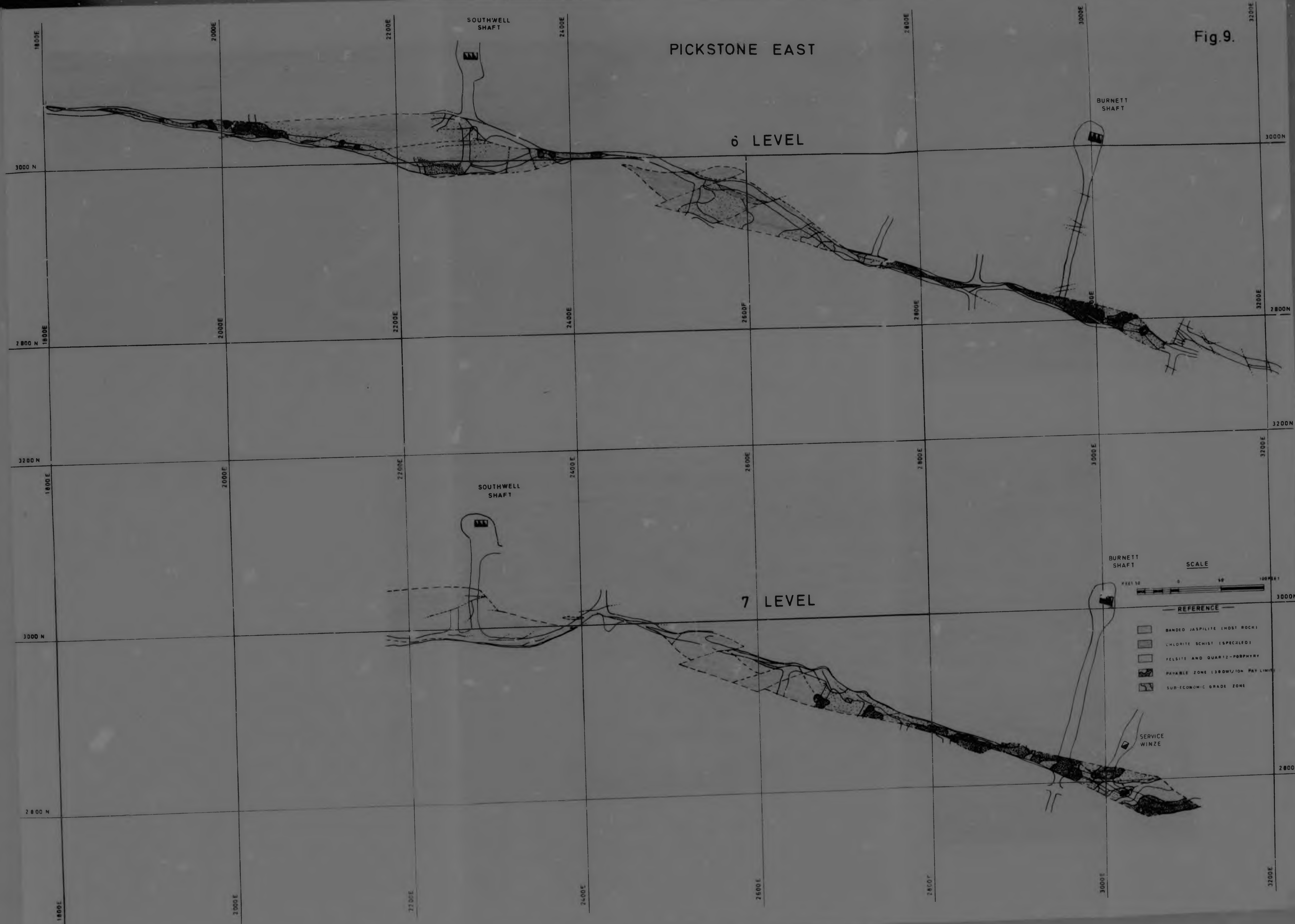

CONCESSION
2 LEVEL
3 LEVEL
4 LEVEL
CONCESSION SHAFT
3300N
3100N
600W
400W
200W
00
200E
400E
600E
800E
SCALE
FEET 50
0
100 FEET
REFERENCE
BANDED JASPILITE (HOST ROCK)
CHLORITE SCHIST (SPECKLED)
FELSITE AND QUARTZ-PORPHYRY
PAYABLE ZONE (3·00WT/TON PAY-LIMIT)
SUB-ECONOMIC GRADE ZONE

Fig. 8.

