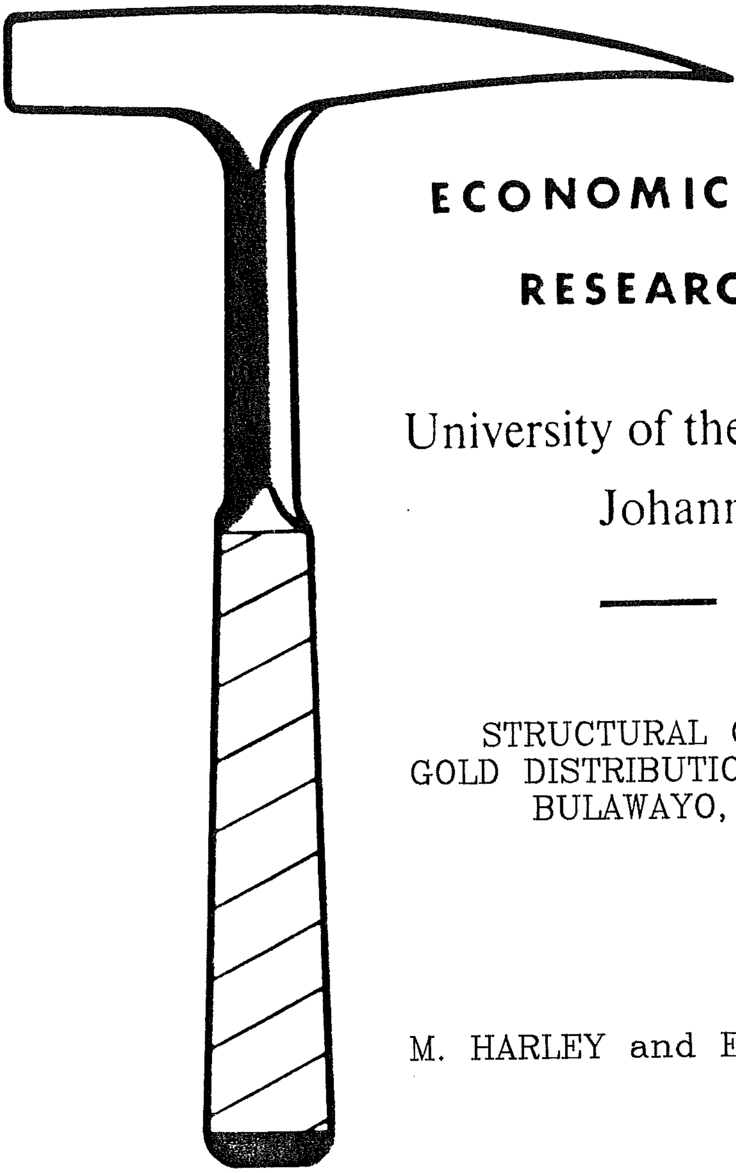

ECONOMIC GEOLOGY RESEARCH UNIT

University of the Witwatersrand
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STRUCTURAL CONTROLS TO GOLD DISTRIBUTION AT HOW MINE, BULAWAYO, ZIMBABWE

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INFORMATION CIRCULAR No. 224

UNIVERSITY OF THE WITWATERSRAND
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by

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September, 1990

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ABSTRACT

How Mine is situated in the south eastern quadrant of the Bulawayo greenstone belt within sediments and volcaniclastic rocks of the late Archaean Dacitic Greenstone Formation of the Upper Bulawayan Group. Sited on the northern limb of a northeast-verging syncline, the mine comprises several ore zones which occur as an en echelon array of parallel, steeply plunging linear shoots. These are confined within an extensional, right-stepping, northerly-trending strike-slip duplex. Faulting has followed preferred lithological contacts.

Mineralization is dominated by a pyrite-gold association and occurs as disseminations within altered mylonites ("felsites") and tuffs, as fabric replacement within tuffs and associated with veins in siltstones and iron formations. Accessory magnetite in tuffs and magnetite layers in iron formation are replaced by pyrite, and ore textures suggest an epigenetic origin to the mineralization. Alteration is widespread and dominated by carbonation, sulphidization, and propylitic alteration.

Permeability within the duplex was generated by slip and dilation of the synclinal axial-planar cleavage, which lies at a high angle to the strike of the duplex. Early ductile deformation is overprinted by later brittle faulting which cuts early mineralization. The linear ore zones parallel the intersection lineation between the pre-existing cleavage and the duplex fault/shear zones. In the north of the mine, ore zones are developed within the fault-bounded tuff unit (e.g.the 180 North ore zone) but in the south the ore zones parallel the Hangingwall Fault/Shear Zone and transgress major lithological contacts.

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STRUCTURAL CONTROLS TO GOLD DISTRIBUTION AT HOW MINE, BULAWAYO, ZIMBABWE

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Published by the Economic Geology Research Unit
Department of Geology
University of the Witwatersrand
1 Jan Smuts Avenue
Johannesburg 2001

ISBN 1 86814 188 8

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1. INTRODUCTION

How Mine is situated in southwest Zimbabwe approximately thirty km southeast of Bulawayo (Fig.1). The property was discovered and registered in 1941. Subsequently, the mine was owned by the Halo syndicate, who undertook opencast mining of the ore zone to a depth in excess of 30 m. During 1950-1951 the Mine was let on option to Goldfields Rhodesia Development Company and detailed exploration work undertaken by them showed that the ore zone extended 200-220 m south of the opencut. Detailed diamond drilling undertaken by Frobisher Limited in 1952-1953 proved the existence of a large tonnage of ore with an average grade of 3,5 g/t. Ballarat Mines (Pvt.) Ltd. took over the options on the mine in 1954 and sank a vertical shaft between the two existing opencuts. Underground development ceased in 1956 due to extraction difficulties, but the mine operated almost continuously with the aid of government loans until 1973, when Lonrho took over the property under the name of the Rhodesian Gemstone Mines (Pvt.) Ltd. Currently, the mine is operated by a subsidiary company, Independence Mining (Pvt.) Ltd. Production is in the order of 180 000 t milled per annum at an average grade of 6,6 g/t. Average gold production is 920 kg per annum with a recovery efficiency of approximately 85%.

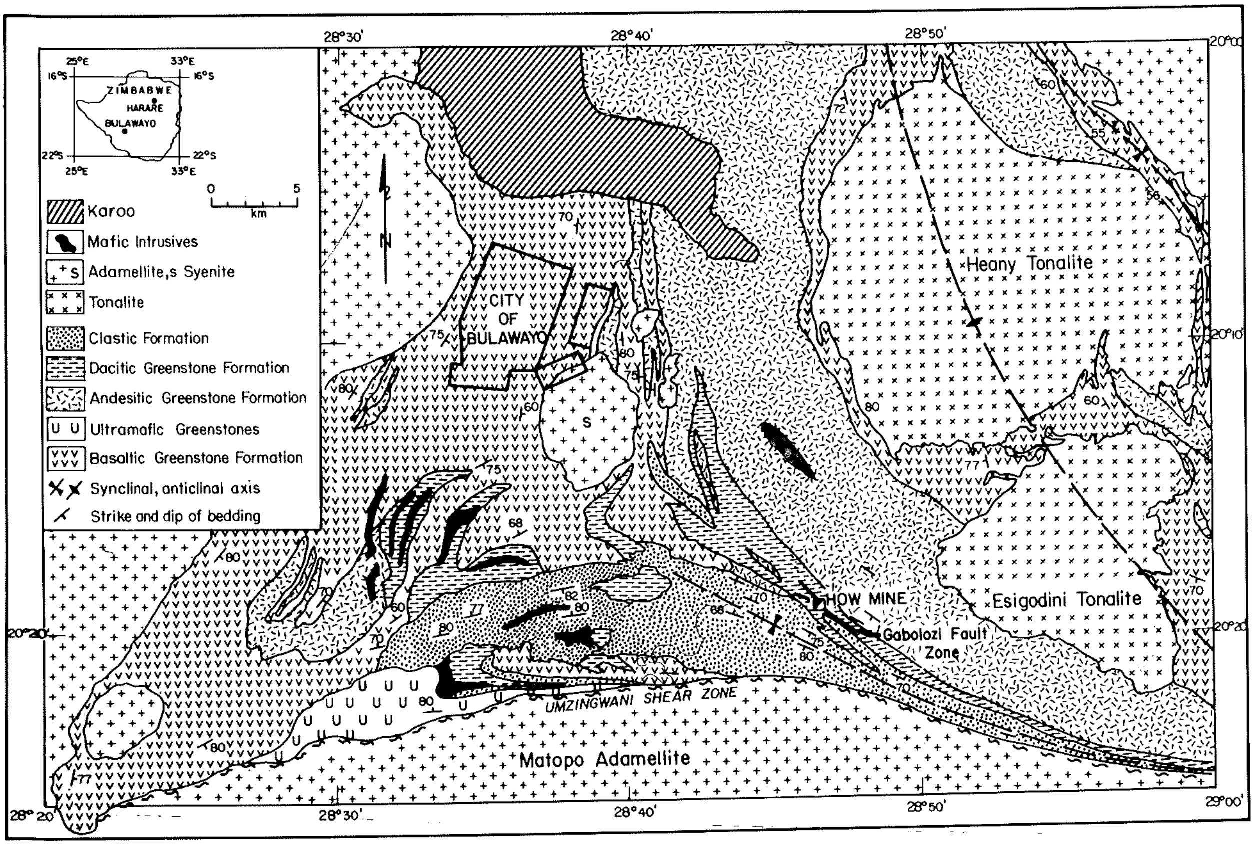

Figure 1: Regional geological map of the Bulawayo greenstone belt showing the locality of How Mine (after Wilson, 1976; Fountain, 1981, 1983; and Amm, 1940).

