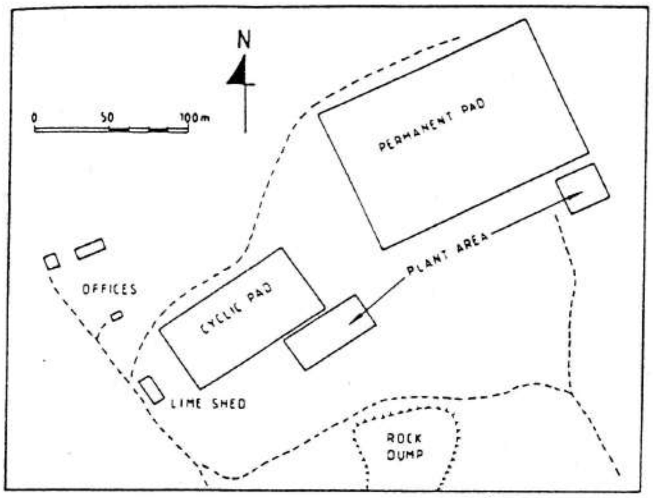

Figure 3. General mine layout of the Ayrshire mine.

preparing the ground for the heap leach pads (cyclic and permanent) and the plant area. In addition workshops and offices had to be built (Fig. 3). The area for the leach pads was carefully chosen so as not to cover any parallel orebodies, yet still have sufficient ground slope to permit drainage. Trees were cleared by hand to allow the surveying of the area followed by grading and levelling.

The initial plans were to use an asphalt pad (100 m × 50 m) for leaching the high-grade ore and for this purpose contractors were brought in. However, poor compaction of the ground resulted in the breaking up of the asphalt pad and the decision to use a plastic membrane was made. Consequently two 50 m × 50 m, 250 μm low density polyethylene (LDPE) sheets, produced in Zimbabwe, were lain on top of a recompacted gravel base covered with some 20 cm of slimes, found locally within the mine area. The two sheets necessary to complete the pad were simply joined by tightly folding together 1 m of each of the sheets. A further layer of slimes was laid on top of the plastic followed by a comprehensive network of drains which comprised both loosely fitted, clay pipes and waste rocks obtained from the rock dump on site.

In the plant area two ponds (350 m^3) were dug and lined with locally available 500 μm PVC liners. A set of five mild steel carbon columns were made and installed in such a way that the counter-current movement of carbon could be achieved by simply moving the joining pipework between the columns. This method negates the need to physically move carbon between columns. The necessary pumps and reticulation were installed completing the plant assembly.

6 MINING

Mining is achieved relatively easily without any drilling and blasting due to the deeply weathered nature of the diorite. The oxide ore at Ayrshire can be categorised into either high-grade (≥ 0.7 g/tonne) or low-grade (0.2 - 0.7 g/tonne). Fortunately the high-grade ore is enveloped by low-grade ore and hence waste stripping is kept to an absolute minimum.

Waste rock is usually chlorite schist confined to the footwall of the ore body and is dumped on a waste pile. Treatment is done on run-of-mine ore which is loaded onto the prepared leach pads. The high-grade ore is initially treated on the cyclic pad, where up to 70% extraction is realised after 4 to 5 weeks of leaching. The low-grade ore is taken directly to the much larger permanent pad, where the partially leached ore from the cyclic pad (tails) is placed, and treatment here continues to extract the remaining gold.

The earthmoving is accomplished using an excavator and 5 tractor-tipper units. When mining, the excavator digs and loads the trailers which can take an average of 7.2 tonnes and on a typical day between 2000 and 4000 tonnes of material can be moved depending on the haulage distance. Once loaded the tractors leave the pit and stop at a lime shed where a 4 kg ore sample for grade control is collected from each trailer after which lime is added at a rate of 3 kg/tonne. Samples from ten loads are bulked together and then thoroughly homogenised prior to splitting through a riffle splitter. The representative sample is then bottle rolled for 12 to 24 hours, filtered and the resultant solution read on the Atomic Absorbtion Spectrophotometer to determine the gold content of that sample.

The tractors then move off to either the cyclic or permanent pad where they end-tip off the top of the heap. The construction of the heap is controlled by the front-end loader which maintains the horizontal attitude of the top of the lift. Typically a heap on the cyclic pad is made approximately 4 m high whereas the permanent pad is constructed using lifts of 5 m each.

Once the high-grade ore has been under leach, it is allowed to drain for 2-3 days before being off-loaded by the excavator and tractor-trailer units. During off-loading the same sampling system is used and additional lime is added at a rate of about 1 kg/tonne.

7 TREATMENT

Solution application onto the heaps is achieved using imported wobbler sprays which can deliver up to 1 m^3/hr. The barren solution is made up to a cyanide strength of 0.25 g/l with an accompanying pH of >10.5 prior to spraying on the heap. With a new heap it takes two days for the pregnant solution to start coming through the drains and this first solution is normally high in gold (Fig. 4). During the progression of the leach the gold values decrease until after approximately 3-4 weeks where the amount of Au in solution levels off. After some 4 weeks under leach the application of barren solution is stopped and the heap allowed to drain for 2 days prior to off-loading.

The cyanide strength of the pregnant solution is normally around 0.08 g/l indicating excess cyanide and hence optimum gold dissolution. The pH is also lower than the barren solution but is buffered at values >9 by the lime added during loading. Treatment on the permanent pad is identical to that at the cyclic pad with pregnant solution pumped into the cyclic pad pregnant pond.

Pregnant solution is then pumped through a series of carbon columns ('Carbon Column Carousel') where the gold is absorbed onto the activated carbon. Counter current movement of the carbon is simply achieved by changing the inter-column pipework such that the column that was first in line becomes the last etc. During the change over of the piping, the 'loaded' carbon is off-loaded and replaced with eluted carbon.

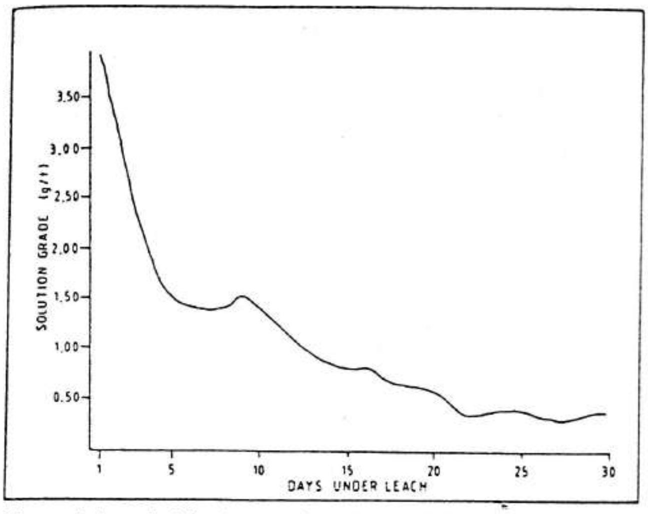

Figure 4. A typical leach curve from the cyclic leach pad at the Ayrshire mine.

8 CONCLUSIONS

The use of heap leaching at the Ayrshire gold mine has proved to be very successful and this success can be attributed to both the techniques being used and the nature of the mineralised host rock.

Initial mine designs and scheduling were made prior to the development of the mine but subsequent to the start of mining, alterations have been made in order to improve the initial ideas. This has been made possible by the fact that the entire operation is done in-house and the decision to alter a technique is made on-site. No matter how much careful planning and thought goes into a project it is only once production starts that one realises the limitations. For example the original plan was to only mine the high-grade ore and to regard everything else as waste, but soon after mining and treatment started it became apparent that most of the so-called waste could in fact be treated profitably.

It was at this stage that the decision to have a permanent pad was made and to date, the value of the gold recovered from the permanent pad is far in excess of the construction and treatment costs. It has also been possible to lower the treatment costs by reducing the cyanide concentration of the barren solution and by using lime in place of caustic soda in pH control. This reduction in the treatment costs has also resulted in the reappraisal of the original oxidised ore reserves considering that a lower cut-off grade can now be used. This has substantially increased the ore reserves and hence life-of-mine.

The use of locally available items such as the LDPE membrane has negated the need to use valuable foreign currency and kept costs low (local LDPE plastic can be purchased at a cost of Z\$6/m^2 whereas imported HDPE comes in at > Z\$30/m^2, and the LDPE has proved to be a viable alternative to HDPE). In addition, the presence of both slimes and waste rock site means that these don't need to be transported in from elsewhere and so helps in keeping down costs.

The nature of the mineralised diorite host rock has also contributed to the success of the mine in that:

a) It is deeply weathered allowing simple low-cost mining methods;

b) Good recoveries from leaching the high-grade ore (70% in 4 weeks) allow for quick cash return with much of the remaining gold being extracted with time;

c) The high fineness of the gold (910) and hence low impurity content reduce reagent requirements.

The efforts of Pan-African Mining have shown that some unusual and unique ideas, together with a competent and professional in-house team, have transformed the rather gloomy history of the mine into a success story. After a three year period of evaluation and numerous feasibility studies, the heap-leach project was brought on-line in six months at a capital cost of Z$800,000. The mine, which was evaluated, designed and constructed by a team of three geologists, currently produces gold at a cash cost of US$120 per ounce.

Plans are now under way to deepen the open pit into low-grade sulphides and work will be started to re-equip the Edwards Shaft to enable a comprehensive underground investigation. Treatment of the sulphide ore will require a Carbon in Pulp (CIP) circuit which will be installed within the next 12 months. Again, this work will largely be carried out in-house, to reduce capital requirements.

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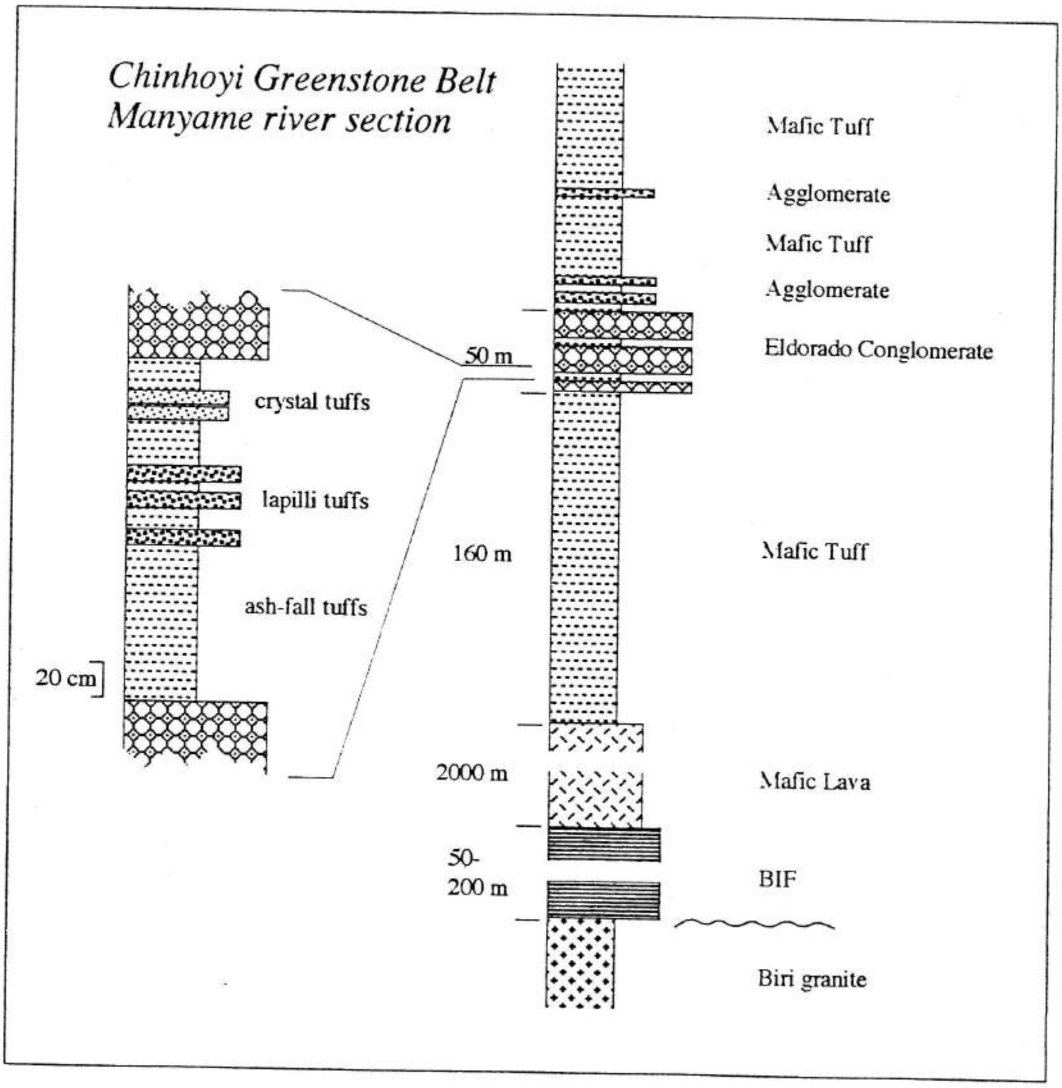
STOP 2. The Eldorado shear zone along the contact between Shamvaian and Bulawayan in the Manyame River, 1 km east of Chinhoyi.