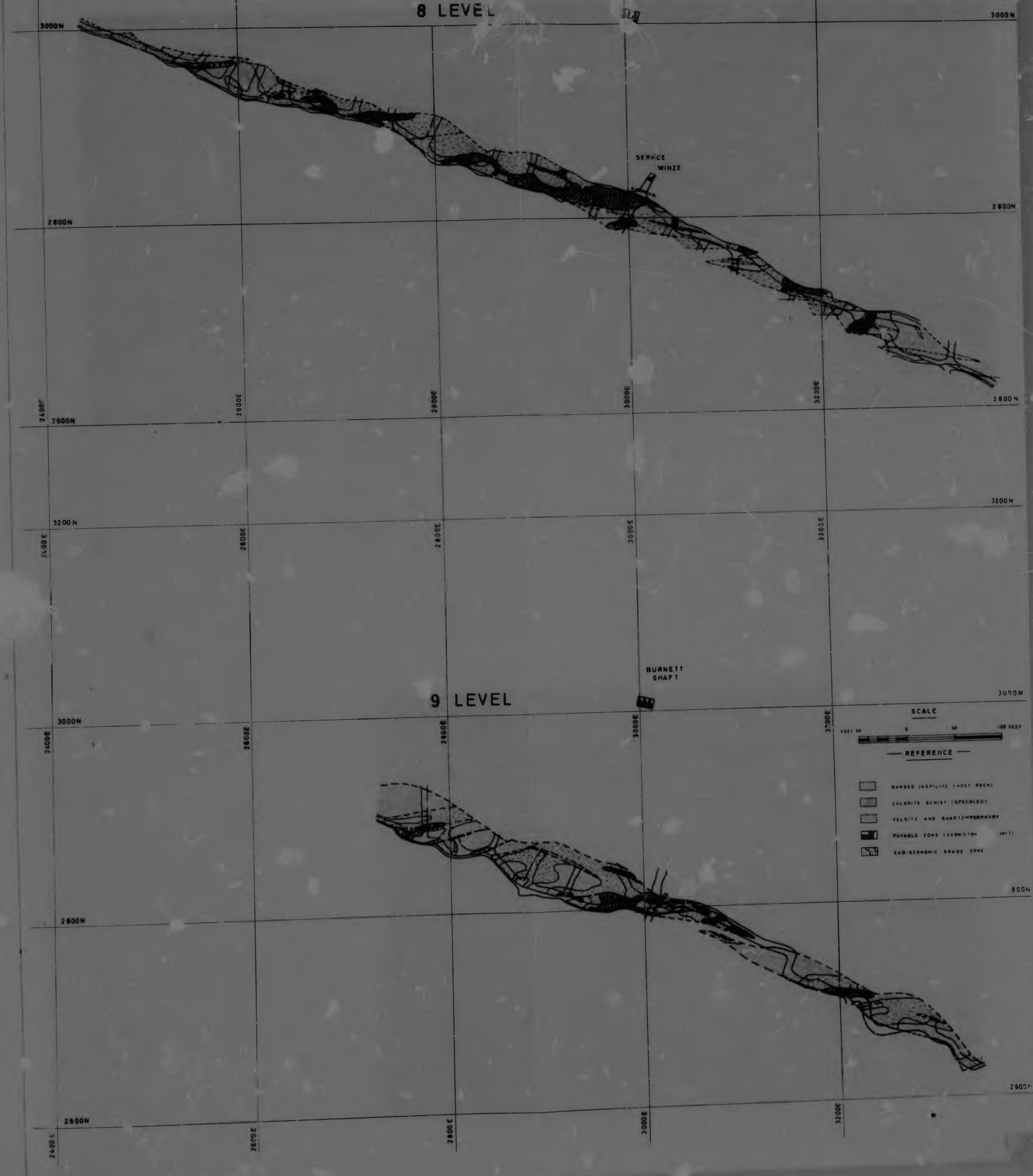
CONCESSION




PICKSTONE EAST
Fig.9.
SOUTHWELL SHAFT
BURNETT SHAFT
6 LEVEL
7 LEVEL
SERVICE WINZE
1800E
2000E
2200E
2400E
2600E
2800E
3000E
3200E
3000N
2800N
3200N
SCALE
FEET 50
0
50
100FEET
REFERENCE
BANDED JASPILITE (HOST ROCK)
CHLORITE SCHIST (SPECKLED)
FELSITE AND QUARTZ-PORPHYRY
PAYABLE ZONE
SUB-ECONOMIC GRADE ZONE

PICKSTONE EAST

Fig.10.