The geology of the mine has been documented in some detail by Barker (1978) and Minne (1982), both of whom emphasised the importance of host-rock type as a primary control to the distribution of gold. Barker (1978) concluded that the gold was syngenetic, although later remobilization into suitable structurally controlled sites was suggested. Similar conclusions were drawn by Minne (1982), although neither worker adequately defined or described the nature of the structural controls to gold distribution. Foster *et al.* (1986) quoted these generally accepted views in their summary of Zimbabwean gold deposits. Foster (1988) classified Zimbabwean gold deposits into three categories; lode deposits, banded iron-formation-hosted deposits and volcaniclastic-hosted deposits. How Mine falls into the last category. Other mines in this class, e.g. Shamva and Nando Mines, are considered to be modified syngenetic deposits (Foster, 1988) and a similar genetic model has also been applied to How Mine.

The purpose of this paper is to present new data on previously overlooked structural features and their influence in the distribution of gold at the How Mine. The writers also question the syngenetic origin of the gold and present evidence to support epigenesis.

11. REGIONAL GEOLOGICAL SETTING

How Mine is situated in the southeastern quadrant of the Archaean Bulawayo greenstone belt which has the form of a large tricuspate synclinorium of supracrustal rocks preserved in a granitoid terrane (Amm, 1940). Three generations of granitic intrusives have been recognised (Garson, 1983), the oldest being the c.2.7 Ga old Sesombi Suite, which includes the Esigodini and Heany Tonalites. These granitoid bodies occur along the northwest-trending boundary of the greenstone belt (Fig. 1). The Chilimanzi Suite, represented by the Matopo Adamellite occurs along the southern margin of the Belt. The contact zone between the greenstones and this adamellite is preserved as the broad east-trending Umzingwani Shear Zone (Stowe, 1980). The third intrusive magmatic event within the belt is represented by a polyphase granite-syenite Complex, the Hillside Syenite, which is well-exposed in the southern part of the Bulawayo townlands.

The Bulawayo greenstone belt (Wilson, 1979) is composed predominantly of mafic-to-intermediate volcanics, minor komatiites, felsic volcanics and pyroclastic rocks, and chemical and clastic sediments of the c.2,8 Ga Upper Bulawayan Group. Stratigraphic relationships within the Belt have been discussed in detail by Amm (1940), Fountain (1981, 1982) and Wilson (1976, 1979). The most comprehensive lithological descriptions have been presented by Amm (1940) and subsequently revised by Fountain (1982) (Table 1).

Table 1: Comparative stratigraphic nomenclature for the eastern Bulawayo Greenstone Belt

Amm (1940)	Wilson (1976)	Fountain (1982)	~~Wilson et al (1978)~~
Phyllite Group	Phyllite Formation	Clastic Formation	
Conglomerate Group	Dacitic Formation	Dacitic Greenstone Formation	Calc Alkaline Suite
Upper Greenstone Group			
Andesite and Agglomerate	Andesite Formation	Ultramafic Greenstone Formation Andesite Formation	Bimodal Suite
Lower Greenstone Group	Epidiorite Formation	Basaltic Greenstone Formation	Tholeiite Basalt Suite

How Mine is underlain by rocks of the Dacitic Greenstone Formation (Fountain, 1982) which crop out mainly in the southeast part of the belt, and comprise tuffaceous rocks with a quartz-feldspar mineralogy. Lapilli tuffs, coarse agglomerates, as well as conglomerates derived from pre-existing volcanics have also been described. Fine-grained argillaceous sediments (mainly shales) occur interbedded with the pyroclastic rocks, frequently with gradational contacts. Closely associated with the shales are small, discontinuous, lensoid bodies of iron formation (Fountain, 1982) and locally developed limestone lenses (Amm, 1940).

The eastern part of the Bulawayo greenstone belt consists of a large-scale, northwesterly trending, upright anticlinal structure, bounded by synclinoria to the north and south (Wilson, 1976) (Fig.1). The southern synclinorium consists of a series of isoclinally folded rocks, predominantly of the Dacitic Greenstone Formation and overlying Clastic Formation (Amm, 1940). Notably, southeast of How Mine, these formations become attenuated along strike, and are sub-vertical in attitude, with the development of a prominent, steeply-oriented foliation. The southern contact with the Matopo Adamellite is marked by the sinistral Umzingwani Shear Zone (Stowe, 1980) (Fig.1) which truncates stratigraphy in the extreme eastern part of the belt and extends at least 60 km along the contact into the surrounding granitoids.

111. HOW MINE GEOLOGY

Strata at How Mine dip steeply to the southwest and young to the south along the northern limb of a northwesterly trending syncline situated within the southern synclinorium. M.C. Barker (unpublished data) produced a surface map of the mine, presented in a modified form as Figure 2. He also mapped the mine workings and environs on 8 Level (280 m) using borehole correlations (Fig. 3). Vertical correlation between the two maps is poor and shows the impersistent nature of the rock units in the mine area. A lens-shaped tuff sequence, which may attain 50 m at its thickest extent, occurs in the centre of the mapped area. Based on mineralogical and textural differences, Barker (1978) and Minne (1982) recognised several types of tuff within the lens. The tuffs contain quartz clasts set in a quartz and plagioclase groundmass, and have been mapped as dacitic and rhyolitic tuffs (Barker 1978 and unpublished data). Small lenses of fine-grained black graphitic argillite and massive black siltstone occur intercalated within the tuffs. Argillites, cherts, and iron formations also occur as laterally impersistent lenses, with their longest dimensions aligned within the foliation. The iron formations are black and show a poorly defined lamination with iron-rich and iron-poor cherty or more commonly, silty layers. Laminae may range from 1 mm to about 2 cm, but are most commonly in the order of 5 to 10 mm in thickness. Magnetite is visible and is the major component in the iron-rich layers. Quartz clasts, similar to those in the tuffs, are common in the peripheral zones of the iron formation lenses and have been recognised within some laminae, indicating contamination of the chemical sediments by pyroclastic material. Thin, black or less commonly, white and grey brecciated chert layers may cap the iron formations. A single lens may range up to 100 m in strike length, with a similar down-dip dimension. The thickness of such a lens rarely exceeds 20 m and is more commonly half this amount. The lensoid nature of these lithologies is well-exposed on the water-polished spillway of the mine dam about 500 m north of the mine workings. The footwall lithology to the tuff unit is dominated by fine-grained sediments, which change from graphitic shales in the northwest area of the property to

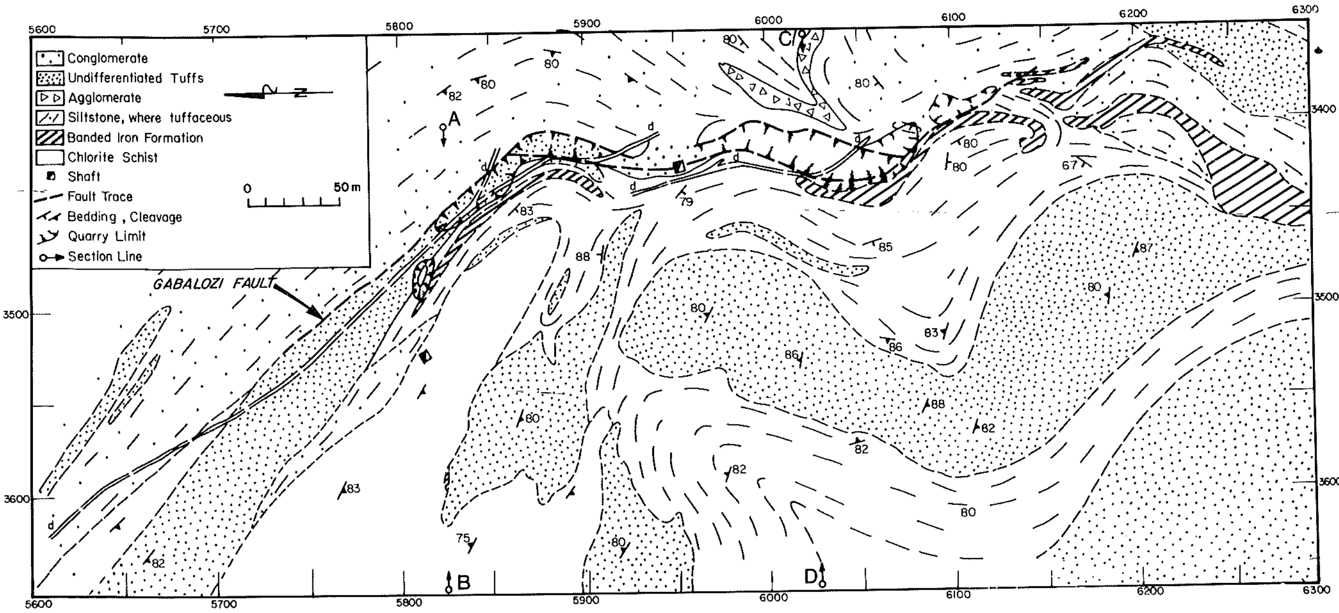

Figure 2: Surface map of How Mine, modified from M.C. Barker (unpubl. mine data, 1977-1978).