The Eldorado Shear Zone is a prominent NE trending structure in the SW part of the CGGB, and separates Shamvaiian sediments to the NW from Bulawayan volcanics to the SE. The shear zone hosts a great many gold deposits. Within the Manyame River at Chinhoyi, the Eldorado shear zone, is a zone of high strain within conglomerates. The polymict conglomerate in the river bed belongs to the Eldorado Conglomerate, which is up to 50 m thick, and contains cobbles and boulders of granitoids, greenstones, porphyries, chert and BIF. The conglomerate occurs in a pyroclastic sequence with tuff and agglomerate, which overlie pillowed mafic greenstone and banded iron-formation. The conglomerate hosted the Eldorado Gold Mine, which at the beginning of the century was the largest gold mine in the country, with mostly free-milling gold and little sulphide. After its discovery it was initially thought that the deposit represented a fossil placer analogous to the Witwatersrand deposits. This sparked a huge gold rush as it was expected that the deposit would extend over a large area. This turned out to be untrue (Ref: Geol. Surv. Zimb. Bull. 49).



Stop 2. Stratigraphic column through the Bulawayan sequence, Manyame River section, ChinHoyi

Saturday 6th September, 1997

North Midlands: The Kadoma and Lily Shear Zones

P.J. CHADWICK
Falcon Gold Zimbabwe, c/o Globe & Phoenix Mine, PoBox 393, Kwekwe, Zimbabwe

Dalny Mine

The Dalny group of mines includes Dalny, Arlandzer and Turkois mines, whose focus is the mining settlement of Chakari, are mostly hosted by greenstones, but some occurs in felsics and rarely even in BIF units. The deposits are mainly associated with the northern extension of the Lily Deformation Zone (LDZ), north of the Whitewaters Pluton, in the Midlands Greenstone Belt, and especially with its system of splays in the Chakari district. Many of the mines are concentrated along the NE-striking, very linear Arlandzer Shear Zone, which can be traced for several kilometres. It splays from the LDZ, and passes through, or close to, Arlandzer, Turkois and Dalny mines. Virtually all of the deposits near Turkois and Arlandzer mines strike parallel to the shear zone. There are a few NW-striking reefs and other trends occur locally. A second significant splay from the Arlandzer Shear Zone, trending more ENE, is initiated near Turkois mine and strikes towards the Chadshunt mine. Numerous small mines are clustered on or near this structure. Earlier structural modelling of Dalny mine and it's satellites in the Chakari area considers this as a prime example of gold mineralization hosted by an isolated, continuous shear that has been broken up by post-mineralization faulting, whereby the kinematics generally indicate a main phase of brittle-ductile, oblique, reverse-sinistral movement. Recent research proposes that the Arlandzer Shear Zone is not a penetrative 300 m wide, 5 km long shear zone, but rather part of an anastomosing network of early shears, which have been re-activated during the mineralising phase of deformation.

At Dalny mine proper, mineralization comprises extensive sulphide replacement and shear-veining within a general zone of silicification. Arsenopyrite and pyrite are the dominant sulphides. Quartz shear-veins are sporadic. Where carbonatization of the shear zone is prevalent, the gold content is reduced. Wall rock alteration is dominated by carbonatization and sericitization, and extends up to 15 m from the ore zone, but carries little gold. The mine geology is complicated by three sets of dykes: pre-shearing; post main-shearing, but pre-mineralising - the Brown dykes; and post mineralization - the Blue dykes. In addition to the main Dalny shear zone, the minor Dalny 'B' and a localised footwall reef are developed. Stoping patterns of the main Dalny Mine, the Dalny Footwall Reef, and the Stella section all suggest WNW-plunging oreshoots. The Dalny 'B' reef oreshoot plunges subvertically.

STOP. 1 Underground visit to Dalny Mine via West 14 Shaft

An underground visit to 34, 35 and possibly 36 levels to observe the relationship of the main Dalny Reef with respect to the host shear, in addition to the Dalny 'B' Reef will be undertaken. It is of interest to note that Dalny mine is the deepest producing gold mine in Zimbabwe, with the lowermost level (38 level) being some 1900 m below surface.

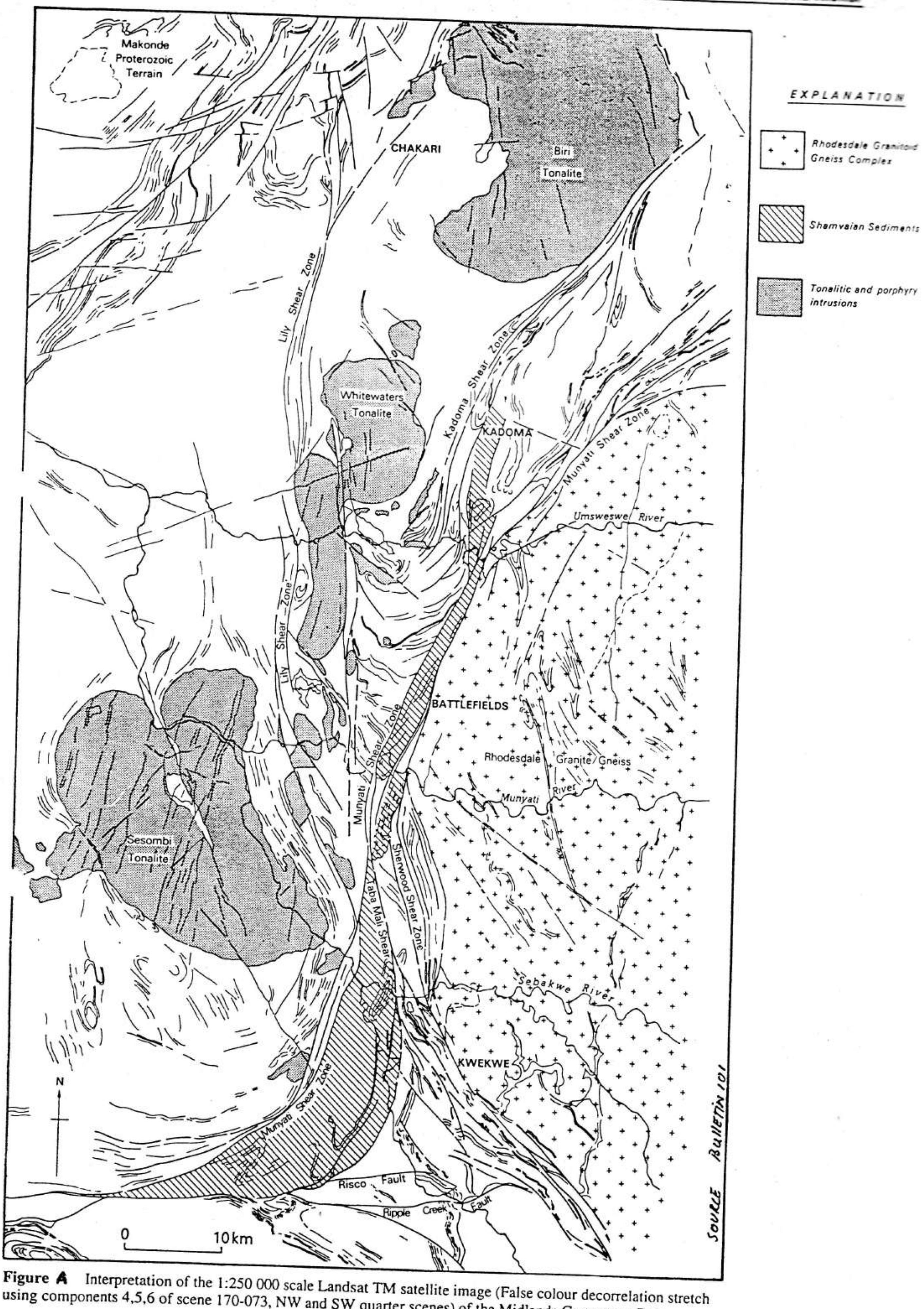


Figure A Interpretation of the 1:250 000 scale Landsat TM satellite image (False colour decorrelation stretch using components 4,5,6 of scene 170-073, NW and SW quarter scenes) of the Midlands Greenstone Belt.

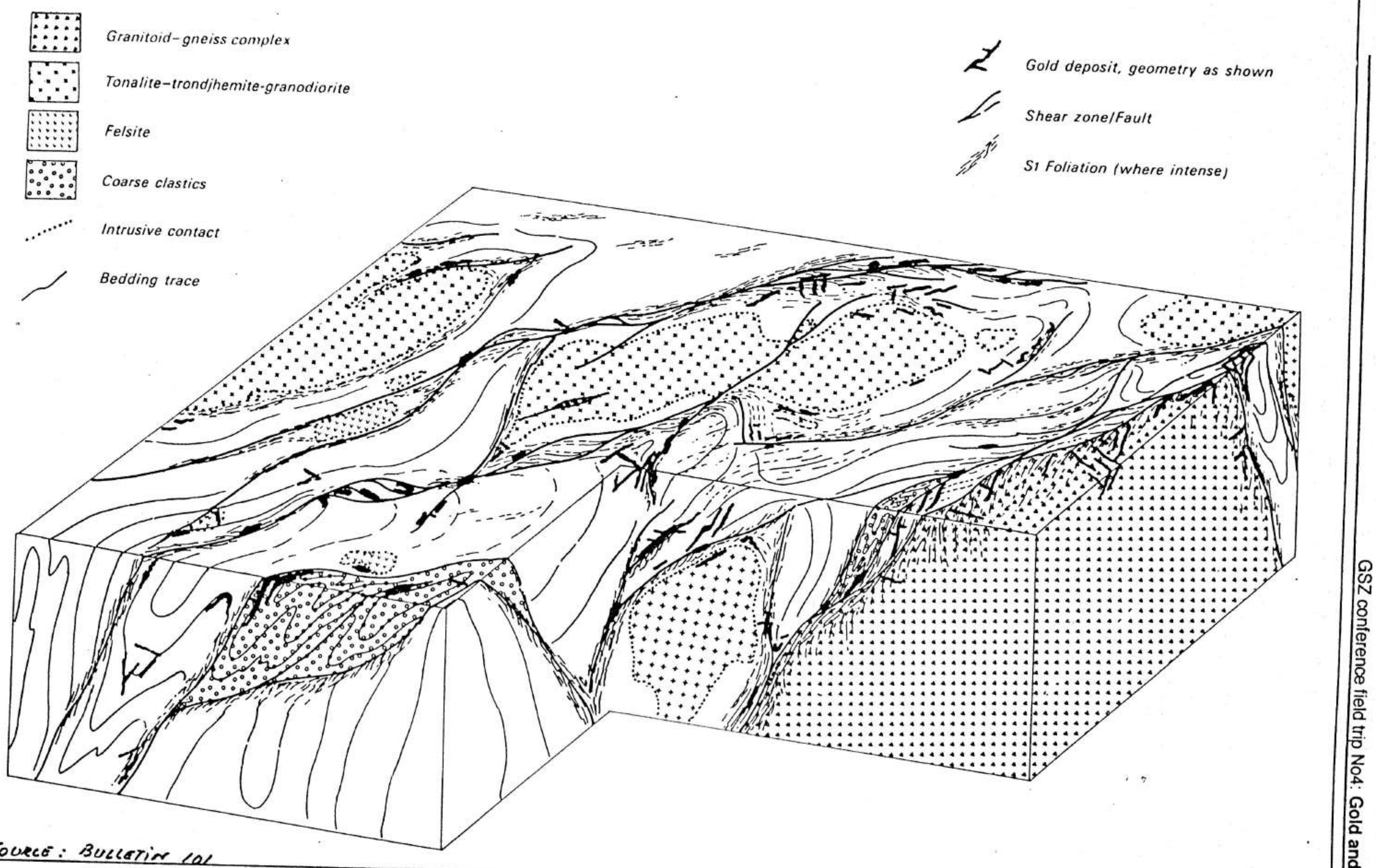
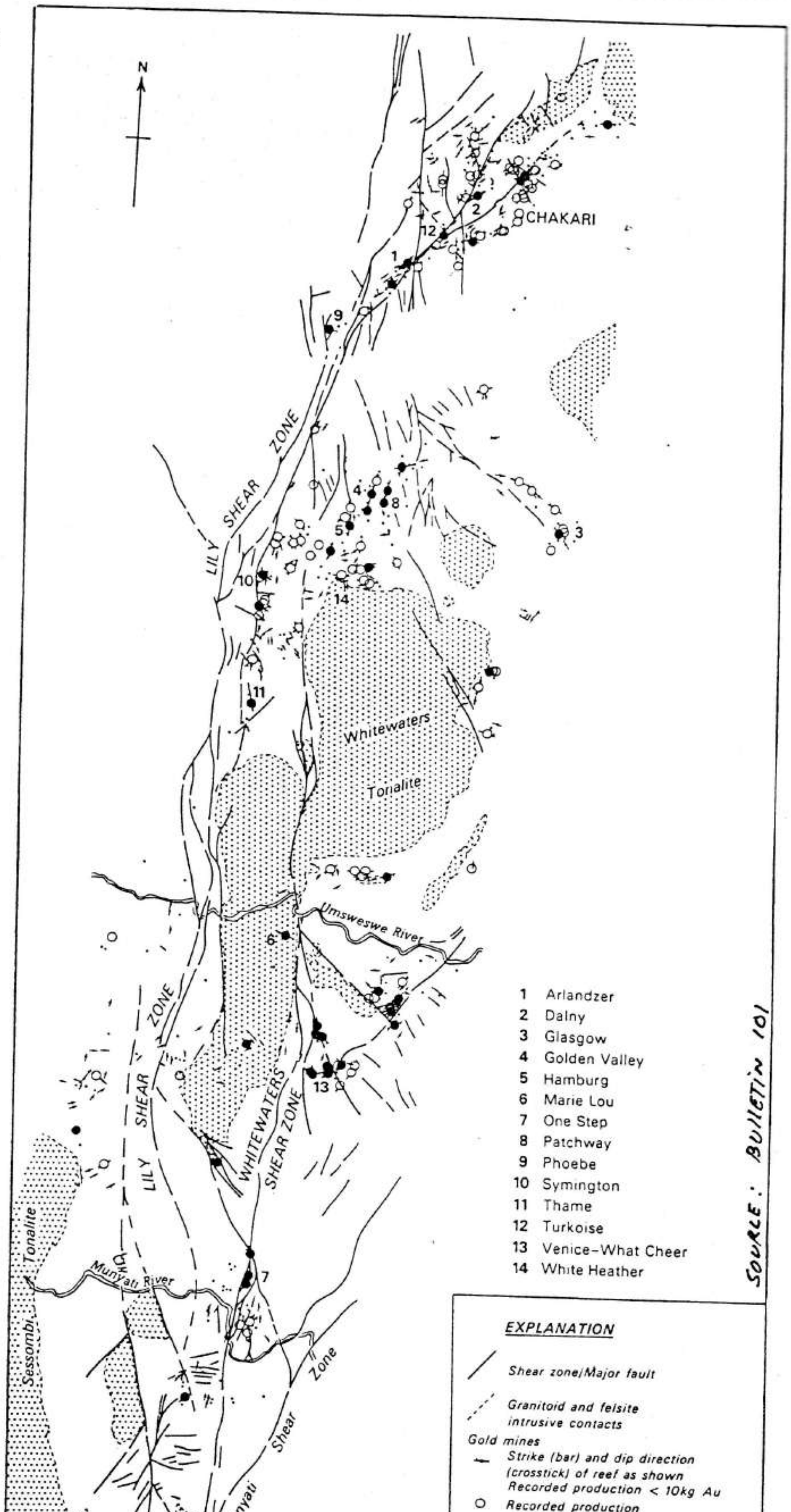