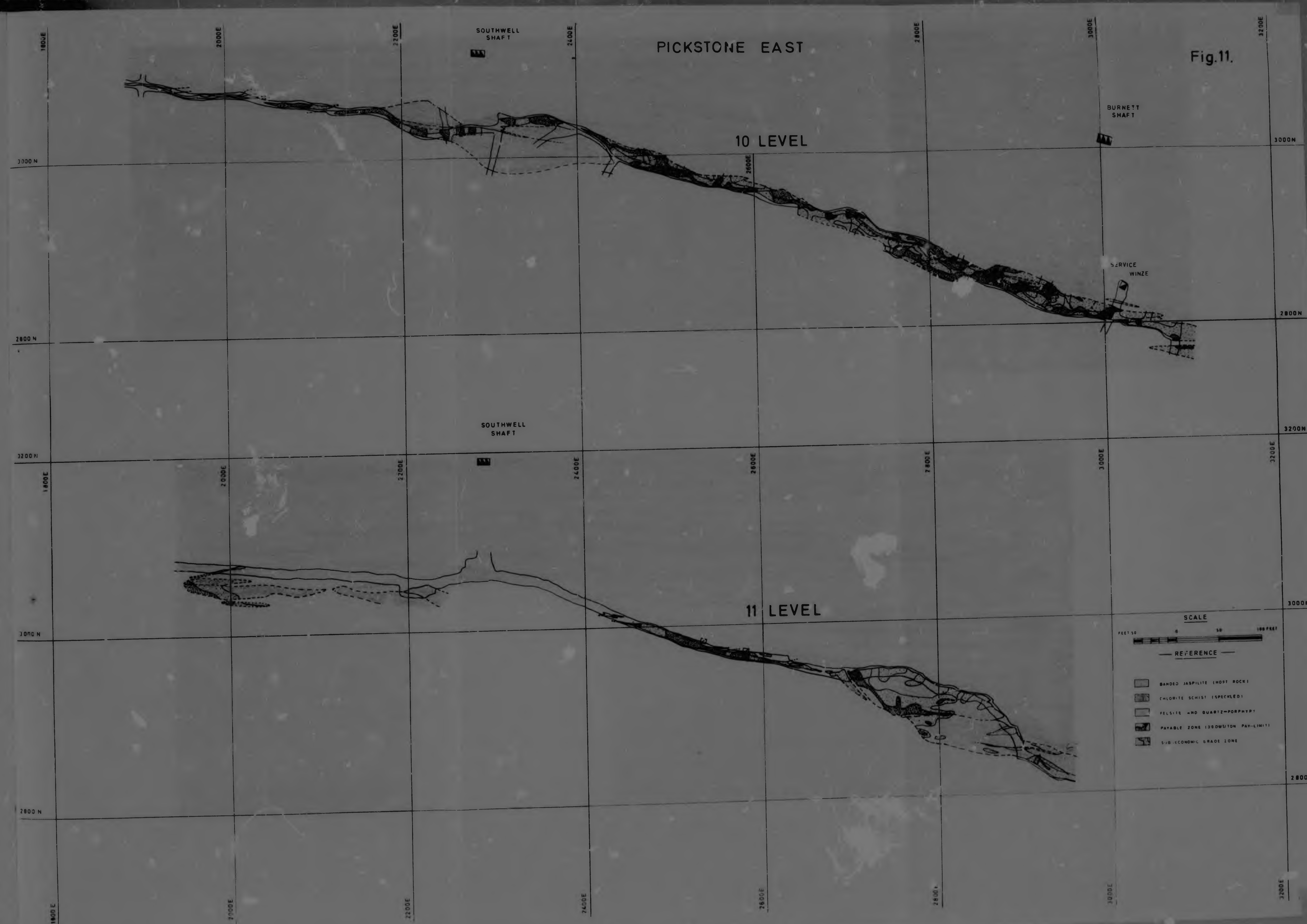

PICKSTONE EAST
Fig.11.
10 LEVEL
11 LEVEL
SOUTHWELL SHAFT
SOUTHWELL SHAFT
BURNETT SHAFT
SERVICE WINZE
1800E
2000E
2200E
2400E
2600E
2800E
3000E
3200E
3000N
2800N
3200N
SCALE
FEET 50
0
50
100 FEET
REFERENCE
BANDED JASPILITE (HOST ROCK)
CHLORITE SCHIST (SPECKLED)
FELSITE AND QUARTZ-PORPHYRY
PAYABLE ZONE (3 DWT/TON PAY-LIMIT)
SUB-ECONOMIC GRADE ZONE