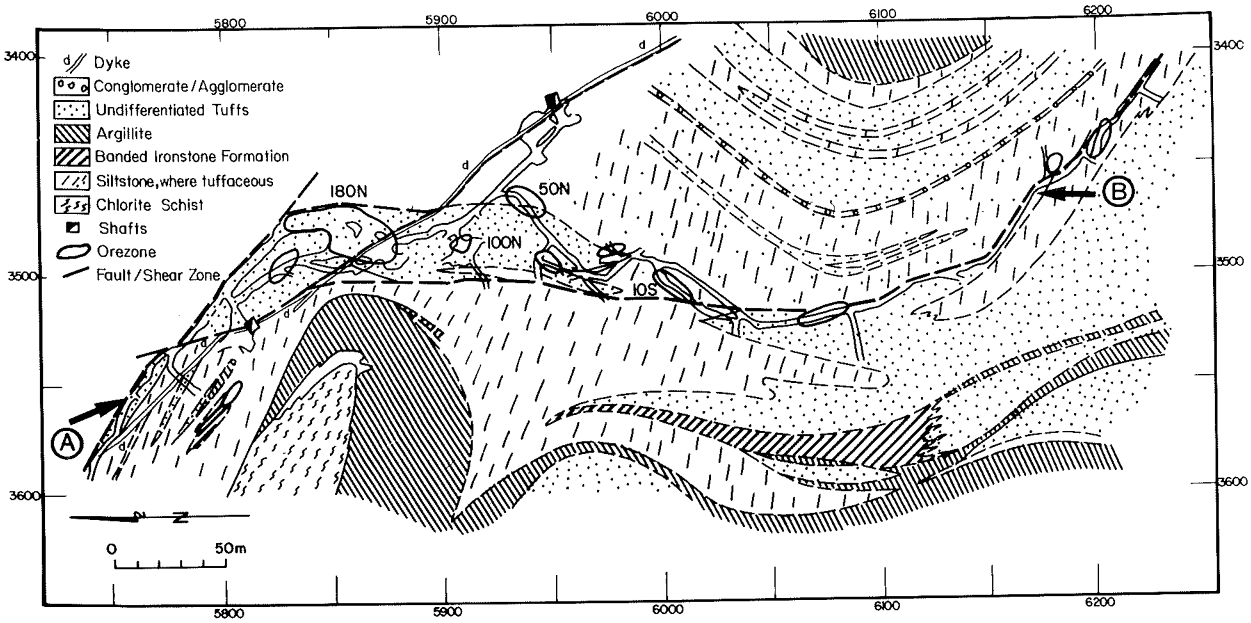

Figure 3: Geological map of 8 Level (280 m), How Mine, showing the delineated ore zones. A: Footwall Fault and B: Hangingwall Fault. From M.C. Barker (unpubl. mine data, 1977).

massive black siltstones in the central and southeastern areas. The hangingwall lithologies, overlying the tuff unit, are well-exposed in an exploratory crosscut west on 10 Level (355m). The immediate hangingwall is a quartz-chlorite carbonate schist which grades westwards into a fine-grained massive argillite.

A. Structure

The How Mine is situated on the northern limb of an asymmetric syncline (Barker, 1978), with a southwesterly dipping axial-planar foliation. This fabric is evident as a close-spaced penetrative cleavage, which in some areas is superimposed by a subparallel, steeply-orientated fracture set, forming a composite cleavage and is well developed in outcrops of argillaceous and tuffaceous lithologies. The footwall sediments are deformed into open folds which plunge at 75 to 85° to the southwest. Folding is also present in the hangingwall strata where folds are tight in the north, but become open to the south. The patterns of folding in the footwall and hangingwall are dissimilar and are separated by a northwest-trending shear zone known as the Gabalozi Fault Zone (Figs. 2 and 4). This shear zone exploits the lithological contact between the

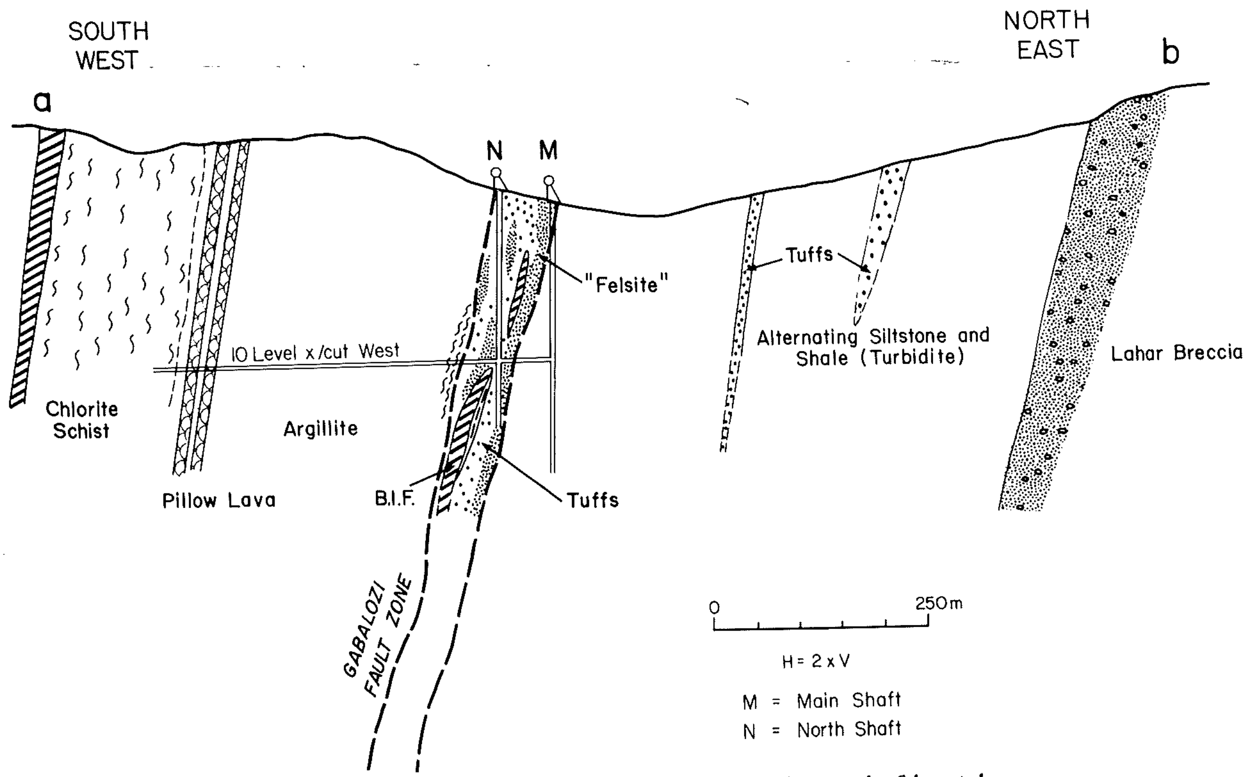

Figure 4: Schematic cross section through How Mine, indicating stratigraphic relationships and the position of the Gabalozi Fault Zone, comprising the Footwall and Hangingwall Faults.

footwall sediments and the tuffs. Within the mine workings two distinct shear zones are evident, locally named the Footwall Fault and Hangingwall Fault, respectively. These two shear zones show a horizontal separation of approximately 200 m. Only the Footwall Fault is exposed in the northern part of the mine, whereas only the Hangingwall Fault is developed in the southern workings (Fig.3). In plan view, the Hangingwall Fault is offset from the Footwall Fault, forming a right stepping fault system. The two major shear zones are interconnected by minor shear splays, forming a duplex structure (Fig. 5A). The greater part of the mine workings are situated within the single horse, which is about 350m long and up to 50 m wide, with a known down-dip dimension of 700 m. In plan, the horse trends