Figure B Schematic diagram showing generalised relationships of structure and gold mineralization in the Midlands Greenstone Belt as viewed from the SE. Geographic relationships are telescoped and subsurface extrapolations are largely hypothetical, but are based on the available information.

Figure C Photointerpretation (1:80 000 scale) of the area of the Lily and Whitewaters deformation zones upon which the loci of recorded gold mines (classified according to production and showing the approximate strike of the deposits) are superimposed.



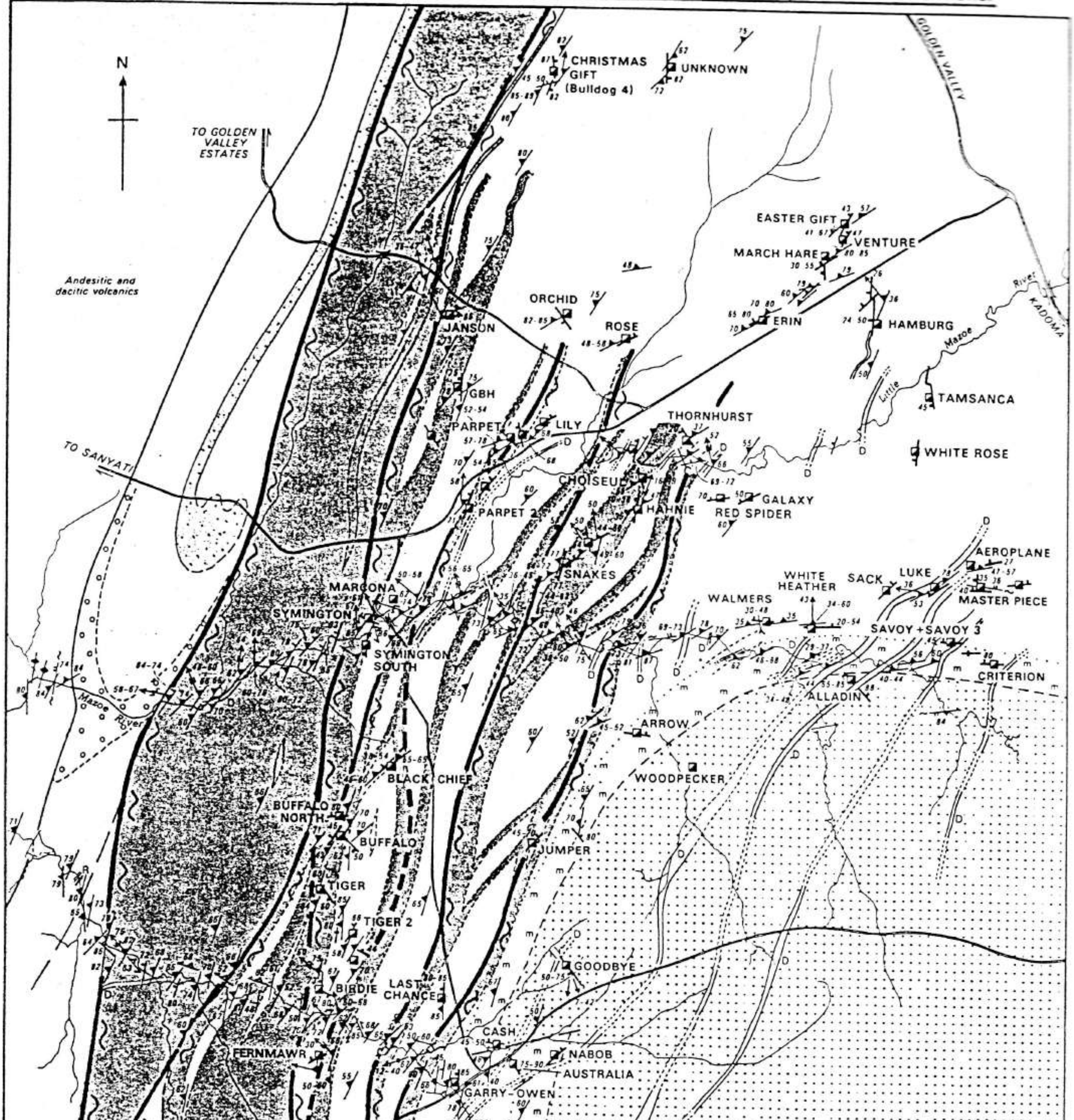


Figure D Geological map of the area of the Lily Deformation Zone (Last Chance Group of Mines) west of Golden Valley and the Whitewaters tonalite. Includes geological data from E.P.O.147^. (Viewing and Anderson, 1966.)

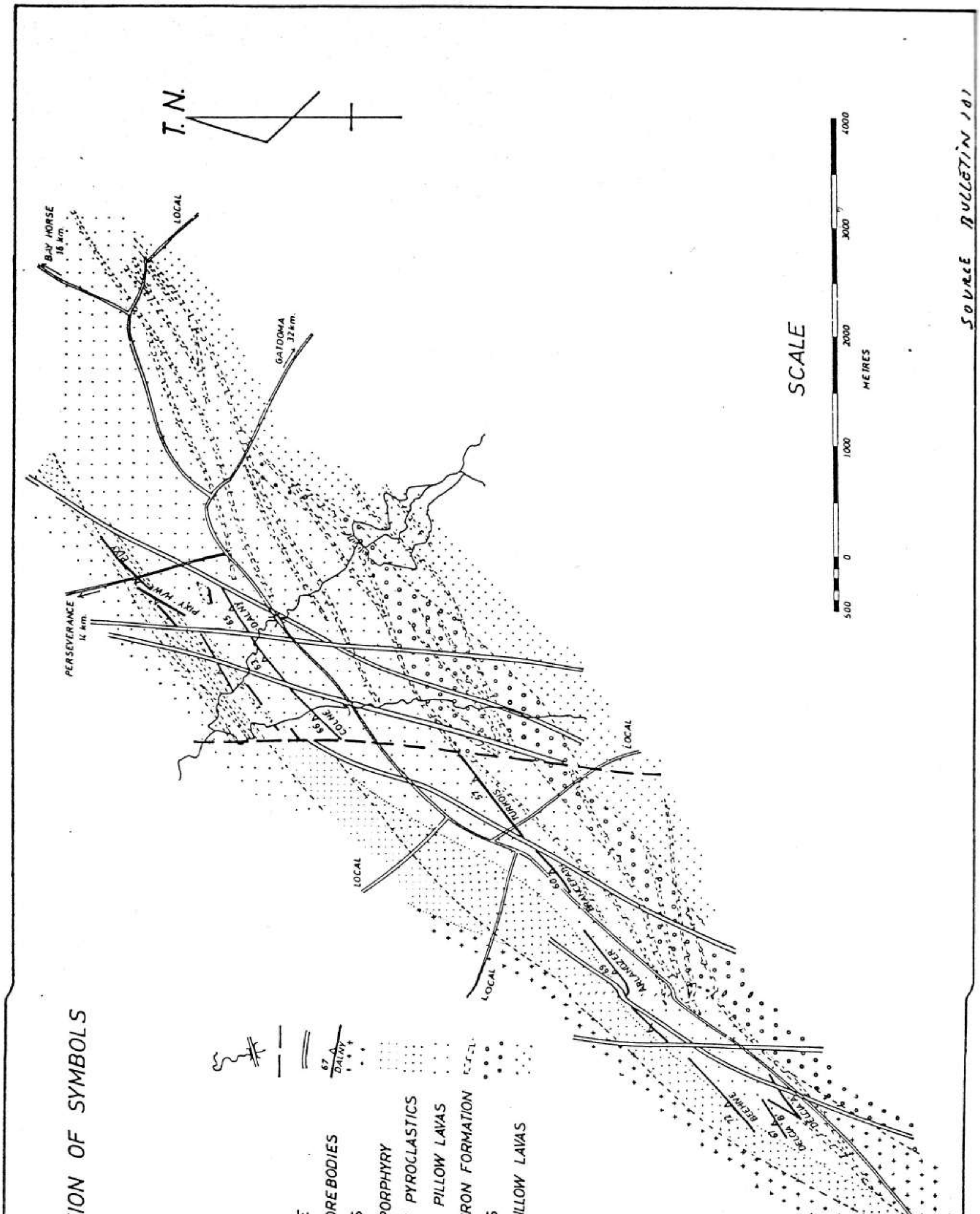


Figure
Geology of the area around Dalny Mine, Chakari.

Structural controls on gold mineralisation at Dalny Mine, Zimbabwe.

The following account is based on DIRKS, P. H. & VAN DER MERWE J. (1997; JAES in press) and is by no means impartial.

Introduction

Many gold deposits in Archaean greenstone belts are related to re-activated ductile-shear zones (e.g. Groves *et al.*, 1984; Colvine *et al.*, 1984, 1988; Sibson *et al.*, 1988; Groves and Foster, 1993; Campbell and Pitfield, 1994; Herrington, 1995). In general precipitation of gold in these settings occurs in the brittle-ductile regime at 2±1.5 kbar and 350°C as large volumes of fluid, probably of mixed magmatic, metamorphic and mantle derivation are channeled into, and forced up shear zones of sufficient scale. Subsequent precipitation in favourable structural traps is due to an array of physio-chemical factors including bulk rock chemistry and a sudden drop in fluid pressure (Sibson *et al.*, 1988). It is not uncommon to find carbonaceous or graphitic shales, and granitic to monzonitic felsic intrusions spatially associated with gold deposits. Brittle-ductile shear zones, especially those with a reverse component, are noted as extremely important in localizing fluid flow and acting as depositional centres (Sibson, 1987; Sibson *et al.*, 1988; Boulier and Robert, 1992; Schmidt Mumm *et al.*, 1994). Shear zones commonly initiate along a sequence of overlapping fractures called Riedel, anti-Riedel and P-shears (Tchalenko,1970), which coalesce at high strains in an anastomosing pattern of fractures comprising dilational and anti-dilational zones (Boulier and Robert, 1992; Schmidt Mumm *et al.*, 1994). During reactivation of such a shear, dilational zones are ideal positions for deposition of gold (Vearncombe *et al.*, 1988).

It has commonly been observed that shear hosted gold deposits in greenstone belts are not directly within a major shear zone, but rather occur within secondary structures (e.g. joint splays) related to a nearby master shear (Foster *et al.* 1986; Foster 1988a, b; Groves and Foster, 1993; Campbell and Pitfield, 1994). Nucleation of these structures presumably reflects movement on the master shear, but this does not automatically explain the fracture geometry and palaeo-permeability of the deposit. The geometry of secondary structures adjacent to larger shears is critically controlled by the distribution of earlier inhomogeneities such as mechanically diverse lithologies and shears. To understand the geometry of gold deposits it is paramount to have an understanding of the underlying, commonly higher grade, ductile geometries, as these constitute the basis for channelways and traps for later auriferous fluids.

It is generally assumed that the cyclic nature and distribution pattern of greenstone lithologies in the Zimbabwe craton reflects primary depositional processes (e.g. Wilson, 1979; Foster *et al.*, 1986; Wilson *et al.*, 1995). This is not necessarily the case for the complex distribution of lithologies in the Dalny Mine area (Fig. c) which may have resulted from tectonic stacking during the earlier stages of development of the greenstone belt. This tectonic stack resulted in a geometrical framework that controlled the position of subsequent gold reefs during later reactivation.