Fig.12.
CONCESSION ORE SHOOTS
VENNING ORE SHOOTS
PICKSTONE EAST ORE SHOOTS
WEST.
EAST.
CONCESSION SHAFT
ROAD
MOMRI RIVER
SOUTHWELL SHAFT
BURNETT SHAFT
PILLAR
2 LEVEL
3 LEVEL
4 LEVEL
5 LEVEL
6 LEVEL
7 LEVEL
8 LEVEL
9 LEVEL
10 LEVEL
1460 SUB-LEVEL
1520 SUB-LEVEL
1580 SUB-LEVEL
1640 SUB-LEVEL
11 LEVEL
PICKSTONE MINE
SCALE
Feet 100 0 100 200 300 400 Feet
EAST-WEST VERTICAL PROJECTION
SHOWING THE RELATIONSHIP OF
ISOPACHS AND THE ORE SHOOTS
Reference
ISOPACHS AT 5' INTERVALS OF THE BANDED JASPILITE (HOST ROCK)
ORE SHOOTS (3 ODWT/TON PAY-LIMIT)
PROJECTED ORE SHOOTS USING OLD STOPES AND SURFACE WORKINGS
LOSS OF BANDED JASPILITE DUE TO STRIKE FAULTING
DOLERITE SILL

X. MINING VALUATION AND UPGRADING

(a) Mining Methods

After having proved substantial ore reserves and the installation of a 7,500 tons per month all-sliming plant, full-scale mining operations were commenced during 1956. At this early stage mining activities were confined to the shallow oxidised zone, where the walls were unsound, and excess water proved problematical.

The stoping method employed was cut and fill with a 10-15 feet lift being taken. During breaking the boxholes were kept open with mopani cribbing, which was then removed and the ore passed through these boxholes to be drawn on the level below. As the stope was drawn the ore passes were extended upwards using concrete bricks, forming a 5 feet diameter pass. The stope was filled with waste and the cycle repeated. Shrinkage stoping was also employed in the oxidised zone of the mine, with 30 feet lifts being taken, but as two thirds of the broken ore had to be retained in the stope until the floor pillar had been reached, this method was abandoned.

As the mine workings deepened to the sulphide zone, underhand stoping was introduced in which a 15-20 feet bench was carried down to the crown pillar horizon, before the next bench was started. Boxholes were raised from the level ahead of the retreating stope face. Although the ore shoots are continuous in the vertical plane the payable zones were found to fluctuate continuously within the broad host rock, and as the vertical distance between levels was 150 feet, selective mining of the payable zones within the host rock was not possible. Thus it was necessary to stope to the full width of the host rock adding greatly to the dilution problem. A further set-back to this method of mining, besides this lack of control, was the large amount of development required in preparing blocks of ore for stoping.

In order to minimise these dilution problems sub-level stoping is at present employed below 10 level. Main haulages are spaced at 300 feet vertically apart and the ore is handled by 48 cubic feet Granby cars to the Southwell Shaft for hoisting. Sub-levels with 9 feet by 8 feet dimensions are placed 60 feet vertically apart and are served by a service winze capable of carrying wagon drills and T 2G loaders. In the sections where the payable zones have mean widths less than 10 feet, jack-hammers are used to underhand stope the ore. In the wider payable zones, some of which exceed 45 feet, long-hole machines are used to drill 30 feet vertical up and down holes, and the ore broken on these sub-levels falls vertically to coned draw-points on the crown pillar of the main haulage. The introduction of sub-level stoping has resulted in a substantial saving in the cost per ton of ore mined and has allowed the mined tonnage to increase from 7,500 tons per month to 15,000 tons per month without increasing the labour strength of the mine.

(b) Mine Sampling

The sampling of the broad banded jaspilite host rock has always been a difficult and costly operation.