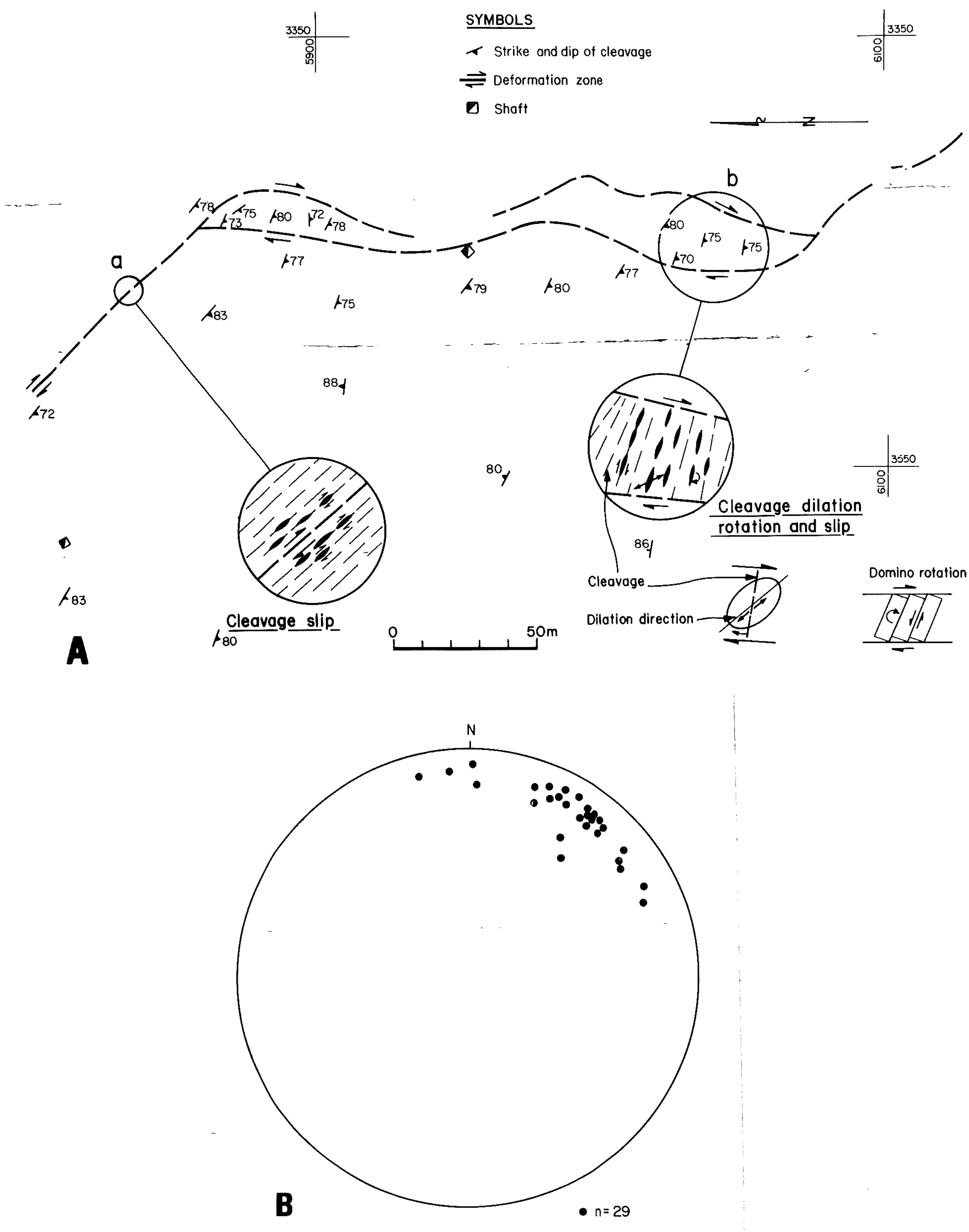

Figure 5: *Synoptic diagram, showing structural features at How Mine.*
A. Surface map showing the right-stepping aspect of the Gabalozi Fault Zone, the development of the duplex structure and the angular relationships between the faults and pre-existing cleavage.
B. Stereographic projection showing poles to cleavages as shown in Figure 6A and sulphide lenses (Lower hemisphere, Schmidt net).

north and lies at a high angle to the axial planar foliation which has a mean orientation 300/75° SW (Fig.5B). The long axis of the horse plunges between 70 and 80° to the west-northwest. The shear zones are seen to cross-cut the foliation and clearly postdate it.

Ductile deformation is evident within the shear zones; shear fabrics are present, marked by the preferred orientation of platy minerals such as sericite and chlorite and also by the orientations of mineral banding within the rock, most commonly carbonate. Fabrics parallel to the margins of the shear zone (or approximately so) represent C-Fabrics of Berthe *et al.* (1979). S-Fabrics related to the shearing are not well-developed within the siliceous lithologies (e.g.tuffs), but do occur in the argillites, particularly in the area around the Footwall Fault. The Footwall Fault is well-exposed for over 700 m in an exploratory drive to the north on 10 Level (355m). At this locality, black graphitic argillites are juxtaposed against highly altered tuffs and metabasalts which are in part sheared into a chlorite-carbonate schist. Carbonate veining, which is subparallel to the shear fabric, is present in the argillites. Boudin structures, with internally developed extensional ladder veins of carbonate occur and have their elongation direction parallel to the strike of the shear fabric. Chlorite-carbonate schists are often locally developed within the shear zones. On 12 Level (425m) Drive South (Fig.6) the

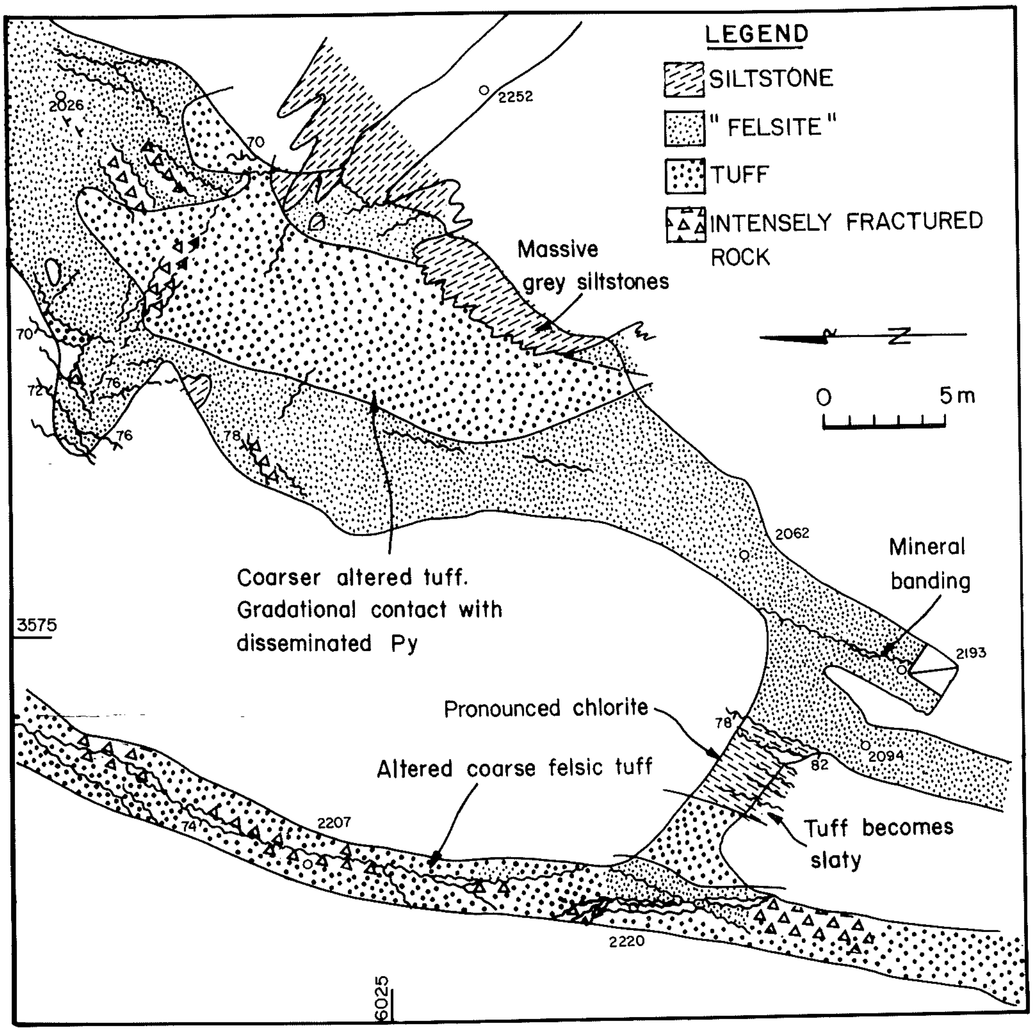

Figure 6: Detailed underground map of the 12 Level Hangingwall Drive South and part of the 10 South ore zone, showing deformation associated with the Hangingwall Fault.

Hangingwall Fault is exposed both in the drive and in a minor crosscut. At these localities, deformation is evident over a 12 m-wide section and exposures in the adjacent 10 South ore zone show that visible deformation extends over a width of 20 m. The style of deformation and general appearance of both the Hangingwall and Footwall Faults is very similar. The sense of shear in both the Hangingwall and Footwall Faults is dextral. Indicators include the orientations of C- and S-Fabrics, sigmoidal blocks within the shear zones, and small folds located on the shear zone margins.

Field evidence indicates that the shear zones have been affected by a later phase of deformation. This is present as a narrow zone of faulting in which comminution of the rock has taken place to form a rock-flour, cemented with carbonate. The brittle faults vary from 2-50 cm in thickness and are always confined within the ductilely deformed shear zone. The faults may lie parallel to the fabric or cut it obliquely and may bifurcate within the ductile zone, but are most commonly aligned with major lithological contacts, such as the tuff-argillite contacts which appear as deformation foci. Carbonate is abundantly developed in these later faults (Fig.7) and sub-horizontal slickensides are very common, indicating strike-slip motion. In addition, quartz-carbonate tension gashes associated with the brittle fault indicate dextral motion.