Regional Geology setting

Dalny Mine is situated in the northern parts of the Midlands Greenstone Belt in the western part of the Zimbabwe Craton (Fig. c). The mine occurs in a thick pile of predominantly mafic metavolcanics ascribed to the upper-Bulawayan sequence of greenstones dated at 2680 Ma (Wilson *et al.*, 1995). It is generally assumed that this part of the greenstone belt occurs to the NW of a major anticlinal structure, the Gatooma Anticline, which is positioned along the axis of the Midlands Greenstone Belt (Bliss, 1970; Herrington, 1995), even though the actual existence of this structure is poorly established, either structurally or with younging criteria. About 5 km to the west of the mine the greenstones are bounded by the N-S trending Lily Shear Zone, which is a major Archaean crustal break and marks the contact between the greenstones to the east and Proterozoic metasediments of the Deweras Group overlying greenstones to the west (Fig. c). This shear is believed to be intimately related to mineralisation at Dalny Mine (e.g. Carter, 1990; Campbell and Pitfield, 1994).

Dalny Mine in Chakari, is the largest of a group of mines including Pixie, Stella, Turkoise and Arlandzer Mines, which occur along a NE trending belt (Figs c, 2) generally referred to as the Arlandzer shear zone (e.g. Campbell and Pitfield, 1994). The mine is one of the largest in the country with a total production to date of about 60 tonnes of gold. Currently the mine is worked to a depth of 1500m (35 level) with development to a depth of 1800m (38 level). Dalny is the largest producer with Stella and Pixie Mines operating as part of the Dalny complex. Arlandzer, Delcia, Jack West and related mines are not producing (Fig. 1).

The main Dalny reef is typically hosted by fine-grained pillowed mafic volcanics although some of the other deposits in the area are hosted by medium-grained massive mafic volcanics, siliceous schists and ironstones (Bliss, 1970; Dube, 1977; Foster *et al.*, 1979). Gold occurs either disseminated in the host rocks near shears or in quartz veins within shear zones. Gold is rarely native and mostly associated with pyrite and arsenopyrite. Other accessory sulphide minerals include tetrahedrite, pyrrhotite, galena, sphalerite and bornite (Carter, 1990; Campbell and Pitfield, 1994). Tourmaline and scheelite are found within auriferous gold veins. Gold was probably transported at ~390°C and 3.6 kbar as the hydrosulphido-complex, AuHSO, in low salinity, CO_2-H_2O rich fluids of pH 5.35 (Carter, 1990). The fO_2, fH_2S and fSO_2 of the fluid was 1.995×10^{-27} bars, 1.24 bars and 3.33×10^{-7} bars respectively, and the total amount of H_2S in solution was ~457ppm (Carter, 1990).

Fig. 2. Composite lithological map of the area around Dalny Mine based on mapping by Dube (1977) and van der Merwe (1995): (a) Distribution of lithological units in the area. (b) Distribution of shear zones in the area. This pattern is partly interpreted assuming that most siliceous schists, graphitic shales and unconformable lithological contacts represent shear zones. The surface position of known gold reefs in the area is superimposed on the shear zone geometry. The inset shows the position of the reefs only. The position of the strain samples (a-h) reported in Table 3, is indicated.

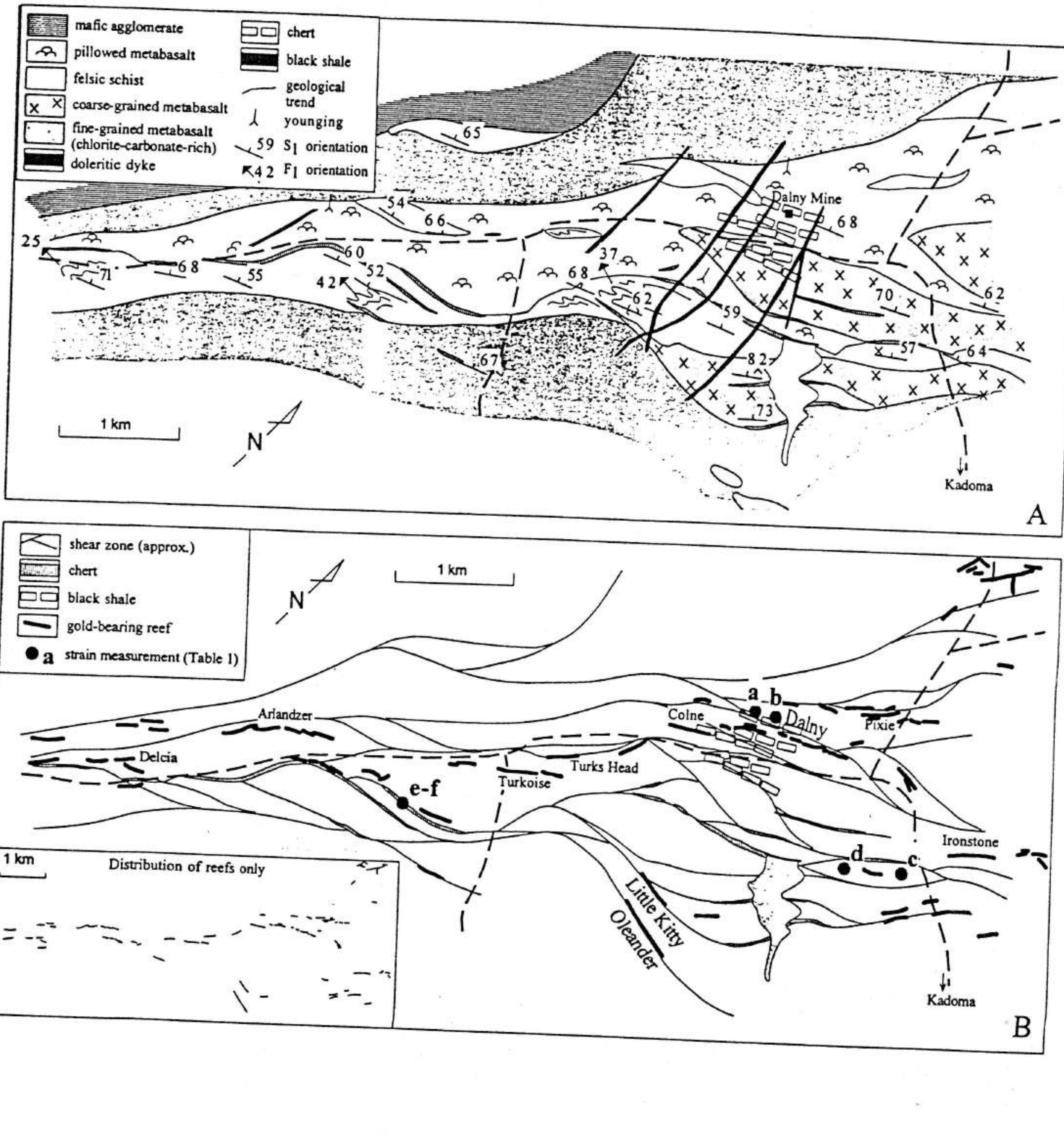
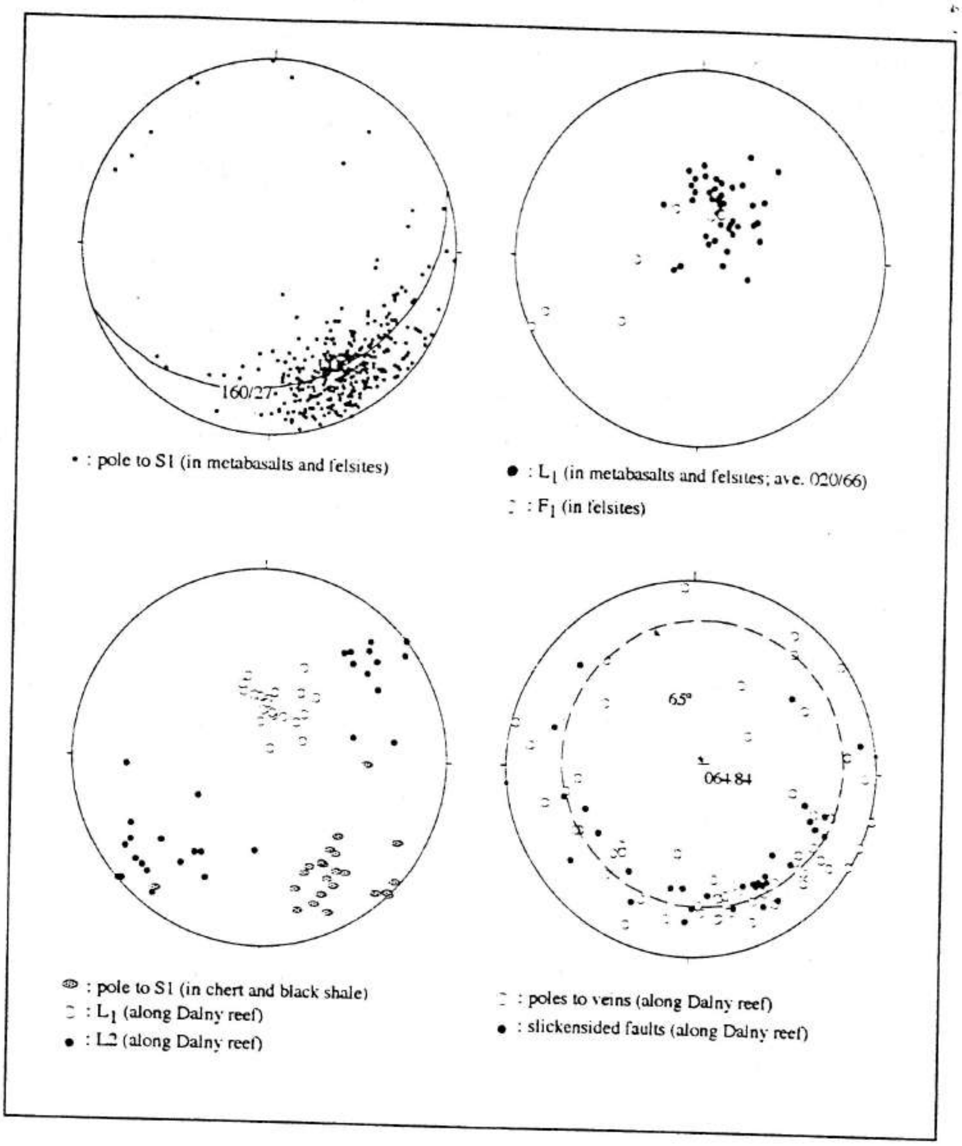


Fig. 3. Stereographic equal area plots of structural elements around Dalny Mine (see text for discussion).



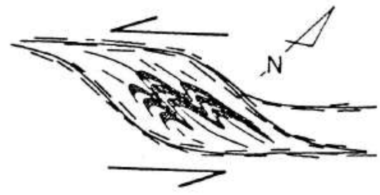
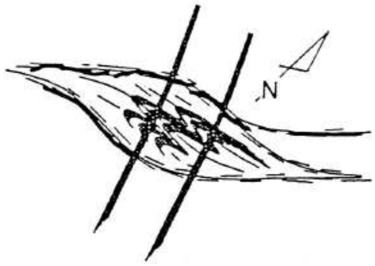
This paper		Leigh (1964), Bliss (1970)
D_1: • Formation of an imbricate stack of lithological units along an anastomosing network of 1-5 m wide shear zones. • F_1 non-cylindrical folding within felsic fault blocks accompanies shearing. • S_1 is axial planar to F_1 folds and parallels the shear zones. *Steepening of the sequence may have occurred during D_1 or could have post-dated it (e.g. during the development of the Gatooma Anticline).*		D_1: • Development of the dominant cleavage, related to the Gatooma Anticline. • Shearing along limbs of vergence folds to the Gatooma Anticline
		D_2: • NW-trending cross folding.
D_2: • Reactivation of D_1 shear zones as brittle-ductile faults. • Multiple episodes of fault motion, reflected in overprinting slickenside lineations (L_{2a}, L_{2b}, L_{2c}). Reverse sinistral and normal movements alternated. • Multiple sets of gold-bearing veins were emplaced.		D_3: • Activation of the Lily Shear Zone. • Emplacement of large batholiths, with associated balooning deformation
D_3: • Emplacement of mafic dykes along NNW trending fractures.		D_4: • Development of NNE trending faults. • Dyke emplacement

Table 2. Summary diagram of the principle deformation events around Dalny Mine, including diagrammatic illustrations of the most important geometrical features. An attemt has been made to correlate the events with the deformation scheme reported in Bliss (1970), which is partly based on Leigh (1964). The D_1 geometries of Bliss (1970) largely coincide with the D_1 geometries reported in this paper, but a direct link with the Gatooma Antiform can not be made. D_2 of Bliss (1970) and his D_4 faulting could not be recognised in the Dalny area (see text for discussion).

Stratigraphy

As a result of intense deformation, the stratigraphy around Dalny Mine is uncertain, therefore, only lithological variations are described here (Table 1). Mafic greenstones consisting of massive to weakly foliated, pillowed, basaltic to andesitic lavas are the most ubiquitous rock type in the area (Bliss, 1970; Foster *et al.*, 1979; van der Merwe, 1995). The mafic greenstones can be subdivided into three lithological units (Dube, 1977), namely: 1) fine-grained, foliated, chlorite-carbonate rich volcanic rocks, probably representing sheared and intensely altered andesitic-basaltic lavas; 2) medium- to coarse-grained massive mafic rock with metamorphic actinolite-epidote-chlorite-albite replacing igneous augite and plagioclase; 3) fine- to medium-grained pillowed metabasalt, with a composition similar to the coarse-grained greenstone variety. The pillowed greenstones are the major host of gold mineralisation. The distribution pattern of each of these units is shown in figure 2.