Main haulages and sub-levels are driven on the less disturbed and more regular south contact between the banded jaspilite host rock and the felsite and quartz-porphyry. The host rock adjacent to this south contact is also generally better mineralized than its northern counterpart. Sampling of these drives is carried out by taking 3 feet chip samples across the daily advancing faces, giving a mean drive sampling interval of approximately 5 feet. The remaining portion of the wide banded jaspilite host rock is sampled using horizontal short-hole diamond drilling directed at right angles to the strike of the host rock, and spaced at 10 feet intervals. The diamond drill core size is E.X.U. and this core is sampled at 3 feet intervals, the whole of the core being assayed. The diamond drill machines used on the Pickstone Mine are the 8 horsepower C.P.55A., and the 12 horsepower C.P.65. These machines are operated by African crews consisting of two men per crew and the overall cost per foot drilled is of the order of 10 shillings.

Sampling of the newly developed Concession oxidised zone on the Pickstone Mine is accomplished using a B.B.X.65. Atlas Copco rock drill with 3 feet and 6 feet extension steels capable of drilling a 65 feet long hole. These drill holes are inserted at right angles to the strike of the host rock and angled upwards at 10° to the horizontal. A short 2½ inch wide starter hole is drilled and a T-piece is tapped into this hole. The T-piece is attached by a thick hose to a cylindrical drum, the bottom of which is coned, and a tap is fitted to the side of the cylinder in line with the brim of this cone. The drilling is carried through the T-piece using 41-38 millimetre tungsten bits, and the sludge is collected in the cylinder at the end of each 3 feet run, the sludge settling in the coned bottom of the cylinder. A small amount of the deflocculating agent Separans is added to the contents of the cylinder, causing all the fine particles in the water above the sludge to immediately sink. The almost pure water remaining in the cylinder above the cone is then tapped off. The sludge in the cone is removed and placed into plastic sample bags. The shift footage drilled is approximately 65-80 feet at an estimated cost per foot drilled of approximately 4 shillings.

Plans, on a scale of 1 inch equals 10 feet combining the geology, the assay results compiled from all of the sampling, and the outlined ore zones that require preparation for stoping, are drawn up for all the levels. Drive sampling, core sampling and sludge sampling are all taken over similar widths, namely 36 inches, so that it was possible to use these assay results as an accurate basis for drawing the graphs illustrated in Figure 13. In order to produce these graphs a total of 2,638 sample values taken from level plans of the Venning, Concession, and Pickstone East ore shoots were split into two pennyweight groups, for example 0-2 dwts, 2-4 dwts, 4-6 dwts, etc. In the case of the group 0-2 dwts, all of and a T-piece is tapped into this hole. The T-piece is attached by a thick hose to a cylindrical drum, the bottom of which is coned, and a tap is fitted to the side of the cylinder in line with the brim of this cone. The drilling is carried through the T-piece using 41-38 millimetre tungsten bits, and the sludge is collected in the cylinder at the end of each 3 feet run, the sludge settling in the coned bottom of the cylinder. A small amount of the deflocculating agent Separans is added to the contents of the cylinder, causing all the fine particles in the water above the sludge to immediately sink. The almost pure water remaining in the cylinder above the cone is then tapped off. The sludge in the cone is removed and placed into plastic sample bags. The shift footage drilled is approximately 65-80 feet at an estimated cost per foot drilled of approximately 4 shillings.

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In the ore reserve valuation, a density factor of 10.8 cubic feet per short ton is used. Ore blocked out and valued using two sub-levels 60 feet vertically apart constitute the primary ore category. When values are only available from one sub-level the tonnage derived from a 60 feet vertical projection of this zone of values is classified as probable ore.

(c) Methods of Upgrading

Although the Pickstone ore shoots persist in the vertical plane, the fluctuating pattern of the payable zones within the banded jaspilite host rock led to an acute dilution problem, particularly during the period when mining operations were predominantly confined to the Venning Ore Shoots between 6 and 10 main levels, where these main levels were spaced 150 feet vertically apart. Methods of ore beneficiation were subsequently carried out which involved preliminary tests incorporating hand sorting of waste material, heavy media concentration, flotation (coarse material), mineral jigs, and pneumatic sorting employing induced electro-conductivity (Wate Sorters).

Hand Sorting of Waste Material

Preliminary hand sorting tests, whereby waste material was removed from the ore, were performed by members of the technical staff and the writer.

Tests were conducted on run-of-mine ore, which was screened at 2½ inches.