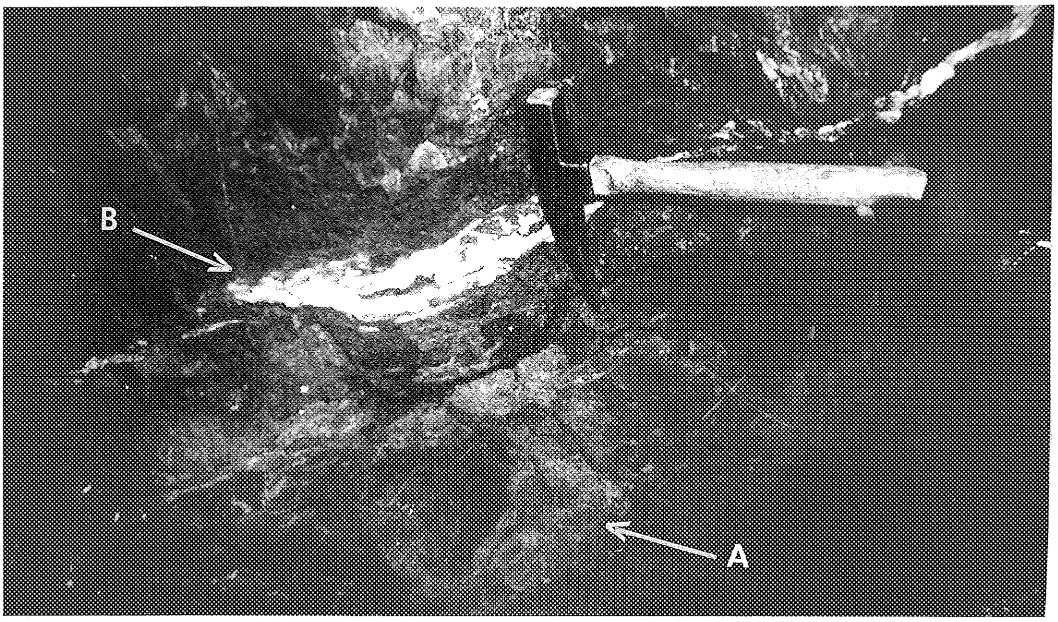

Figure 7: Photograph showing bleached siltstones at A, representing typical propylitic alteration, cut by later quartz-carbonate veining, at B. Locality: 16 Level, South ore zone.

1V. GEOLOGY OF THE ORE ZONES

During mining operations over the last twenty years, several ore zones have been delineated by detailed underground sampling and assaying. Two major ore zones are currently being mined at How Mine, namely, the 10 South and 180 North in approximate order of importance. These ore zones are situated adjacent to major bends in the Gabalozi Shear Zone, close to the closures of the duplex (Fig.3). In addition, numerous smaller ore zones have also been delineated and mined; the 220 North, 50 North, 100 North, and 80 South are some of the more important. Figure 8 shows the spatial orientation of four selected ore zones, which have the form of steeply plunging shoots with oval- to crescent-shaped cross sections. Most ore zones have been traced down-plunge to depths of 400m, while the major ore zones have been delineated to depths in excess of 700m. These ore zones occur in an array with the form of an open Z, which approximately parallels the regional foliation and the Gabalozi Fault Zone. Orientation data, presented in Figure 9, show that all ore zones plunge steeply to the west and form a tight spatial cluster. Most ore zones lie within the single horse of the duplex, but several smaller ore zones lie within the main shears themselves, outside the projected closures of the duplex. These ore zones (e.g. 300 North, 80 South, and 90 South) have a lenticular cross-section striking parallel to the shear zone and do not demonstrate the same persistence with depth as that of the main ore zones. Significantly, ore zones are not strictly stratabound, and plunge slightly discordant to the strata. In general, ore zones maintain a constant plunge

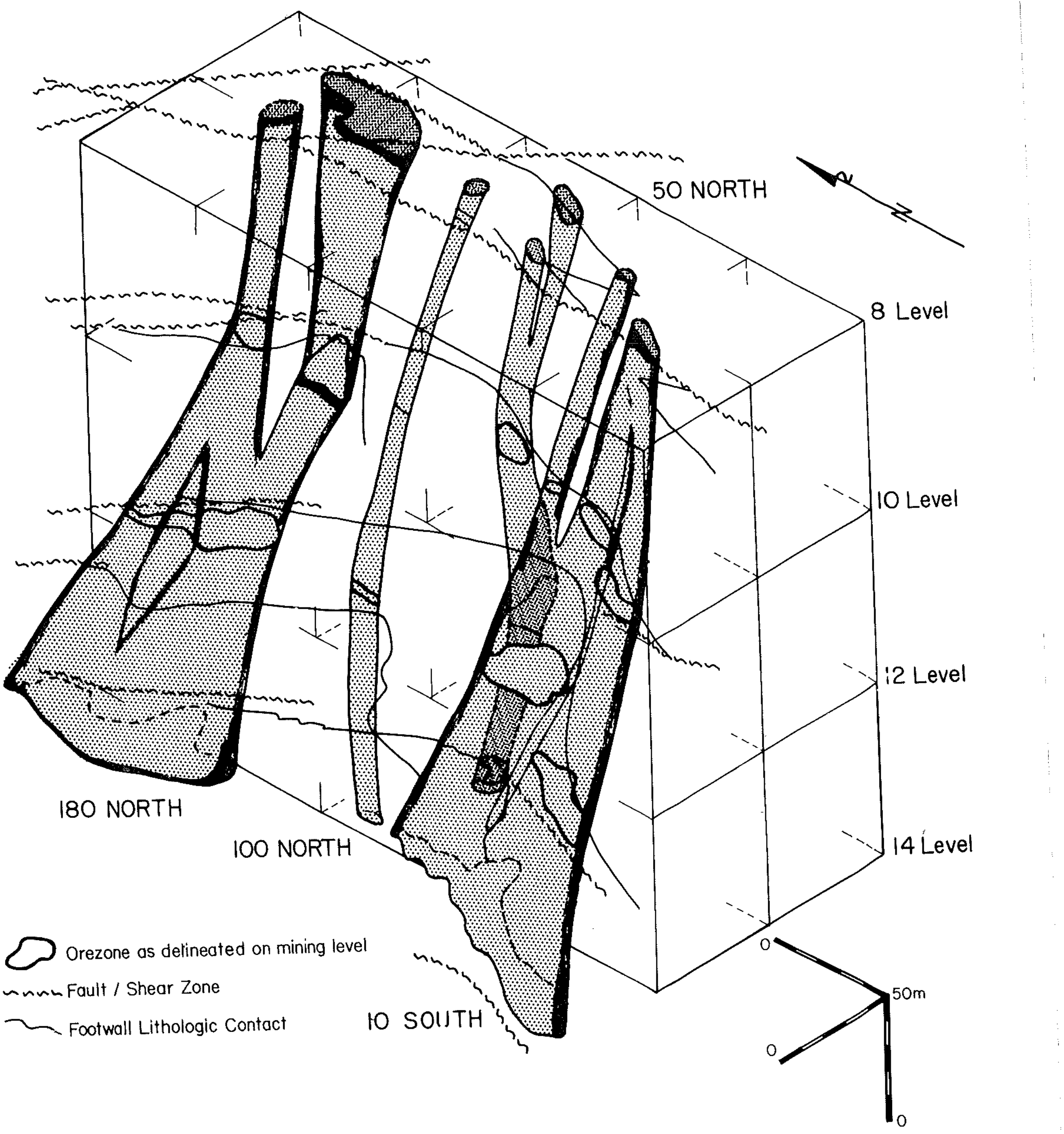

Figure 8: Isometric projection of selected ore zones showing a consistent westerly plunge. Constructed from mine data.

whereas strata display rather variable dips. For example, the 180 North ore zone is hosted within tuffs on 12 Level, close to the footwall contact with the siltstones (R. Kaegi. unpublished mine maps). On 15 and 16 Levels

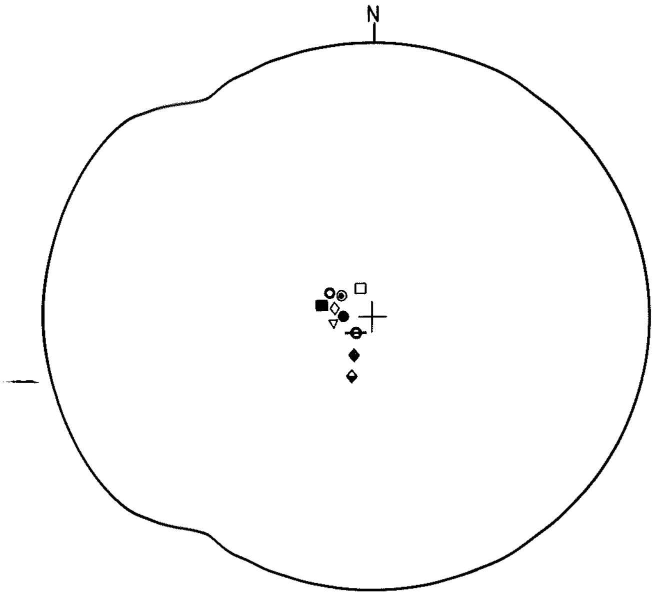

Figure 9: Stereographic projection showing plunges of ore zones. Note steep orientation (Lower hemisphere, Schmidt net).

the ore zone lies within the contact zone between the tuffs and the siltstones and plunges steeper than the dip of the contact (Fig.10A). Similarly, the 50 North ore zone is hosted within tuffs in the upper levels of the mine and within the footwall siltstones on 12 and 14 Levels. The 100 North ore zone is situated within iron formation and tuffs on 12 Level, plunge is steeper than the dip of the iron formation with the result that the ore zone is hosted entirely within tuffs on 15 Level. In contrast, the 10 South ore zone is situated within the footwall siltstones on 8 Level, it transgresses the contact between the siltstones and tuffs on 9 Level and is hosted within tuffs on 10 Level (Fig.10B). In addition to the contact relationships, lenses of siltstone and iron formation may be either partially or totally enclosed within the ore zones, with the result that host rocks within an ore zone are varied and almost all rock types present within the mine may host mineralization to varying degrees.