Quartzofeldspathic mica schists outcrop as a series of fawn-coloured, lozenge-shaped bodies, most prominently to the south of the main mine workings (Figs 1, 2). Other quartzofeldspathic schist lenses or lozenges occur isolated within the greenstones. The lozenges are typically 1-2 km by 0.5 km in size and locally bounded by silicified horizons. They commonly contain mm- to m-scale open to tight folding of a primary compositional layering (S_0) that is defined by 0.5 cm scale, light-dark colour banding resulting from variations in mica content. The unit can be subdivided into a felsic schist and an conglomerate member with similar mineralogy. The schist consists of <0.5 mm large rounded clasts (phenocrysts ?) of quartz and feldspar in a fine-grained (20-50 μm) matrix of quartz (<45%), feldspar (10-30%), muscovite (20-25%) and opaques (<25%). Feldspar is generally sericitised and clasts are commonly only visible as ghosts of mica. Some biotite locally occurs in the ground mass, but it is mostly altered to chlorite. The conglomerate contains 5-15cm clasts of quartz and chert in a fine-grained matrix of a similar composition as described above. The common occurrence of amygdale fillings in the felsic schist member suggests a volcanic origin of the unit (Bliss, 1970; Dube, 1977). The schists are generally moderately foliated in the field, but in thin section a strong fabric of aligned muscovite grains can be observed.

Siliceous schists typically occur as ridges of beige to red-brown rocks along the quartzofeldspathic schist-mafic greenstone contact (Fig. 2). Although the straight siliceous schist ridges have been regarded as BIF's by previous workers (e.g. Foster *et al.*, 1979; 1986), they locally bound and transect strongly folded schists (Fig. 2), testifying that at least some are secondary in origin. The siliceous schists generally consist of quartz (>70%), muscovite (10-15%), opaques (5%), glassy (non-structured quartz) clasts (10%) and a small proportion of feldspar. Locally the siliceous schist bands are strongly brecciated and infiltrated by iron oxides or sulphides resulting in a gossanous BIF-like appearance. However, a regular interlayering of iron-rich and silica-rich bands, typical for primary BIF deposits, is completely lacking, and therefore none of the siliceous or "cherty" units in the area can be equated with sedimentary BIF. Siliceous schist bands locally contain isoclinal and intrafolial folds. In thin section they show remarkable pressure shadows and grain size reduction textures (see below).

Black shale occurs as 0.1-5 m wide anastomosing zones within the mafic greenstones. The shales are not exposed on surface, but are commonly found underground, both in the mine and in boreholes. Projection of such intersections to surface suggests that shale bands are ubiquitous, parallel to the general stratigraphic trend (Fig. 2). It is not obvious whether all bands are parallel, or whether bands actually bifurcate. The black shales are intensely foliated and lineated and associated with numerous open to isoclinal, as well as intrafolial folds. The black shales mainly consist of quartz (30-60%), opaques (20-50%) and calcite (<15%). The opaques consist mostly of graphite and pyrite. The calcite is associated with secondary alteration, growth in pressure shadows and veining. Although the black shales are commonly in close proximity to the reefs and are rich in pyrite, gold values tend to be low (1-2g/t) compared to the greenstone hosted gold.

'Dyke' on the mine is used to refer to both dolerite and gabbro dykes, which were emplaced at different stages either pre-dating or post-dating mineralisation (Bliss,1970; Leigh, 1964). The most prominent dykes are N-S trending dolerites that truncate the gold reefs (the "blue dykes" of Leigh, 1964).

Dube (1977) noted that the mafic greenstone units and quartzofeldspathic schists are complexly interleaved and commonly separated by minor "unconformities" (Fig. 2), and equated this pattern with cyclic volcanic units of limited lateral extend. This pattern was also noted on a regional scale by Bliss (1970), who explained the stacking of felsic lenses to result from tight vergence folding along the NW limb of the Gatooma anticline. A summary of the different litho-tectonic units around Dalny Mine is presented in Table 1.

Metamorphism

The rocks around Dalny Mine preserve few indicative metamorphic assemblages. The mafic greenstones are locally metamorphosed to chlorite-actinolite-epidote-albite (An_7) assemblages (Bliss, 1970; Dube, 1977), typical of greenschist facies conditions. Quartzofeldspathic and siliceous schists contain albite-muscovite-chlorite and rare biotite. Feldspar is commonly broken down to white mica. Quartz and albite show plastic deformation and dynamic recrystallisation features and larger augen commonly preserve pressure fringes of quartz. These observations suggest that peak-conditions reached lower to middle greenschist facies (400-450°C). The pressure of metamorphism is unconstrained, but comparison with geothermal gradients obtained from nearby greenstone belts (e.g. Jelsma *et al.*, 1993) suggests that pressures would be around 2-4 kbar. Peak assemblages define the regional foliation, prominent in the felsic units, the siliceous schists and the black shales.

Gold reefs cut the regional foliation and mineralisation post-dates the peak of metamorphism. Early gold mineralisation was associated with the break-down of actinolite and albite at estimated fluid conditions of 390°C and 3.6 kbar (Carter, 1990). Most of the gold-bearing veins are associated with low-salinity, CO_2-rich fluids, probably of metamorphic origin (Carter, 1990). Only late-stage quartz-carbonate veins contain more saline (9.33 wt.% NaCl) aqueous primary fluid inclusions which also occur as later generations within the auriferous quartz.

This late fluid flux along the shear zone and extensive hydration and carbonatization of the wall rocks may have originated from magmatic fluids. A possible source of magmatic fluid is the minor intrusion of porphyries to the North and South of Dalny Mine (Fig 1).

Wall rock alteration at Dalny is attributed primarily to the early gold-bearing fluids (Bliss, 1970; Carter, 1990), and is distinguished by the breakdown of actinolite and epidote to chlorite and calcite. The alteration of albite and chlorite to K-mica is apparent. The alteration zone is characterized by the distinctive depletion of Na_2O and enrichment in SiO_2, K_2O, CaO, Rb, Ba, W, As, Cu and Sb (Foster *et al.*, 1986).

Structure

Leigh (1964) and Bliss (1970), noted the stacking of felsic and mafic lenses in the Dalny area, which they interpreted to have resulted from tight vergence folding along the NW limb of the Gatooma Anticline. The position of the reef was interpreted to coincide with the sheared limb of a tight parasitic syncline of the Gatooma Anticline. Dalny Mine is generally interpreted as a typical example of a linear, shear zone hosted deposit occurring in the central portions of an extensive zone of sheared and faulted rocks referred to as the Arlandzer Shear Zone (Foster *et al.*, 1979, 1986; Campbell and Pitfield, 1994; Herrington, 1995). Although not all the mines in the area lie on the same strike line the above interpretation is supported by the proposal that the original linear array was offset by later faults such as the Turkoise Gap Fault and the Eastern Cutoff Fault (Leigh, 1964; Bliss, 1970 and Foster *et al.*, 1979), even though no clear physical evidence of these faults has been presented. Carter (1990) suggested that the Arlandzer Shear Zone is a Riedel offshoot of the Lily Shear Zone to the west.

Kinematic data for the Dalny shear were first collected by Carter (1990) who showed that s-c fabrics indicate a reverse-sinistral movements. Further work by Campbell and Pitfield (1994) corroborated this on the basis of s-c fabrics, vein fibre growth and vein arrays. They also found that there were isolated occurrences of dextral-normal movement, possibly related to anti-Riedel shears.

A revised structural framework

On the basis of our data and reinterpretation of previous data it is possible to distinguish a minimum of three deformation events around Dalny Mine (Table 2). The earliest, D_1, is a composite event which pre-dates the gold mineralisation, the second, D_2, accompanies gold mineralisation and D_3 represents the final stages of deformation that post-date gold mineralisation. D_1 coincided with the peak of metamorphism and is responsible for the lithological arrangement that underlies the mineralized fault zones. This arrangement is associated with a juxtaposition of coherent lithological blocks across discrete ductile mylonite zones. D_2 is associated with brittle-ductile fault zones that propagated parallel to underlying geometrical boundaries, including ductile shear zones. D_3 is associated with late stage intrusion of dolerite and gabbro dykes.

Pre-mineralisation deformation, D_1

D_1 comprises a number of deformation features including the development of the regional foliation, which is axial planar to folds in the felsic schists, the development of lozenge-shaped lithological units bounded by siliceous schists and the development of an intense layer parallel foliation and lineation in the black shales within mafic units that are otherwise relatively weakly deformed (Table 2).

The regional foliation and associated folding

The most prominent D_1 deformation features are a variably developed schistosity, S_1, and associated mineral elongation lineation, L_1. Within the greenstones, S_1 and L_1 are generally weakly developed except within discrete shear zones characterised by chlorite-actinolite assemblages. Within the quartzofeldspathic schists, S_1 and L_1 are prominent. Within the 'cherty' siliceous schists and especially black shales, S_1 and L_1 are very strongly developed. The orientation of foliation and lineation is similar in all units with S_1 predominantly oriented at ~330°/65° and L_1 pitching steeply to the NE (Fig. 3). S_1 trends are not entirely constant, but range from 030-070° around a largely constant lineation direction (Fig. 3). This variation in trend mimics the wavy outcrop pattern of most lithological contacts (Fig. 2), and is caused by two effects (Table 1): 1) S_1 traces in schist zones (i.e. shear zones, see below) anastomose around lithological blocks of relatively low strain. The anastomosing nature of the shears causes a spread in orientations of S_1; 2) within in the centres of low strain blocks, S_1 is commonly oriented at a slight angle to the bounding schist zones. On approaching the boundary of a low strain block S_1 will rotate into parallelism with the bounding shear. This means that the S_1 orientation partly depends on bulk strain, which indicates that S_1 formed in a non-coaxial environment. There is no field evidence such as crenulation lineations or later cleavage planes, which indicates that the spread in S_1 was caused by refolding during a later deformation stage.

In the mafic units S_1 and L_1 are defined by oriented metamorphic minerals, especially chlorite and actinolite, and by elongated objects such as pillows and agglomerate clasts. In the quartzofeldspathic schist, S_1 is defined by strongly oriented muscovite grains and trails of opaques. In siliceous schists and black shales S_1 is defined by oriented micas and opaques as well as ribboned quartz grains (bands) and pressure shadows (see below). In all felsic units, L_1 is generally defined by quartz rodding.

Early workers in the area (e.g. Leigh, 1964; Bliss, 1970) report extensive folding, partly to explain the complicated interfingering of felsic and mafic units, and S_1 is considered to be axial planar to such folds (Table 1;

Bliss, 1970). Except within lenses of quartzofeldspathic schist (Fig. 2), and within the graphitic shale horizons, no evidence exists for large-scale (i.e. >1 m) folding in the area. Younging directions in pillowed greenstones that envelop some of the felsic units invariably indicate a younging direction to the NW and do not appear to be folded (Fig. 2; Dube, 1977). Therefore, D_1 foldng in the area is restricted to certain lithological units. In the quartzofeldspathic schists S_1 is axial planar to mm to m-scale, similar folds with gently to moderately west plunging fold axes (Fig. 3). The folds vary from open, box-like to tight. The enveloping surfaces describe more open SW-verging folds with fold axes more or less normal to L_1 (Figs 2, 3).

The Arlandzer Shear Zone has been described as a prominent structure in the area (e.g. Foster *et al.*, 1979, 1986; Campbell and Pitfield, 1994; Herrington, 1995), however there is no evidence of a continuous lineament to coincide with the suggested position of the shear zone on either Landsat TM images or airphotographs (Fig. 1). To establish the existence of the Arlandzer Shear Zone a comparative study of strain within and outside the supposed shear zone was made which suggests that the overall strain in the area is rather low.The strain within the cited 'Arlandzer Shear Zone' is not significantly different from values found outside the shear zone, especially if one considers that the felsic schists are intensely folded, whereas the mafic greenstones show little evidence of folding and appear to behave as rigid blocks. From this, and the lack of a continuous lineament we conclude that the 300 m wide Arlandzer Shear Zone does not exist as such.

Siliceous schists and black shales

Siliceous schist bands with a cherty appearance, with or without a large proportion of iron-oxides, are closely associated with the early deformation event. Quartzofeldspathic schist lenses are commonly bounded by strongly silicified schist units, which typically contain rounded clasts of altered feldspar and unstructured quartz, and in thin section appear to be heavily silicified equivalents of the felsic unit. In a number of localities these siliceous schist bands cross the felsic unit parallel to the main tectonic foliation, and transect a strongly folded compositional layering. The composition of the transecting siliceous schist bands is similar to the siliceous schists that are comformable with stratigraphy, and generally they form part of a continuous unit (Fig. 2). This indicates that silicification occurred during or after the folding event as a result of siliceous fluid fluxing along discrete zones of weakness.

Siliceous schist bands locally occur in the greenstones as well, commonly in close association with minor felsic lenses, sheared chloritic schist or along the contact of two separate lithological greenstone units (Fig. 2). In one such locality 100 m north of the Dalny Mine Dam wall 1-3 m-scale steeply NNE plunging isoclinal folds occur in a 10-20 m zone of silicified felsic schist and chlorite schist, which separate coarse-grained, massive, metabasite to the north, from fine-grained pillowed metabasalt to the south, neither of which show evidence of folding (Dube, 1977). The fold axes in this siliceous unit parallel a north plunging mineral lineation.