Screened Size	Weight (lbs)	Value (dwts/ton)
+ 2½ "	5,492	8.31
- 2½ "	22,911	5.22
Fines washed from +2½"	158	4.90
TOTAL	28,561	5.80

The plus 2½ inch product was washed and sub-divided into the following categories for hand sorting:

(1) Banded jaspilite showing strong sulphide mineralization -- ORE

(2) Banded jaspilite showing poor sulphide mineralization -- MIDDLING

(3) Barren banded jaspilite and wall-rocks -- WASTE

	Product	Weight (lbs)	Value (dwts/ton)
(1)	Ore	3,438	12.6
(2)	Middling	881	1.51
(3)	Waste	1,173	0.72
	Total	5,492	8.31

induced electro-conductivity (Wate Sorters).

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The middling and waste products together represent the total hand sorted waste material amounting to 7½ per cent of the total sample of run-of-mine ore tested. The original run-of-mine ore of 28,561 pounds averaging 5.80 pennyweights per ton minus the waste sorted becomes 26,507 pounds averaging 6.17 pennyweights per ton.

At present hand sorting of waste material on surface is the only form of ore beneficiation in operation on the Pickstone Mine, the washing and sorting taking place prior to the primary crushing.

Heavy Media Concentration

Heavy media concentration tests were carried out on Pickstone Mine ore by a firm of consulting engineers in South Africa.

Mean specific gravity tests conducted on the rock types constituting the Pickstone Mine ore were as follows:

Rock Types	Mean Specific Gravity
Mineralized banded jaspilite	3.35
Banded jaspilite	2.99
Speckled chlorite schist (Wall-rock)	2.86

Heavy media concentration tests were carried out on Pickstone Mine ore using ferro-silicon as a medium. The following tabulation shows the mean results obtained by varying the specific gravity of the ferro-silicon medium.

TYPICAL RECOVERIES OF CYCLONE SECTION

A. BASED ON AVERAGE RESULTS AT 3.15 SPECIFIC GRAVITY OF SEPARATION

HEAD	PRODUCT (Sink)			TAILS (Float)		
ASSAY	Wt. %	Assay	Recovery	Wt. %	Assay	Recovery
5.28	48.41	10.48	90.84%	51.13	1.0	9.16%

B. BASED ON AVERAGE RESULTS AT 3.25 SPECIFIC GRAVITY OF SEPARATION

4.6	30.20	15.4	80.44%	69.79	1.82	19.56%
5.8	34.64	12.54	76.87%	65.36	2.00	23.13%

C. BASED ON AVERAGE RESULTS AT 3.05 SPECIFIC GRAVITY OF SEPARATION

4.6	54.79	9.8	90.60%	45.25	1.23	9.40%
5.8	67.23	7.80	92.27%	32.77	1.35	7.73%

TYPICAL RECOVERIES OF SPIRALS SECTION

BASED ON SPIRAL TESTS ON - 1mm + 150 MESH ORE

5.25	19.45	18.00	75.24%	80.55	1.43	24.70%
5.25	19.1	21.20	78.51%	80.90	1.37	21.49%
5.25	22.9	17.00	77.69%	77.10	1.45	22.31%

The best result obtained for the cyclone section was with the medium having a specific gravity of separation of 3.15, the sink or up-graded ore being 48.41 per cent by weight with the float or waste being 51.13 per cent at the comparatively low value of 1.0 pennyweights per ton. It is interesting to note that the fines of the spiral section carried the high waste rating of approximately 80 per cent by weight, probably due to the high degree of splintering during blasting of the silica bands as opposed to the more compact sulphide-replaced siderite bands.

These tests were exceptionally promising, but the capital outlay for the installation of a heavy media plant designed to treat 50 tons per hour was considered to be too high for this size of mine.

Flotation

Members of the technical staff conducted a series of flotation tests using a Unit Cell which operates most effectively on pulp of a high density. The purpose of these tests was to prove whether, a large percentage concentrate could be separated from a relatively coarse product (-10 mesh), and in so doing reduce the amount of material which would require fine-grinding. For these tests, samples were taken from the classifier underflow and from the ball mill feed.

In tests 7 and 8 the classifier underflow sample was screened through 10 mesh screen and the plus 10 mesh product discarded.

Screen analysis of the whole sample used in both tests.

+10	4.7%
+35	33.8%
+100	37.2%
+200	11.0%
+325	2.1%
-325	11.2%

TEST 7

A sample was conditioned for 5 minutes and two concentrates of 3 minutes and 2 minutes taken.