Several ore types are recognised on the basis of appearance of the mineralization:

1. occurrence of mineralization in alteration haloes associated with veins;
2. mineralization in iron formations;
3. disseminated mineralization; and
4. mineralization hosted within shear zones

A. <u>Mineralisation Associated with Alteration Haloes</u>

This type of mineralization occurs as fine disseminations of sulphides and gold within bleached alteration haloes surrounding small quartz-carbonate veins. Ore material is characterised by a high density of

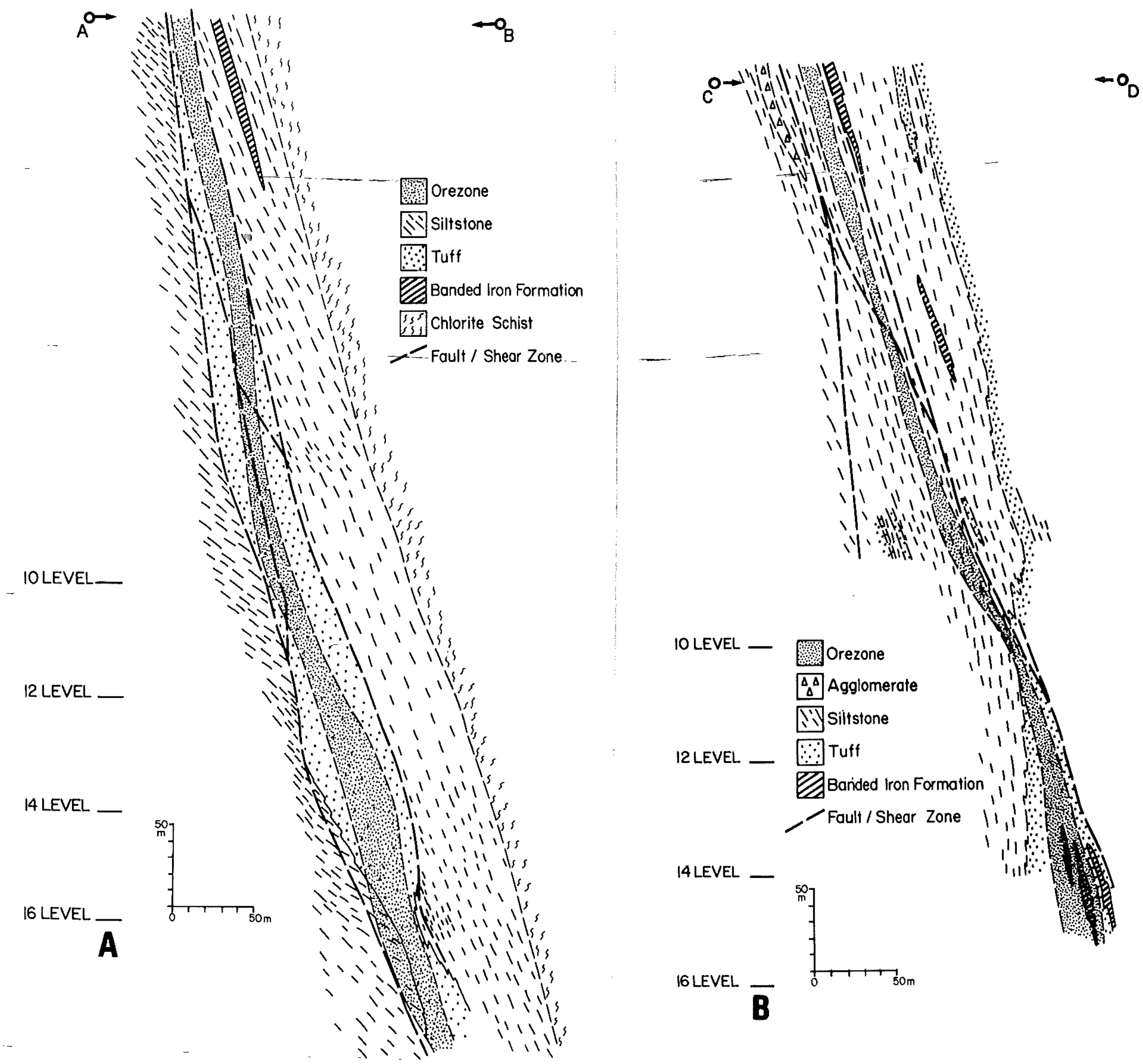

Figure 10 : A. Cross section through the 180 North ore zone.
B. Cross section through the 10 South ore zone. Note the discordant relationship between the ore zone and the siltstone-tuff contact at the 10 Level elevation. Refer to Figure 2 for locations of cross sections.

veins and extensive zones of alteration. Sulphides are rarely seen within the vein itself, although some arsenopyrite and pyrite has been observed as inclusions within carbonates. Vein sets are commonly observed in siltstones and iron formations and to a lesser extent within the tuffs. The alteration haloes range from 2-20 cm in width and are not always symmetrically distributed about the vein, which may range from 0,1 to 1,5 cm in thickness. The alteration, visible as a khaki-coloured bleaching, is characterized by an introduction of carbonate and sulphides, together with white micas. These micas may occur as large, coarse, aggregates within the altered haloes in contrast to fine-grained biotite that is evenly distributed throughout unaltered siltstones. Veins are seen to splay-off the main shears and cut siltstones and iron formations alike. A set of sub-vertical veins has an orientation subparallel to the axial-planar cleavage, whereas other veins have a more random orientation. Veins associated with ore are believed to be contemporaneous as no cross-cutting relationships between veins of differing orientations can be determined. Highly variable gold grades are also characteristic of this ore. Sulphide mineralization consists predominantly of pyrite, with lesser arsenopyrite. Gold seems unrelated to the presence of arsenopyrite, which appears to post-date the pyrite. Later post-ore veins are present and generally have a sub-horizontal orientation. These veins may carry pyrite and galena, but have no associated alteration haloes and carry no gold.

B. Mineralization in Iron Formations

The prominent occurrence of this type of mineralization is clearly evident where pyrite occurs along and replaces magnetite laminae. The aspect of bedding-parallel mineralization has primarily led previous authors (e.g Fripp, 1976) to propose a syngenetic model for ore genesis. Nevertheless, it is significant to note that, at How Mine, as well as many other deposits (e.g. Phillips *et al.*, 1984; Colvine *et al.*, 1984; Wyman *et al.*, 1986; Master *et al.*, 1989) sulphide rich layers are observed to grade rapidly along strike into magnetite beds and commonly can be traced to transgressive quartz veins (Fig.11). In addition, layers of pyrite are observed to occur as symmetric haloes around veins (Fig.12). In some cases, pyrite-rich layers may extend up to 2m away from the visible veins, but more commonly extend in the range of 10-20 cm. Within the pyrite-rich layers, magnetite occurs as small xenomorphic grains, overgrown, replaced,

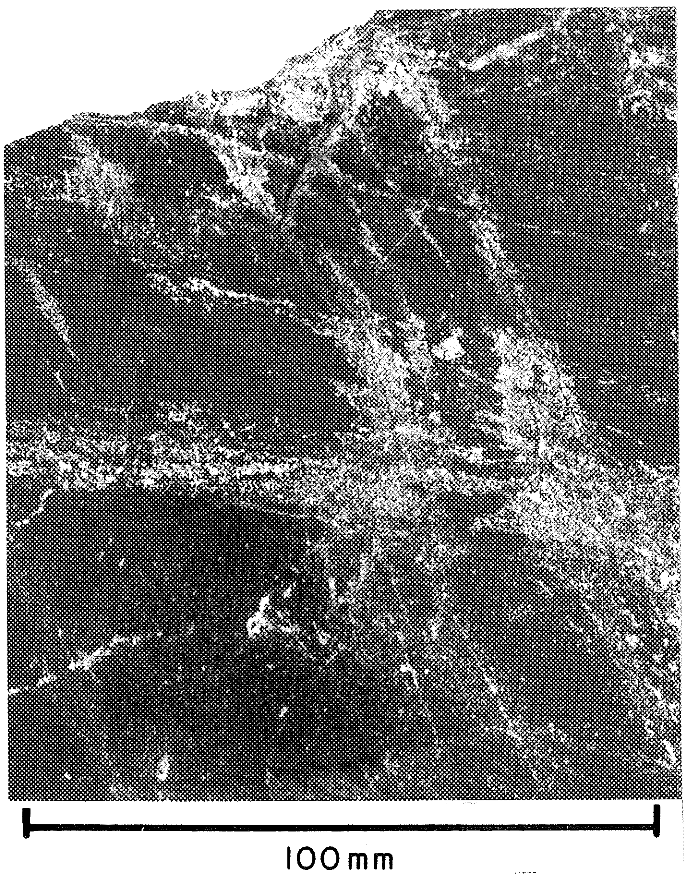

Figure 11: Hand specimen photograph of mineralized iron formation. Note the sulphide replacement of bedding (subhorizontal in photograph) around transgressive quartz-carbonate veins. Specimen from 12 Level, 100 North ore zone.

and locally enclosed within subhedral to euhedral pyrite. In some cases folded beds of pyrite occur, but the pyrite layers can often be traced both to small fractures, and veins which cut through the cores of the folds, usually parallel to the axial plane.