Field relations indicate that at least a number of the siliceous schist bands are secondary and closely associated with locally unconformable lithological contacts, possibly shear zones. In thin section both conformable and unconformable siliceous schists are characterized by a very strong planar fabric, defined by oriented micas, trails of opaques and quartz ribbons. Dynamic recrystallisation and grain size reduction textures, and an apparent, strong quartz lattice preferred orientation are common. Regrettably the latter could not be confirmed with the universal stage set-up at the University of Zimbabwe because of the extremely fine grain size (<25 μm). Microscopic deformation features are consistent with a mylonitic origin of the fine-grained siliceous schist giving them a cherty appearance. In some siliceous schists, quartz pressure fringes have formed on either side of 0.2-1 mm large clasts of opaques and non-structured silica (chalcedony or chert). Similar pressure fringes consisting of quartz and calcite have formed in the black shales mainly around pyrite. The pressure fringes in the siliceous schist, consist of matrix material (quartz) that is not in optical continuity with the quartz clasts (Fig. 5a), indicating syntaxial growth (growth from matrix inwards). Fringes are curved, however individual fibres retain a constant crystallographic orientation and fibre curvature patterns can be correlated between clasts, indicating that fibre curvature is a growth rather than a deformation feature. Trends of fibre isogons are sub-parallel to the face of the rigid clasts indicating displacement controlled fibre growth making it possible to describe the pressure shadow type with the rigid fibre model (Ramsay and Huber, 1983). Using this model, calculations were carried out on four 'clasts' from a siliceous schist unit that bounds a folded felsic schist (Table 3).

Most fringes show clear evidence of dynamic recrystallisation along their outer margin where relatively coarse quartz fibres show strong undulatary extinction and very irregular grain boundaries as parts of the fibre are replaced by round quartz grains with a grain size similar to the matrix . The irregular grain boundaries and lack of clear subgrains indicate that dynamic recrystallisation is grain boundary migration controlled. Because of dynamic recrystallisation of the fringes, the strain estimates in Table 3 can only be considered as a minimum, more so because it is not clear at what stage of the deformation process the matrix grains became detached from the clasts and fringes started developing. Considering the mylonitic features of the matrix it is not unlikely that fringes formed towards the end of a shearing episode. The incremental strain history of the round clasts shows a consistently anti-clockwise rotation of younger fibres relative to the external foliation. This is less consistent with elongated clasts which were not able to rotate freely in the matrix.

The strongly foliated and lineated siliceous black shales are interpreted as the tectonic equivalents of the cherty siliceous schist within the greenstone sequence. They show the same mylonitic macro- and microscopic features as the siliceous schist including intense localised folding with an axial planar foliation defined by oriented graphite or a quartz grain shape fabric (precluding a syn-depositional origin of the folds), pressure fringes of quartz and calcite in fracture fills and pressure shadows around opaques, s-c fabrics and dynamic recrystallisation and tectonic grain size reduction features .

Considering all mesoscopic and microscopic deformation features, the siliceous schists and black shales probably represent mylonite zones recording considerably higher ductile strains than the surrounding rocks. They formed during the early stages of deformation contemporaneous with regional metamorphism and folding of the felsic schists. The black shales may have been primary sedimentary units with strain being preferentially partitioned along them during deformation. The mylonite zones form an anastomosing network separating relatively rigid blocks (Fig. 2b). It is the tectonic juxtaposition of these blocks that causes the disjointed stratigraphy first noted by Bliss (1970). The movement sense appears to be reverse with a sinistral component, based on s-c fabrics in chloritic schists, and vergence of folds in the quartzofeldspathic schists that are bounded by the siliceous mylonite bands.

D_1 tectonic stacking of the greenstone sequence

D_1 mylonite zones accommodated the interleaving of lozenge-shaped lithological blocks of greenstone and quartzofeldspathic schist. The lozenge-shaped geometry is visible on landsat images and aerial photographs (Fig. c). Landsat images show the overlapping sigmoidal-shape bodies that constitute the chain of felsic hills SW of Dalny Mine. This lensoidal pattern extends into the greenstones (Figs c, 2). Most of the lensoidal felsic bodies are bounded and transected by cherty mylonites, whereas lensoidal greenstone units are commonly bounded by chloritic schist zones. Considering the discordant distribution of lithological units and the fact that wherever younging directions have been observed these are invariably to the NW (e.g. Leigh, 1964; Dube, 1977; Carter, 1990), the greenstones around Dalny Mine are best interpreted as a tectonically stacked sequence of felsic and mafic blocks, each with an average size of about 1-1.5 by 0.5 km. Stacking resulted in the formation of duplexes, and is responsible for the wavy attitude of S_1 observed in the area. Whereas the felsic schists are folded within each fault block, the mafic greenstones have largely retained their coherency testifying to their larger competency at the conditions prevailing during D_1. The current steep orientation of duplexes indicates that stacking resulted from reverse-sinistral movements. It is not clear whether this is also the original orientation in which stacking took place (Table 1; see below).

To the west of the Dalny area the sequence of NW trending fault blocks merges with the N-S trending Lily Shear Zone and a parallel band of felsic schists (Fig. c; Bliss, 1970). The discordant relationship between the Lily Shear and the duplexes at Dalny Mine is not clear. A similar relationship also exists farther south around the Golden Valley and the What-Cheer Group of Mines (Bliss, 1970; Robertson, 1976; Catchpole, 1987; Herrington, 1995). Three possible relationships may be considered: either the Lily Shear is late and truncates the duplexes; or the Lily Shear formed in conjunction with the duplexes (e.g. as a roof thrust); or the Lily Shear is a multi-deformational zone with components of both.

D_2, syn-mineralisation deformation

Gold mineralisation is associated with up to 1.5 km long segments of brittle-ductile shear zones (Table 2). The main Dalny Reef has a strike length of about 1200 m and trends at a fairly constant angle of 050° with dips varying between 60-80° NW. At the extremities of the reef, trends change to 020-030° at relatively constant dip, giving the reefs a curved geometry on plan view (Fig. 2). The reef is not one continuous planar zone, but consists of a series of 80-250 m long segments that are arranged in line along the trend of the reef. They display a limited overlap and a small degree (5-10 m) of mainly right stepping. This is consistent with a Riedel array along a compressional shear zone with a sinistral component. Other reefs in the area like Turkoise and Arlandzer have similar dimensions and display similar variations in trend.

Within Dalny Reef, the foliation is sub-parallel to the regional foliation and is defined in a 1-3 m wide zone by a large number of anastomosing, sub-paralel slickensided fracture-planes. These are associated with complicated arrays of crack-seal veins parallel to the shear zone wall and extension veins at variable angles to the shear zone wall. The slickensides parallel a more pervasive schistosity in silicified chlorite-rich greenstones adjacent to the shear zone. Several generations of slicken fibre lineations and grooves can be observed, although all of these are not always developed on one foliation plane. The dominant lineation, L_{2a}, and generally the earliest visible, plunges steeply to the NE (pitching 50-80°NE on the fault plane) and closely parallels L_1 (Fig. 3). S-c-like fracture arrays, slickenfibre steps and tension fracture arrays indicate a reverse-sinistral sense of movement. A second slickenfibre lineation, L_{2b}, is locally developed and pitches shallowly to the SW (Fig. 3). In east Dalny and Pixie this lineation appears to be dominant. This lineation is associated with a sinistral normal sense of movement. Locally, a third generation of down dip striations (L_{2c}) is developed associated with a normal sense of movement, however, these are uncommon. The different L_2 lineations, which appear to alternate within the same fault segments, testify to a complicated multi-staged fault history in which the dominant movement is reverse sinistral. The normal movements probably occurred during (transient ?) episodes of fault (ie. stress) relaxation. This process can be clearly demonstrated when vein geometries are considered. Although most veins and slickensided fractures parallel S_1, their overall distribution defines a small-circle on a stereoplot (Fig. 3). The centre of the small-circle is near-verticle with a half-angle to the veins of ~25°. This distribution pattern suggests that the fractures, including those hosting the veins, nucleated and propagated within a uniaxial stress field with s_1 vertical. This means that fracturing and fluid infiltration occurred during episodes of extension and normal movement, which must have alternated with the pervasive reverse movements.

Not all veins and fractures formed simultaneously, and a complex vein chronology has been established (Carter, 1990). Early mineralisation involved highly deformed grey auriferous quartz veins (V_{1a}) and black quartz veins (V_{1b}, with native gold) that impinge on the black shales, and mostly parallel to shear zone wall. Deposition followed of massive white auriferous quartz (V_2, with native gold) parallel to the shear zones and tensional ankerite veins (V_3) that cut across the shear fabric. Lastly, quartz-carbonate veins (V_4) were deposited in a variety of orientations. Some of the earlier veins are crack-seal veins with a large number (10-25) of vein-wall parallel cracks preserved as trails of epidote crystals, presenting evidence for cyclic fluid flushing through the shears.

Reefs are generally dipping steeply (60-80°) to the NW, but trends vary significantly (between 010 and 080°) together with variations in the trend of S_1. The main deposits like Arlandzer, Turkoise, Stella, Oleander and Chadshunt are about 1.5 km apart, but not necessarilly on the same trend (Fig. c). The assumption that these reefs were once on the same trend invoked the need of later N-S faults for which there is no physical evidence (e.g. Bliss, 1970). If the reef distribution around Dalny Mine is placed on top of the underlying duplex geometry, it becomes apparent that the variations in reef trends closely match the lithological trends imposed by D_1 tectonic stacking (Fig. 2). Many of the reefs occur within, or close to mylonite zones that demarcate tectonic blocks. The spacing of major deposits (1.5 km) matches the average size of a single fault block within the tectonic stack. This observation implies that the geometry and distribution of reefs is controlled by reactivation of D_1 duplex structures, mostly via brittle ductile reactivation of bounding mylonite zones. This readily accounts for the strike of the Oleander, Little Kitty and Ironstone Reefs, which were previously thought to be anomalously orientated (Fig. 2; Campbell and Pitfield, 1994).

Post-Mineralisation Deformation

It has generally been assumed that the mines between Dalny and Arlandzer were broken up by later sinistral N-S striking faults, possibly related to dyke intrusion (e.g. Bliss, 1970; Foster *et al.*, 1979; Campbell and Pitfield, 1994; Table 2). The most prominent of these faults are supposed to be the Turkoise Gap Fault causing the separation of the Turkoise and Dalny Reefs, and the Chevy Chase or Eastern Cutoff Fault truncating the Dalny Reef in the east and possibly displacing it towards Pomposa (Fig. c; Leigh, 1964; Bliss, 1970 and Foster *et al.*, 1979; Carter, 1990; Campbell and Pitfield, 1994). Despite claims that these faults can be seen on landsat TM images (Campbell and Pitfield, 1994; Herrington, 1995) we were unable to identify them, not only on landsat TM images, but also on air photographs or in the field. It is likely that the D_1, sigmoidal nature and thinning of the felsic schist lenses south of Turkoise has been confused with later fault displacements. To our knowledge, no person (including the current mine geologists; P. Chadwick, pers. comm. 1996) has been able to unambiguously identify the position and orientation of the faults. For this reason and because the geometry of the reefs can be simply explained using the underlying D_1 structures, it is concluded that the Eastern Cutoff and Turkoise Gap Faults do not exist.

The only post-mineralisation event to affect the area is the intrusion of dolerite and gabbro dykes (Table 2). Most of these dykes are sub-vertical and trend NNW-SSE. Where they truncate the SW-trending reefs, they cause an apparent dextral displacement proportional to the width of the dyke. There is no evidence for dextral shear zones parallel to the dykes.

Discussion

Implications of the observations are two-fold: 1) it is possible to define a number of geometrical factors that constrain the distribution of gold mineralisation in the Dalny area, and may serve as a model for comparable terrains elsewhere in greenstone sequences; 2) the observation that tectonic stacking occurred in the greenstone sequence during the peak of metamorphism and possibly before upright folding of the sequence, opens a possibility that horizontal thin-skinned processes occurred in the greenstone belt and questions existing stratigraphic and diapiric models of greenstone belts in Zimbabwe (e.g. Jelsma *et al.*, 1993; Wilson *et al.*, 1995).

The idea that gold reefs in the Dalny area occur along a 5-30 m wide zone of reactivation within the centre of a continuous, 300 m wide Arlandzer Shear Zone (e.g. Carter, 1990, Campbell and Pitfield, 1994) is incorrect, because regional strain and fabric intensity variations do not justify the definition of such a shear. Instead, a network of 0.5-5 m wide silicified mylonite zones enveloping low strain lozenges of country rock can be identified as siliceous schists and black shales, that occur both within and outside the area previously defined as the Arlandzer Shear Zone (Fig. 2). The intensity and consistent asymmetry of deformation features (folding, crystallographic orientation, ribboned grains, s-c fabrics, asymmetric pressure fringes, dynamic recrystallisation and grain size reduction textures) relative to the surrounding rocks, testifies to their high strain, non-coaxial, origin, i.e. they are mylonites in shear zones. These shears predated mineralisation and separate various lithological blocks. Therefore it is reasonable to conclude that the lensoidal distribution of consistently NW younging lithological units separated by unconformble contacts (e.g. Bliss, 1970; Dube, 1977) resulted from tectonic stacking across shear zones that also accommodated fluid flow. The resulting duplex geometry is closely paralleled by the distribution of gold reefs (Fig. 2b). Reefs appear preferentially within fine-grained pillowed greenstones. This either reflects some chemical, host rock control or a mechanical control: e.g. blocks of pillowed basalts are more competent causing bounding shears to be more readily reactivated or fractured during the auriferous D_2 events.