The reagents used were as follows:

$CuSO_4$	- 0.25 lbs/ton	R301	- 0.12 lbs/ton
Z6	- 0.08 lbs/ton	Pine oil	- 0.10 lbs/ton

Flotation tails	7.63 dwts/ton
Concentrate 1	38.80 dwts/ton
Concentrate 2	32.70 dwts/ton
Calculated Head Value	10.30 dwts/ton
Extraction	34.9%
Concentrates	9.0%
Moisture	64.0%

TEST 8

The reagents used were as for Test 7 except that in place of the Pine oil, Dowfroth of 0.10 lbs/ton was used.

Flotation tails	3.98 dwts/ton
Concentrates 1	76.90 dwts/ton
Concentrates 2	38.40 dwts/ton
Calculated Head Value	10.80 dwts/ton
Extraction	63.0%
Concentrates	11.5%
Moisture	70.0%

TEST A

This test was on a sample of Ball Mill feed, which was screened through 8 mesh and 14 mesh screens giving the following:

-4 + 8 mesh - 855 grams at 3.5 dwts/ton

-8 + 14 mesh - 652 grams at 3.2 dwts/ton

-14 mesh - 1083 grams

The -14 mesh product was conditioned for 10 minutes with $CuSO_4$ (0.25 lbs/ton), then floated for 1 minute with Z6 (0.08 lbs/ton), R301 (0.16 lbs/ton), and Dowforth (0.082 lbs/ton). Total flotation time was 3 minutes. The concentrates were weighed and assayed, the tails graded and the fractions assayed.

Concentrates	138 grams at	23.4 dwts/ton
Tails +35	381 grams at	2.8 dwts/ton
+100	208 grams at	1.6 dwts/ton
+200	69 grams at	0.45 dwts/ton
-200	283 grams at	0.55 dwts/ton

Calculated Head Value on -14 mesh - 4.46 dwts/ton

Calculated Tail Value on -14 mesh - 1.68 dwts/ton

Percentage extraction on -14 mesh - 62.3%

It was proved from the numerous tests that were carried out that the percentage extraction was too low and that extraction was almost negligable on the +35 mesh sizes.

Mineral Jigs

Members of the technical staff carried out preliminary tests using a laboratory jig which at that stage gave promising results. A 18 inch by 24 inch jig was installed in the

Pickstone plant to take classifier underflow as a feed. After considerable teething problems jig tests were shown to give the following approximate means:

Percentage concentrates - 45% at 7.0 dwts/ton

Tails concentrates - 55% at 1.7 dwts/ton

The tests were disappointing due to the high percentage of fines at high values, reporting in the relatively high percentage tails concentrates.

Pneumatic Sorting (Wate Sorters)

This method of sorting is only described in general as test figures are not available.

After primary 2½ inch crushing the ore was sized, dried, and passed over the wate sorters. These wate sorters, using extremely high voltages, induce electro-conductivity through sulphide mineralized rocks that are passed between contacts, electronically triggering off pneumatic blasts, which diverted the mineralized rocks into separate collecting bins.

(d) Gold Outputs

A gold slime concentrate is produced on the Pickstone Mine and is transported to the Cam and Motor Mine plant for refining and the production of gold bars. Assay results showing the gold and silver fineness ~~in parts per thousand~~, together with the calculated impurities are illustrated in graph form in Figures 14 and 15, covering the periods from 1957 to 1959, and from mid-1963 to mid-1966 respectively. These graphs indicate that during certain periods of time the fineness of the gold fluctuated strongly while at other times it remained relatively steady. Furthermore, the fineness of the silver in these gold bars remained extremely steady at all times, leading to the conclusion that there is a direct inverse relationship between the gold and impurities present in these gold bars and that the variation in the fineness of the bullion produced is not due to significant variation in silver content. The impurities are thought to consist essentially of iron, which is present in the iron-rich sulphides, copper in the form of chalcopyrite usually as fillings in cracks and between the interlocking boundries of the arsenopyrite and pyrite, and minor amounts of nickel which are detected as a green staining on the cupels during assaying.

The ratios of the oxidised to sulphide ores milled during these periods in which the fineness of the gold was either comparatively constant or fluctuated considerably, were calculated using the tonnages drawn from the oxidised and sulphide stopes. These ratios

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