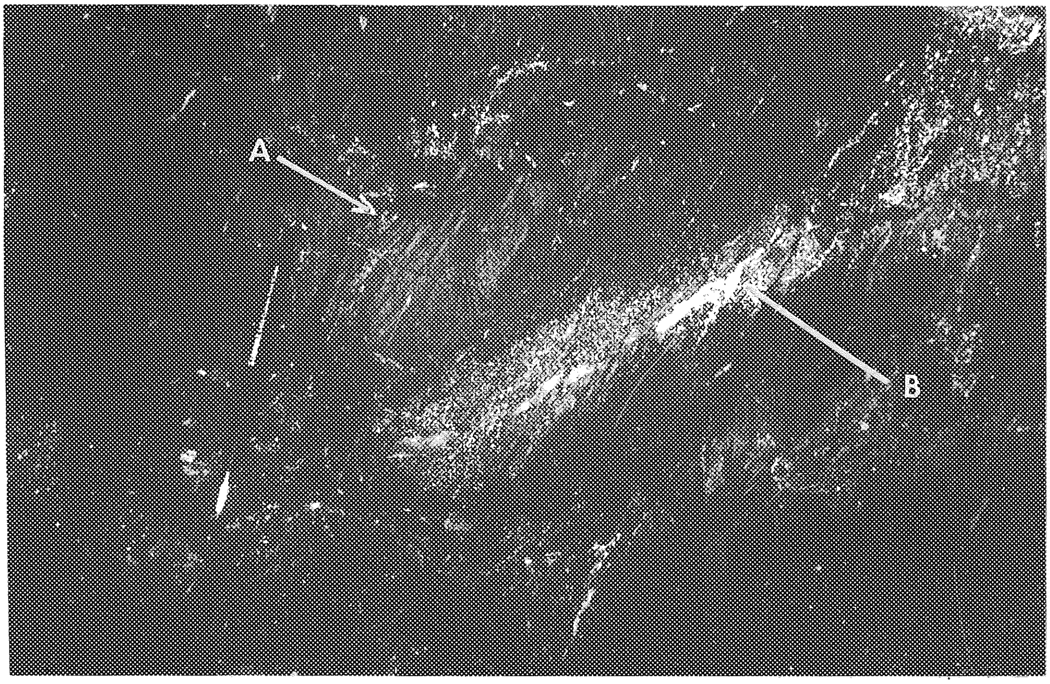

Figure 12: Underground photograph, showing relationship of mineralisation to bedding. Bedding, A comprising finely bedded magnetite siltstone (BIF) cut by quartz-carbonate veining at B. Note development of symmetric sulphide (pyrite) mineralization replacing the bedding. Location: 16 Level, 10 South ore zone.

In the northern half of the 10 South ore zone, a distinctive halo of coarse, hydrothermal biotite is developed within the tuffs and siltstones. The coarse biotite overprints the earlier, metamorphic sericite and also occurs within quartz veins cutting iron formations in the lower parts of the 10 South ore zone. This evidence indicates a potassium metasomatic event, which is closely associated with mineralization and post-dates metamorphism.

C. Disseminated Mineralization

Disseminated sulphides constitute one of the more abundant ore types. Pyrite, which often shows a subhedral to anhedral form and is less commonly euhedral, occurs disseminated throughout the host lithology. The most common host is a pale grey to green, fine-grained lithology, which both Barker (1978) and Minne (1982) termed a "felsite". The mineralogy of this rock type is dominated by fine quartz, carbonate, chlorite, epidote, micas (often biotite, although fine sericite also occurs) and sulphides. Contacts with adjacent lithologies may occasionally be sharp and this aspect was cited by earlier writers to indicate an intrusive nature of the felsite. However, far more common are lithological contacts which are gradational. Moreover, there is a very close resemblance between "felsite" and alteration products within the siltstones. Close-spaced quartz vein networks may also occur within the "felsites" and the mineralogy and field relationships show the "felsite" to be an alteration assemblage rather than an igneous intrusive. Disseminated sulphide mineralization also occurs within tuffaceous lithologies, which often lie in contact with the completely altered rock. Alteration within the tuffs is evident as a partial destruction of the feldspars and their replacement by chlorite or less commonly by clinozoisite. Reduction of the grain size of quartz clasts is common with the development of whisps of chlorite, sericite, and biotite within the rock. Anhedral to subhedral pyrite is the dominant sulphide and is often seen overgrowing accessory magnetite. The sulphides appear to accompany the alteration minerals, clinozoisite and chlorite, within the tuffaceous and "felsitic" lithologies. Fabric-hosted mineralization is developed within the tuffs and to a much lesser extent within the completely altered rock. The axial-planar cleavage hosts discrete lenses of undeformed pyrite. These lenses, which have their greatest dimension (commonly 10-20 cm) aligned down-dip, produce a crude lineation (Fig.13). Lenses rarely exceed 2mm in thickness and may show compositional zonation when viewed in cross section. Coarse, euhedral pyrite forms envelopes enclosing finer-grained anhedral pyrite and rare arsenopyrite, which is invariably euhedral. Thinner lenses lack the zonation displayed by thicker ones and contain subhedral pyrite only. The density of sulphide lenses within the foliated rock is highly variable and irregularly spaced. Disseminated mineralization is commonly developed in association with fabric-hosted lenses and gradations between the two end members are common.

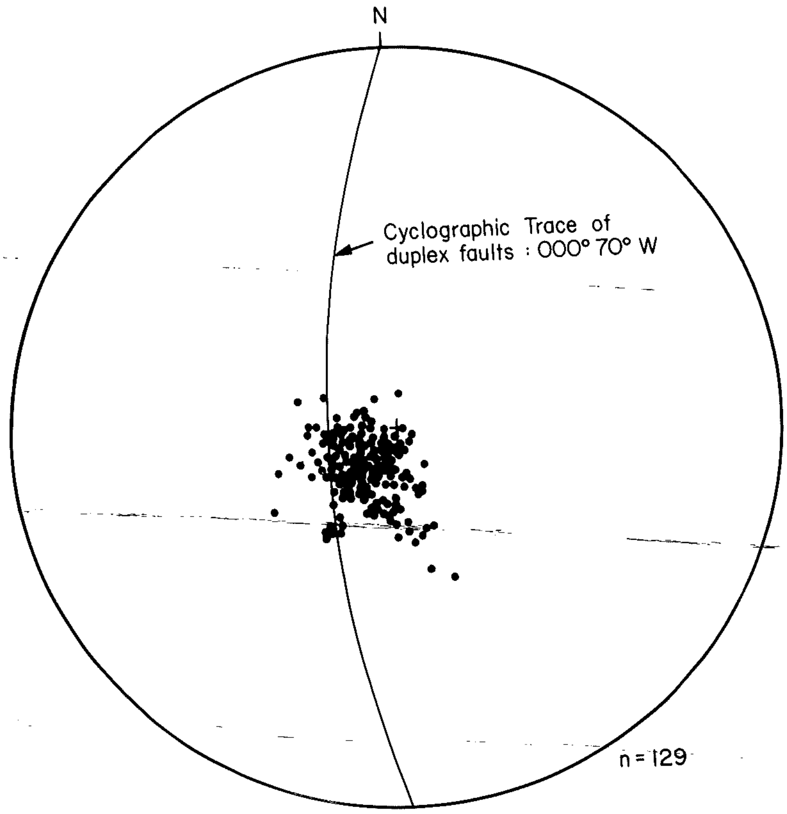

Figure 13: Stereographic projection showing orientation of lineations defined by the long-axis of pyrite lenses within tuffs. Note the similar orientation between the lamellae and the ore zones (Fig. 10) (Lower hemisphere, Schmidt net).

D. Mineralization Hosted in Shear Zones

Shear zone-hosted mineralization is a minor source of gold. For the most part, the shear zones are poorly mineralized, with the development of mineralization being sparse and irregular. However, some of the minor ore zones occur within or immediately adjacent to the shear zones, for example the 300 North ore zone occurs within the Footwall Fault and the 80 South ore zone occurs in the Hangingwall Fault. Within the shear zones mineralization occurs in two forms, namely: shear-fabric hosted mineralization and disseminated mineralization. Coarse- and fine-grained pyrite occurs as stringers within shear bands (C-Fabrics of Berthe *et al.*, 1979) and within intrafolial folds. Alteration is evident throughout the shear zones and in some cases alteration overprints and obliterates fabrics. Disseminated mineralization is present within intensely altered and replaced zones which closely resemble "felsites". The two styles of mineralization are spatially associated and alternate within the shear-zone-hosted ore zones.