The first order control on the distribution of gold in D_2 shears is therefore the underlying D_1, duplex geometry. A D_2 stress field of undefined orientation or origin caused fracturing of the D_1 tectonostratigraphic pile with fractures propagating predominantly along or in close proximity to D_1 shear zones that represent zones of mechanical contrast or weakness. These fractures did not always propagate as single fractures but Riedel arrays with a low degree of overlap are common. This Riedel geometry constitutes a second order control, which is of more immediate interest to the mining operations. With this in mind some interesting points can be made about reef distribution. Reefs are of limited lateral extent; i.e. up to 1.5 km long, equalling the maximum length of a single D_1 fault block. By the same token, the 1-1.5 km spacing of major deposits probably reflects the average dimension of D_1 fault blocks. Importantly, there is no need to invoke later faults such as the Turkoise Gap, or East

Dalny Faults to explain the apparent "offsets" of reefs; there never was a continuous reef, and the reefs are not constant in orientation, but curve in accordance with D_1 shear zones. The orientations of Little Kitty and Oleander Reefs are not 'anomalous', but merely follow D_1 shears in a slightly different orientation.

Lineations along the mineralised shears are variable both within a single mine and from one mine to the next (e.g. Dube, 1977). Although they predominantly parallel the regional peak-metamorphic lineation and record reverse-sinistral movement, shears with similar orientations, can be sinistral-normal or pure normal, and it is not uncommon to find complex slickensided surfaces that record all three movements. It appears that during D_2 the various D_1 lithological blocks were "reshuffled" in a mostly compressional regime, although sections along fractured zones experienced episodes of normal movement and dilation. During these episodes of dilation a network of secondary fractures developed along which large volumes of auriferous fluids penetrated the wall rock causing deposition of gold in veins which display a characteristic small-circle distribution around a vertical axis (Fig. 3). The cyclic nature of crack-seal veins at Dalny suggests that this scenario was repeated many times. The above is consistent with the fluid-activated valve model of Sibson *et al.* (1988; see also Boullier and Robert, 1992; Schmidt Mumm *et al.*, 1994) in which rising fluid pressures cause seismic fault failure with increased permeability, a reduction in deviatoric stress and post-failure fluid discharge. The abrupt drop in fluid pressures towards hydrostatic triggers mineral deposition in the fracture network resulting in self-sealing and a repetition of the cycle. The genesis of large volumes of auriferous H_2O - CO_2 fluid with a low salinity, moderate density and a pH of about 5 is likely to have resulted from metamorphism in the greenstone belt (Colvine *et al.*, 1984, 1988; Groves *et al.*,1984, 1987; Carter, 1990).

Pre-existing structures, like the D_1 duplex stack at Dalny, play an important role in the distribution of many gold deposits in greenstone belts as mineralisation occurs relatively late in the deformation sequence (Colvine *et al.* 1984; Groves *et al.*, 1987; Groves and Foster, 1993; Campbell and Pitfield, 1994). Similar peak-metamorphic imbricate stacking may exist and control other deposits in Zimbabwe. The Venice, What-Cheer group of mines 35 km south of Dalny is a good example where similar early shear zones separate alternating felsic-mafic lenses and appear to control the geometry of later gold deposits (Nutt, 1984; Catchpole, 1987; Lotz, 1994).

The second implication of arguments presented here is that duplexing may have occurred in the greenstone sequence around Dalny and that this may have seriously affected (i.e. repeated) the stratigraphy in the region. Imbricate stacks have been recognized in the Midlands Greenstone Belt (Catchpole, 1987; Wilson, 1990; Wilson *et al.*, 1995; Campbell and Pitfield, 1994), and are generally related to strike-slip zones that transect the domed granite-greenstone sequence. Although the imbricate stacks at Dalny could have formed within a strike-slip setting, evidence for this is limited. Strike-slip movements along the major faults in the Midlands Greenstone Belt generally represent the last major deformation in the belt (e.g. Wilson, 1990), and horizontal lineations are commonly preserved (Campbell and Pittfield, 1994). At Dalny, the imbricate stacks formed relatvely early, during the metamorphic peak, and lineations in the shears are not horizontal. The alternating felsic-mafic lenses extend to the north and northeast of Dalny and are not restricted to the viscinity of a discrete strike-slip fault (such as the Lily Shear). The D_1 geometries at Dalny can be correlated with interleaved felsic and mafic greenstones separated by sheared graphitic shales and siliceous schists that occur in the same stratigraphic position at the Venice, What-Cheer and Nando Mines, 35 km south (Nutt, 1984; Catchpole, 1987; Lotz, 1994). Here, the D_1 tectonic sequence is folded by NW trending upright folds in the nose of the Gatooma Anticline.

Considering the above it seems reasonable to assume that the formation of the D_1 imbricate stack at Dalny predated steepening of the greenstone belt and upright folding (i.e. the formation of the Gatooma Anticline). It is therefore possible that the D_1 geometries formed in a horizontal position and resulted from thin-skinned processes that caused repetition of the stratigraphy early during the evolution of the greenstone belt, similar to thin-skinned thrusting described from other granite-greenstone terrains such as the Yilgarn and the Barberton (e.g. de Wit, 1982; Lamb, 1984; Martyn, 1987; Swager and Griffin, 1990)

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Surface visit to outcrop in Chakari area

STOP 2. Pixy Reef Outcrop

Situated approximately 1 km to the N of Dalny mine. A brief review of the Pixy reef complex as regards to the host shear.

STOP 3. Colne/Rubbish Dump Outcrop

Situated some 500 m to the SW of Stella shaft. A brief review of the footwall Colne reef - is this the western extension of the Dalny reef? This will be followed by a brief visit to a well-sheared area defined by a ridge some 200 m further into the hanging wall.

STOP 4. Turkois Shaft Outcrop

A gentle ridge some 150 m to the SE of Turkois shaft which forms the junction of the Arlandzer shear and the Little Kitty/Oleander shear.

STOP 5. Maldon BIF Outcrop

Situated approximately 1 km to the S of Turkois shaft is a good example of BIF, which was once mined for gold.

STOP 6. Arlandzer Surface Diggings

A brief stop will be made to this area to observe surface reef mineralization with respect to the host shear (Arlandzer shear), and to observe small-scale structures within the actual shear zone itself.

STOP 7. Kadoma Rockery

An example of the sporadic development of an S2 crenulation cleavage, orthogonal to S1 with weak elongation lineations, associated with a major duplex shear between the Kadoma and Munyati shear zones.

Sunday 7th September, 1997

South Midlands: The Sherwood and Taba Mali Shear Zones

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Falcon Gold Zimbabwe, c/o Globe & Phoenix Mine, PoBox 393, Kwekwe, Zimbabwe

STOP 1. Underground visit to Phoenix Section of Globe & Phoenix and Riverlae Mine

Globe & Phoenix Mine

The Globe and Phoenix mine, situated on the western boundary of the city of Kwe Kwe, occurs at the point of maximum inflection of the Sherwood Deformation Zone (SDZ) along the granitoid gneiss contact. The complexity of the vein array is interpreted in terms of transpression associated with a bend in the shear zone. The Phoenix mine (c.109 t gold produced) has worked a complex of reefs which transgress the sheared contact between the Kwe Kwe Utramafic Complex and the granitoid gneisses. Though the mine extends in depth to 43 level, current operations are restricted above 14 level, below which the mine is flooded. There is no access to the Globe section at present. A visit will be made to Phoenix 6 level to observe the sigmoidal duplexing of the Phoenix Main and Phoenix Parallel reefs. The steeply-dipping East reef will also be visited, which is characterised by a reverse-dextral movement and appears to be displaced sinistrally by the Apple reef, which shows evidence of both normal and reverse movements. The North I reef exhibits oblique-sinistral displacement with a reverse component, whilst the North II reef shows no differential movement. Shallow-dipping stibnite veins will also be observed which appears to post-date the quartz reefs with a reverse movement.

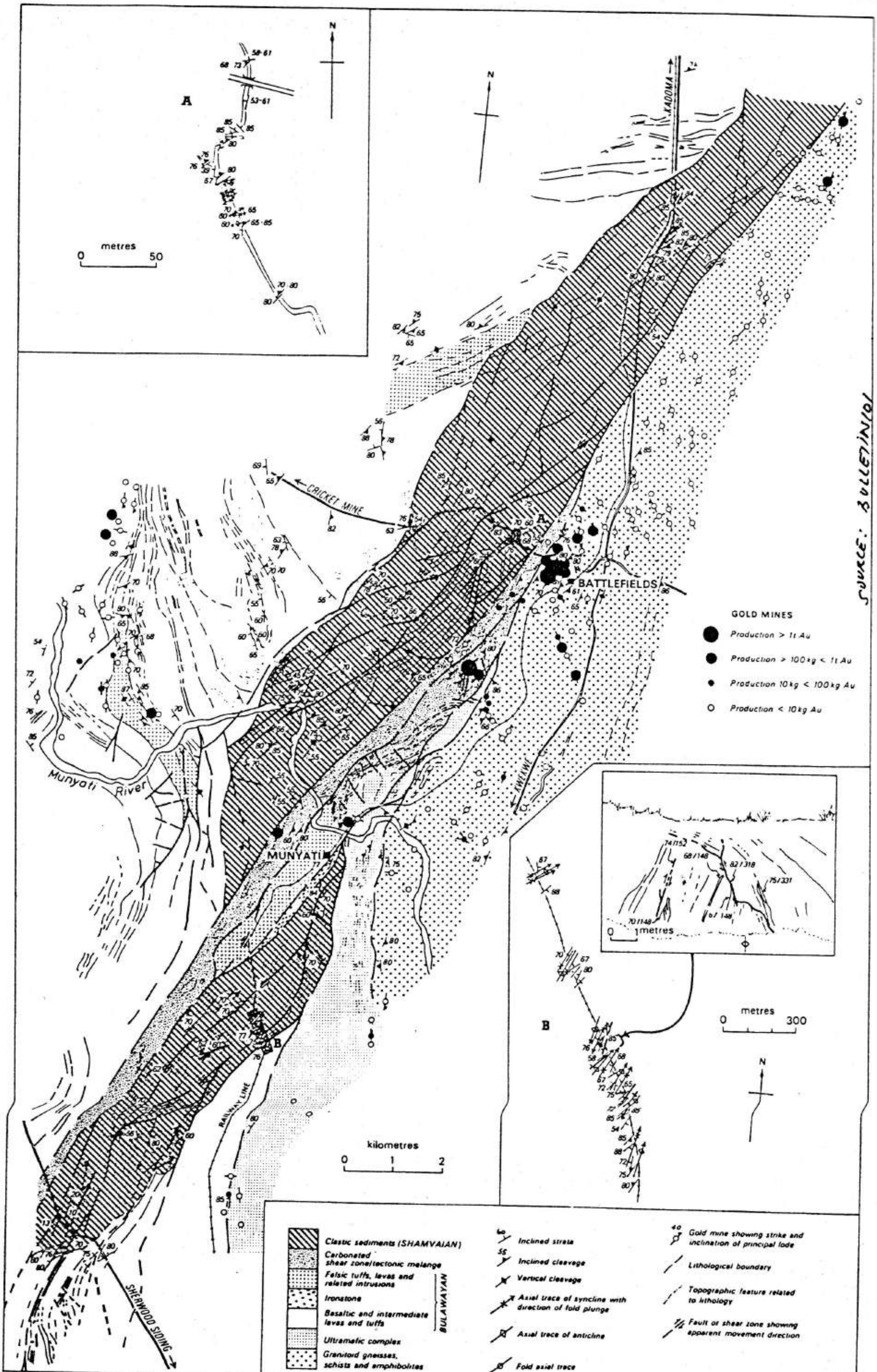

Figure F. Geology of the Munyati and Battlefields districts based on photo-geological interpretation at 1:25 000 scale. Insets show selected traverse sections through the Shamvaian Group sediments.

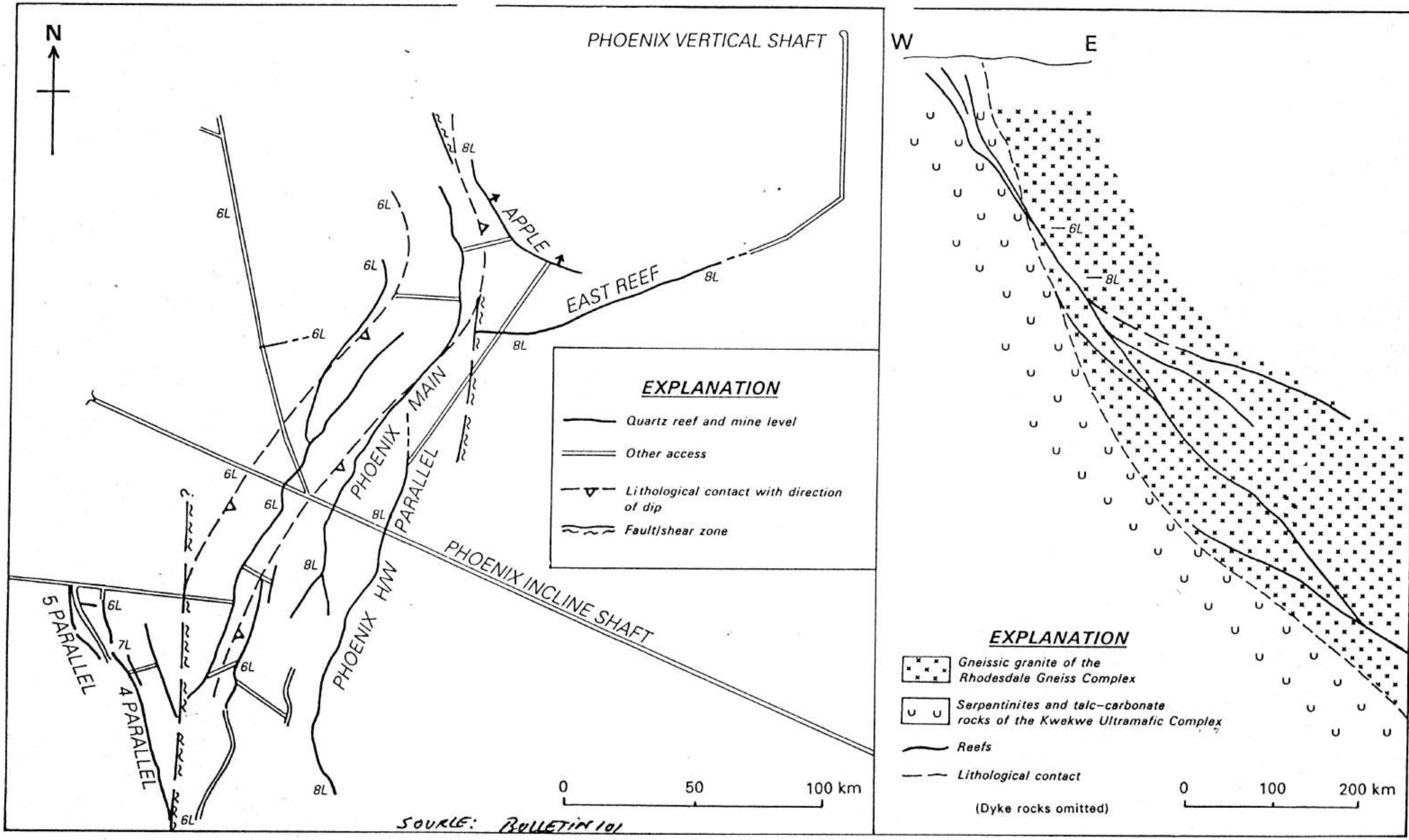

Figure G Phoenix Mine: (A) Plan of the gold-bearing quartz reefs on levels 6 and 8 (adapted from Arita and Sato, 1987) showing the lateral components to oblique reverse movements on the reef structures, (B) Diagrammatic cross-section of the reefs in the neighbourhood of the Main Incline Shaft (after MacGregor, 1932).

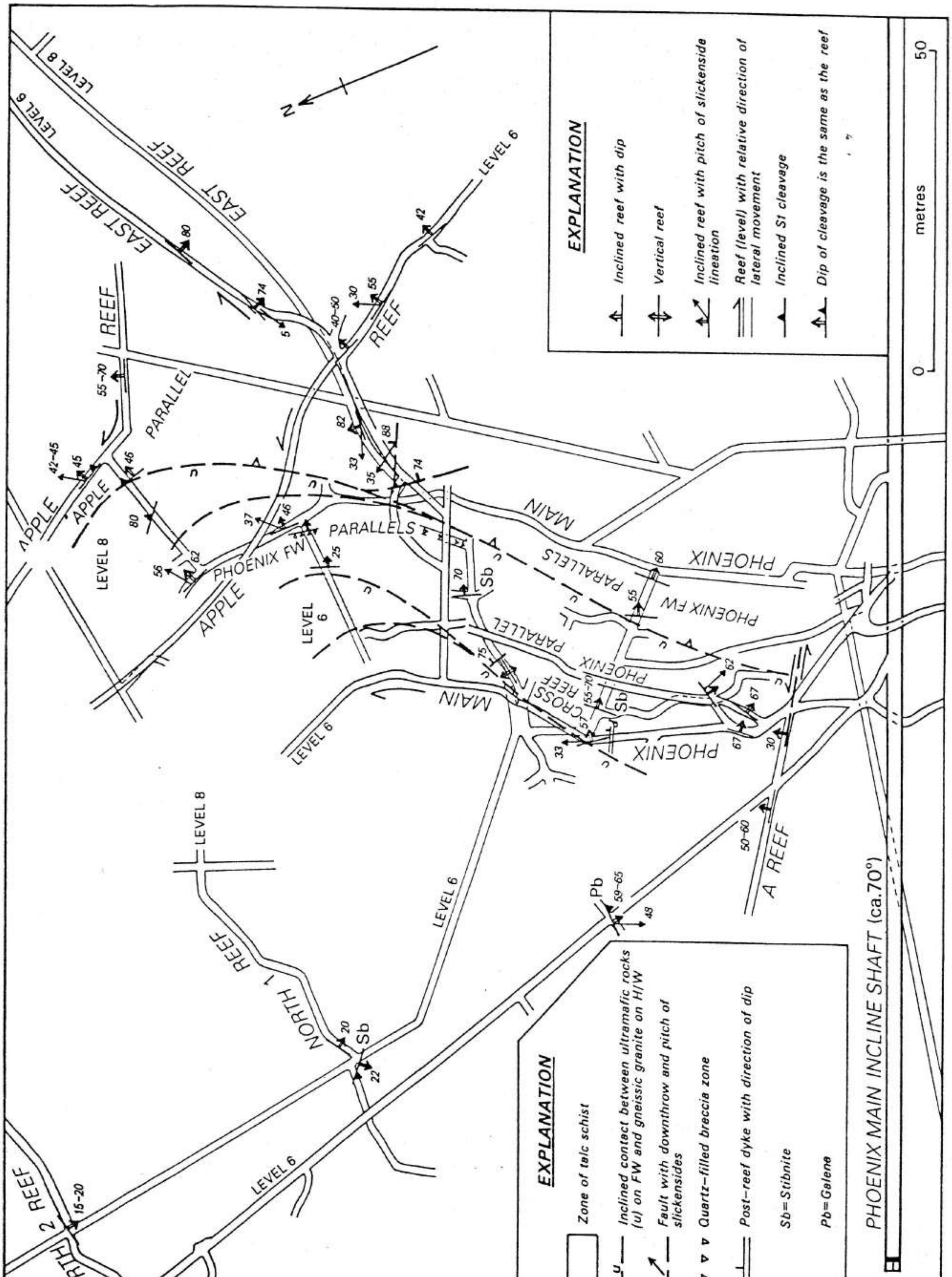

Figure H Phoenix Mine: Detailed structural plan of levels 6 and 8 to the north of the main incline shaft. Based on level plans provided by Tabex (Pvt.) Ltd.

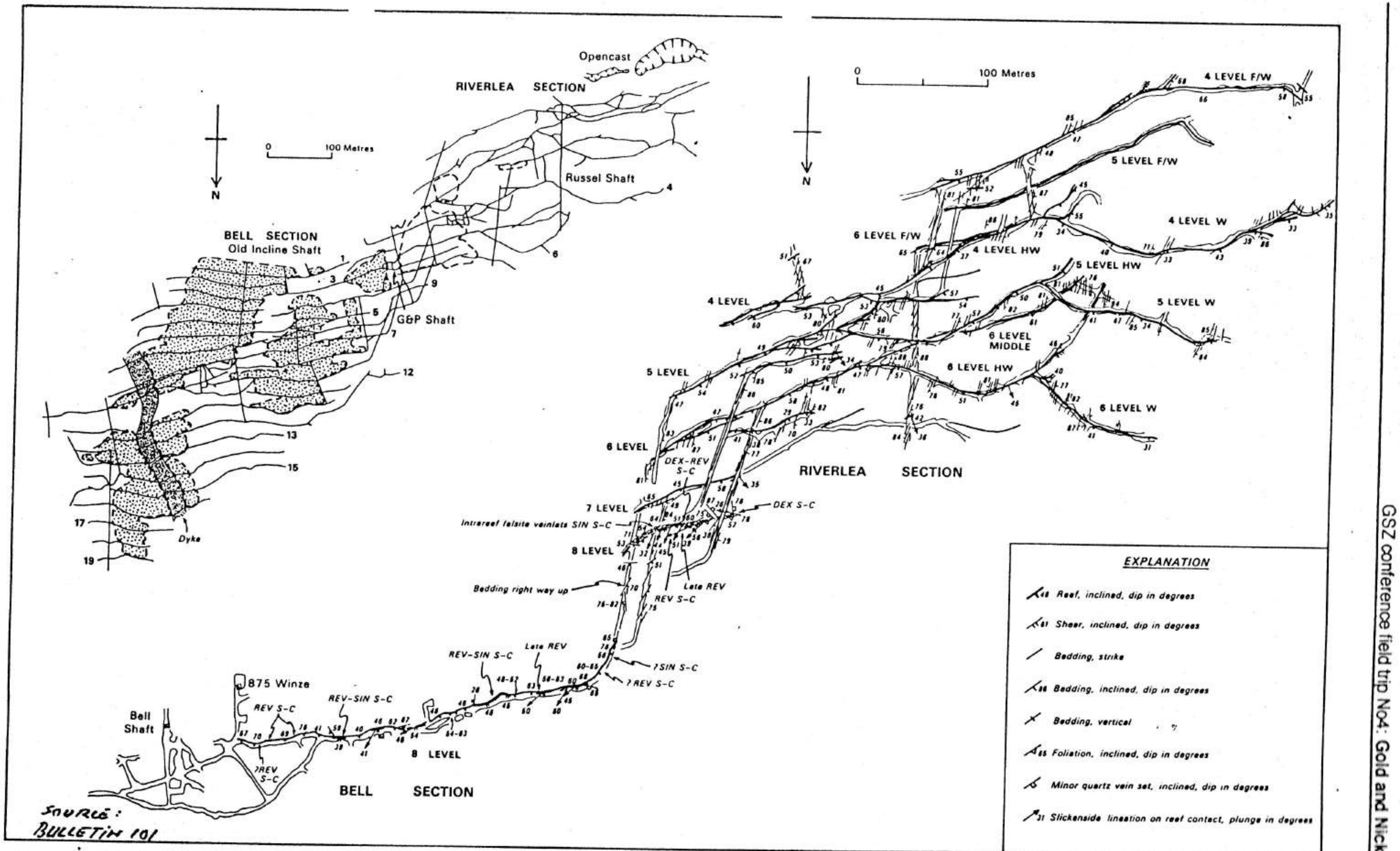

Figure *L* Bell-Riverlea Mine: detailed structural plan of 8 level, Bell Section, and levels 4–8, Riverlea Section. Data for levels 4–7, Riverlea Section based on an unpublished plan by T H C Nutt (1987). Inset diagram is a level plan of the mine showing areas of stoping (heavy stipple) of the Bell Section, up to 1967, based on a plan held by the Gweru Office, Geological Survey Dept. Note the comparable plunges of lineations on level 8, Bell Section, and the Bell Section oreshoots.

Bell-Riverlea Mine

The Bell-Riverlea mine (c. 10 t gold produced) is situated some 9 km W of Kwe Kwe. Historically, most of the production came from the Bell section. The two orebodies, Bell section and Riverlea section, are separate within the present limits of the mine, but they may merge with depth. Both sections are hosted by coarse clastic sediments, consisting of grewackes and conglomerates, where bedding dips steeply to the W, and the mine complex is located on the western limb of the Riverlea syncline. The mineralization is concentrated in obliquely cross-cutting E-W and NW-trending shear zones, which dip some 35-60o to the N. Mineralization in the Riverlea section comprises quartz lenses and veinlets, general silicification of the host rocks and extensive sulphide impregnation (Mostly arsenopyrite and pyrite), with some free gold. Up to four principal reefs occur: The Footwall Reef; the Middle Reef; the Hangingwall Reef ; and the West Reef. Each of these reflect periodic splays into the hangingwall towards the west. The Bell section comprises a white to grey, variably laminated, quartz shear vein, up to 3 m thick, associated with wallrock brecciation. The reef locally splits and shearing occurs both in the wallrocks and the reef. Oreshoots in both sections plunge to the NE. The ground between the Riverlea and Bell sections is strongly fractured, with numerous quartz stringers.

The underground visit will concentrate on 8 level covering both the Riverlea and Bell sections. Kinematic indicators towards the west end of the Riverlea section, contradict those in the rest of the section. Towards the extreme west, S-C fabrics both within the reef and marginal to it, indicate dextral-reverse movement. Towards the east, indicate reverse and sinistral movements. The cross-cut between the Bell and Riverlea sections is poorly mineralised and quartz veins and stringers are sporadic. The Bell reef is a well developed white to light grey quartz vein (1-2 m thick). Slickensides on the hangingwall plunge to the NE, as do the oreshoots of the Bell section and lineations near the east end of the Riverlea section.

STOP 2. Phoenix Oxide Pit

Situated just to the west of the main Phoenix incline shaft, a pit was recently developed as a source cyanide-leachable, low grade, oxide-hosted gold ore, to support a heap-leach pad. Pitting operations have fully exposed what is known locally as the Footwall Shear Zone, which hosts a series of reefs which are parallel and in the footwall of the Phoenix main reef. These reefs include the West Reef and the WR Reef, both of which were extensively mined on 4 level, and have been developed on below 4 level. It is believed that the Phoenix pit represents the surface expression of an oxide plume associated with these lenticular-shaped, high-grade, gold-bearing lodes. This zone may well form part of the southern limit of the Sherwood Shear Zone.

STOP 3. Impamesa Oxide Pit

Like the Phoenix pit, though much smaller in scale, the Impamesa pit was developed recently as a source of ore for the heap-leach operation. Once again, pitting exposed the near surface expression of the Impamesa reef, which would appear to be the northerly extension of the same shear zone within which the Phoenix pit is developed. Mine records indicate that limited development of the Impamesa pit was undertaken up to 2 level, and recent percussion drilling in the area has yielded some encouraging gold values along strike, both to the north and south of these old workings.