E. Controls on Mineralization

Siltstones and iron formations are particularly important lithological hosts for gold mineralization, especially in the 10 South ore zone and with depth, in the 180 North ore zone. Notably, the 10 South ore zone increases in cross-sectional area between 12 Level and 14 Level, and this can be attributed to the occurrence of a large iron formation lens close to the Hangingwall Fault. The ore zone swells with depth and encloses the lens almost totally on 14 Level. Similarly, the 100 North ore zone has a strike length of approximately 20m on 12 Level where it is hosted within interbedded tuffs and iron formation. In contrast, on 15 Level the host rock is exclusively tuffaceous and the strike of the orebody is only 8 to 10m in length. However, iron formation is a very favourable host rock and ore zones such as the 220 North and the 116 North (which forms part of the 180 North ore zone) are hosted entirely within iron formation lithologies. The prevalence of fractures and veins within iron formations and siltstones reflects the brittle response of these rocks to deformation, and illustrates the close temporal relationship between deformation and mineralization. Where mineralization cuts across lithological contacts within the ore zones the style of mineralization is seen to change. For example, disseminated pyrite mineralization in tuffs may pass directly into bedding-hosted mineralization in iron formations. Differences in mineralization style reflect host rock influence during the mineralization event and do not appear to indicate a sequence of mineralizing events with changing deformational signatures. There are no transgressive relationships between different styles of mineralization, which are generally restricted to specific lithological hosts. Veins are generally rare within the tuffs, but where they do occur they do not cut fabric-hosted pyrite lenses, but rather the lenses may branch off the veins. Later, post-ore veins transgress all types of mineralization and generally show very specific orientations. Detailed field observations clearly show that pre-existing structural features influence mineralization. This is evident in the occurrence of euhedral to subhedral sulphide mineralization within the dilated axial-planar cleavage, well-developed within the tuffs. Similarly, the occurrence of veins and fractures, sub-parallel to the axial-planar cleavage, within shales and iron formations, shows the influence of pre-existing structure.

F. Ore Paragenesis

Ore microscopic investigations into the nature of sulphide minerals present, based on samples mainly from the 180 North and 10 South ore zones, yielded the following observations. Pyrite is the dominant sulphide mineral present and comprises approximately 90% of the total sulphides. Arsenopyrite, pyrrhotite, chalcopyrite, and chalcocite also occur but comprise less than 10% of the sulphides. A provisional paragenetic sequence is presented in Figure 14. Pyrrhotite and chalcopyrite occur as tiny anhedral grains enclosed within early, inclusion-rich pyrite. Arsenopyrite may overgrow inclusion-rich pyrite and may, in turn, be overgrown by inclusion-free pyrite.

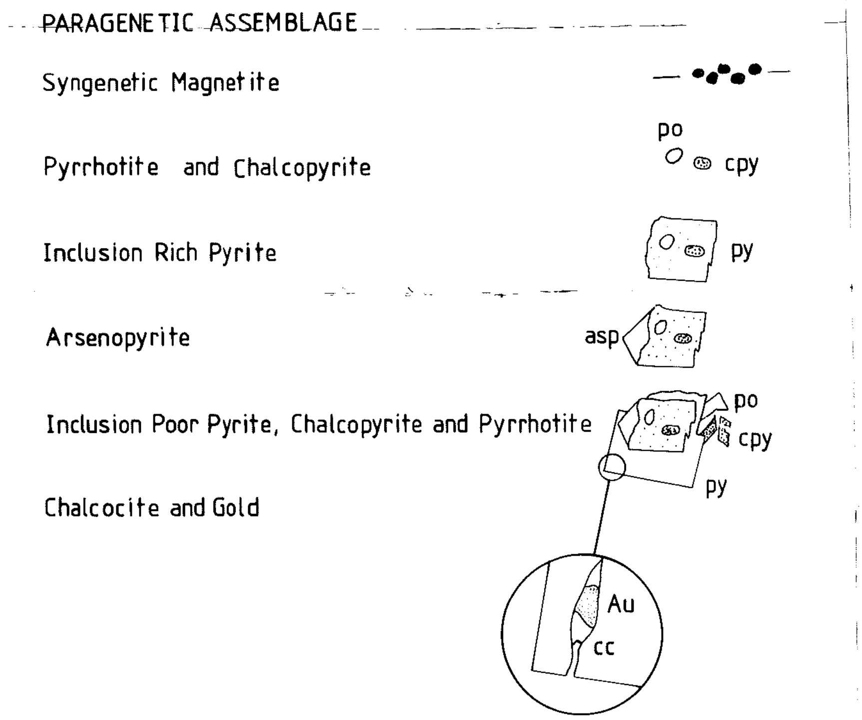

Figure 14: Paragenetic diagram indicating the sequence of ore mineral development at How Mine.

Coarse, anhedral pyrrhotite and chalcopyrite grains are in places, associated with the inclusion-poor pyrite. In many cases sulphide minerals overgrow or include tiny grains of magnetite. Gold is associated with the late generation, inclusion-free, pyrite and chalcocite, and is hosted in fractures within the sulphides and on grain surfaces.

V. DISCUSSION AND CONCLUSIONS

A. In Archean lode-gold deposits, structural features are important in forming feeder systems along which mineralizing fluids may pass (Colvine *et al.*, 1984). Within the siltstones and iron formations these feeders are the fractures which formed during development of major, regional shear zones. Relationships within the iron formation are similar to those described by Phillips *et al.* (1984), with symmetric sulphide mineralization around transgressive quartz veins and associated layer replacement. Rock permeability, coupled with structurally induced dilation must have been important in determining the amount of infiltration of the rock by the mineralizing fluids, and the thickness of alteration halo is in no way related to thickness of the vein. The occurrence of alteration haloes is an indication of the passage of fluids which are in chemical disequilibrium with the wall rocks. In some cases broad alteration zones occur with no apparent feeder system (veins) evident, indicating massive, unfocussed fluid flow through the rock. Permeability within the tuffaceous units is, in part, affected by the axial-planar cleavage. The cleavage is inclined at a high angle to the dominant north-south trend of the duplex (Fig.5). It is concluded that dextral motion across the shears gave rise to dilation within the right-stepping duplex. Dilation of the pre-existing fabric took place to allow fluid passage (as indicated in Fig.5 insets).

B. It is important to note that within the extreme northern and southern exposures of the mine no major ore zones have been located despite intensive exploration. In these areas the shear zones trend subparallel to the foliation and motion across the shear zones generated localized fabric slip with no extensive dilation. These areas also lie outside the dilational duplex, hence no major ore zones formed. The ore zones plunge in the direction of the dip of the shear zones and lie perpendicular to the direction of shearing, analagous to relationships within dilational jogs as described by Sibson (1987). The pre-existing axial-planar cleavage is important in creating fluid conduits within the tuffaceous rocks and pyrite lenses are hosted within the dilated cleavage and display a crude lineation. The orientation of this lineation (Fig.13) corresponds with the intersection lineation between the north-trending duplex shears and the axial-planar cleavage (Fig. 5B) and is parallel to that of the ore zones (Fig.9). The writers conclude that the orientation of the ore zones is controlled by the intersection lineation between the early axial planar cleavage and the later superimposed shearing within the Gabalozi Fault Zone, and that fluids passing up the ductile shear zones entered these dilational sites and formed the ore zones.

C. Alteration at How Mine consists dominantly of carbonation and sulphidization with lesser sericitization, biotitization, and propylitic alteration, particularly within the tuffs. These forms of alteration have been described from Archaean gold deposits worldwide (e.g. Thomson, 1986; Phillips *et al.*, 1983, 1984; Boyle, 1978). On the basis of the observed alteration styles it would appear that the fluids responsible for gold mineralization at How Mine were not significantly different from fluids which gave rise to similar deposits elsewhere. However, the source(s) of fluids responsible for the genesis of Archaean gold deposits, remain unresolved. Opinion exists citing magmatic sources, (e.g. Burrows *et al.*, 1986; Wood *et al.*, 1986; Keays, 1984), possibly related to lamprophyres (Rock and Groves, 1988), whilst other authors, (e.g.Phillips *et al.*, 1983; Cameron, 1988), favoured a metamorphic origin for the fluids and the gold (possibly linked to mantle degassing). Further research suggests a meteoric source for the fluids (Nesbitt, 1988; Nesbitt *et al.*, 1986). Major gold deposits in Zimbabwe are located within greenstone belts, spatially associated with tonalite trondjhemite-granodiorite (TTG) rocks of the Sesombi Suite (Mann, 1984; Foster *et al.*, 1986; Foster, 1988) and this may indicate a genetic relationship between the TTG suite and the gold mineralization as indicated by Mann (1984) and Foster (1988).

D. How Mine shares many characteristics with other Archaean gold deposits, most notably: structural features created fluid pathways and controlled dilation of the host material and, hence, were critically important in determining the location, size, and attitude of the ore zones within the mine.

ACKNOWLEDGEMENTS

M.H. acknowledges logistic support from Independence Mining Zimbabwe (Pvt.) Ltd. during fieldwork and extends thanks to J.R. Rheam and staff of How Mine for their friendly co-operation and J. Urie of Lonrho, for permission to publish this paper. E.G.C. acknowledges partial support from the Witwatersrand University Council. Lyn Whitfield and Mark Hudson provided invaluable technical support. We also thank L.J. Robb who critically reviewed an initial draft and the referees, C.W. Stowe and F. Piranjo for their constructive comments.

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