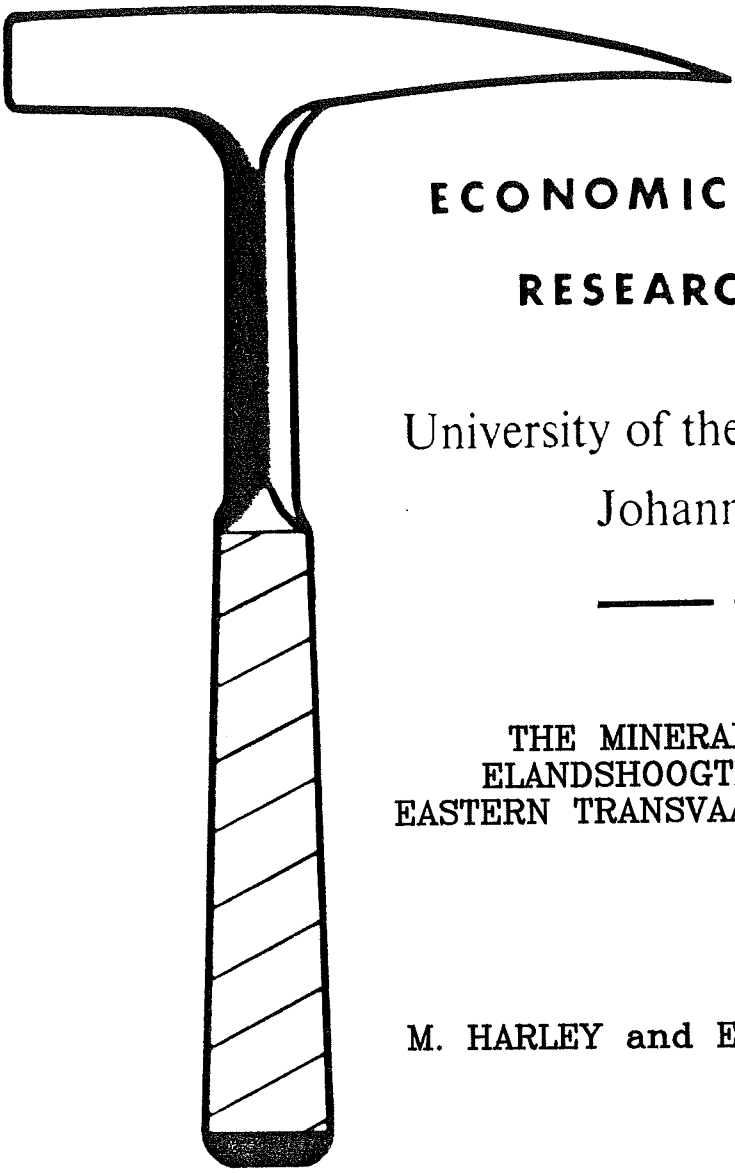

ECONOMIC GEOLOGY RESEARCH UNIT

University of the Witwatersrand
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THE MINERALISATION AT ELANDSHOOGTE GOLD MINE, EASTERN TRANSVAAL, SOUTH AFRICA

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INFORMATION CIRCULAR No. 226

UNIVERSITY OF THE WITWATERSRAND
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by

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ABSTRACT

Stratiform quartz-sulphide-gold veins, locally termed "reefs", are hosted within the Proterozoic Transvaal Supergroup sediments in the Sabie-Pilgrim's Rest Goldfield, eastern Transvaal. These deposits have produced about 180 tonnes of gold and share many characteristics with those of Telfer, Western Australia. Detailed examination of the Elandshoogte Gold Mine shows that gold deposition occurred in two stages, both linked to bedding-parallel thrusting within the sedimentary pile. The majority of gold was introduced in the second stage of mineralisation. New data on post-reef thrust deformation is presented. Thrust-related fractures in early sulphides are a preferred site of late gold and the role of structure in preparing sites for mineralisation and transporting fluids is emphasised. Fluids accompanying faulting are implied to have transported gold and a magmatic source of mineralisation is suggested.

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THE MINERALISATION AT ELANDSHOOGTE GOLD MINE, EASTERN TRANSVAAL, SOUTH AFRICA

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INTRODUCTION

Several large ore bodies of a million tonnes or more and many smaller ore bodies containing hundreds to hundreds of thousands of tonnes of ore have been mined in the Sabie Pilgrim's Rest Goldfield. Ore grades for these deposits range from 2 to 50 g/t with most ore bodies averaging between 6 and 10 g/t gold (A.L. Marx pers.comm., 1989) and variable silver content. The style of mineralisation in the goldfield has no classical analogues: deposits consist of stratiform auriferous quartz-sulphide veins within Proterozoic carbonaceous siliciclastic rocks. In terms of geological setting, styles of mineralisation, age of host lithologies, and nature of ore-fluids, these deposits show striking similarities with the massive Telfer deposit of Western Australia (Button, 1976: Goellnicht et al., 1988a, b). Previous workers in the Sabie-Pilgrim's Rest Goldfield (e.g. Meyer, 1988; Meyer et al.,1986; Tyler, 1985; Ash and Tyler, 1986) have concentrated on aspects of the geochemistry and mineralisation of several deposits, while Zietsman (1967) and Tyler (1989) have briefly described structural features of some of the reefs.

The medium-sized Elandshoogte Gold Mine is one of the two mines still active in this goldfield. Detailed surface and underground investigations were undertaken at the mine in an attempt to establish the relationship between the structure and mineralisation of the Elandshoogte Reef, a typical ore body within the goldfield.

REGIONAL GEOLOGY AND HISTORICAL OVERVIEW

The Sabie-Pilgrim's Rest Goldfield comprises a north-trending strip of country, 110 km long and 30 km wide, underlain by lithologies forming the eastern rim of the early Proterozoic Transvaal Basin (Fig. 1). Mining activities commenced in 1872 and reached a peak in the early 1950s. Production has gradually waned and today only 2 deposits are actively mined, but exploration and re-evaluation is taking place on several other properties. Mining activities occurred in four main areas, the dominant area being around the central village of Pilgrim's Rest. Nine major mines, situated around the village, have recorded production; the cumulative total to 1967 was of the order of 133 tonnes of gold (Fowler, 1968). The largest mine of the Sabie-Pilgrim's Rest Goldfield, the Glynn's Lydenburg Mine (production 41 tonnes of gold, Fowler, 1968) is situated immediately south of Sabie (Fig.1), which was the central town of the second major mining area. Mining has also taken place around Vaalhoek and Bourke's Luck, north of Pilgrim's Rest. The fourth group of mines is spread out south of Sabie and includes the deposits at Elandsdrift and Spitzkop, near Hendriksdal, and Elandshoogte and Rietvallei near Sudwala Caves. A prominent series of NNE-trending lineaments visible on ERTS imagery and aerial photographs forms the structural grain of the goldfield. Mafic dyke emplacement, post mineralisation normal faulting, and limited graben development have occurred parallel to this trend. Bedding in the goldfield strikes subparallel to the structural grain and dips between 4 and 15° to the west. Some mine plans indicate an alignment of stope areas subparallel to the structural grain (Fig.2), but in mines around Pilgrim's Rest no distinct orientations are developed.

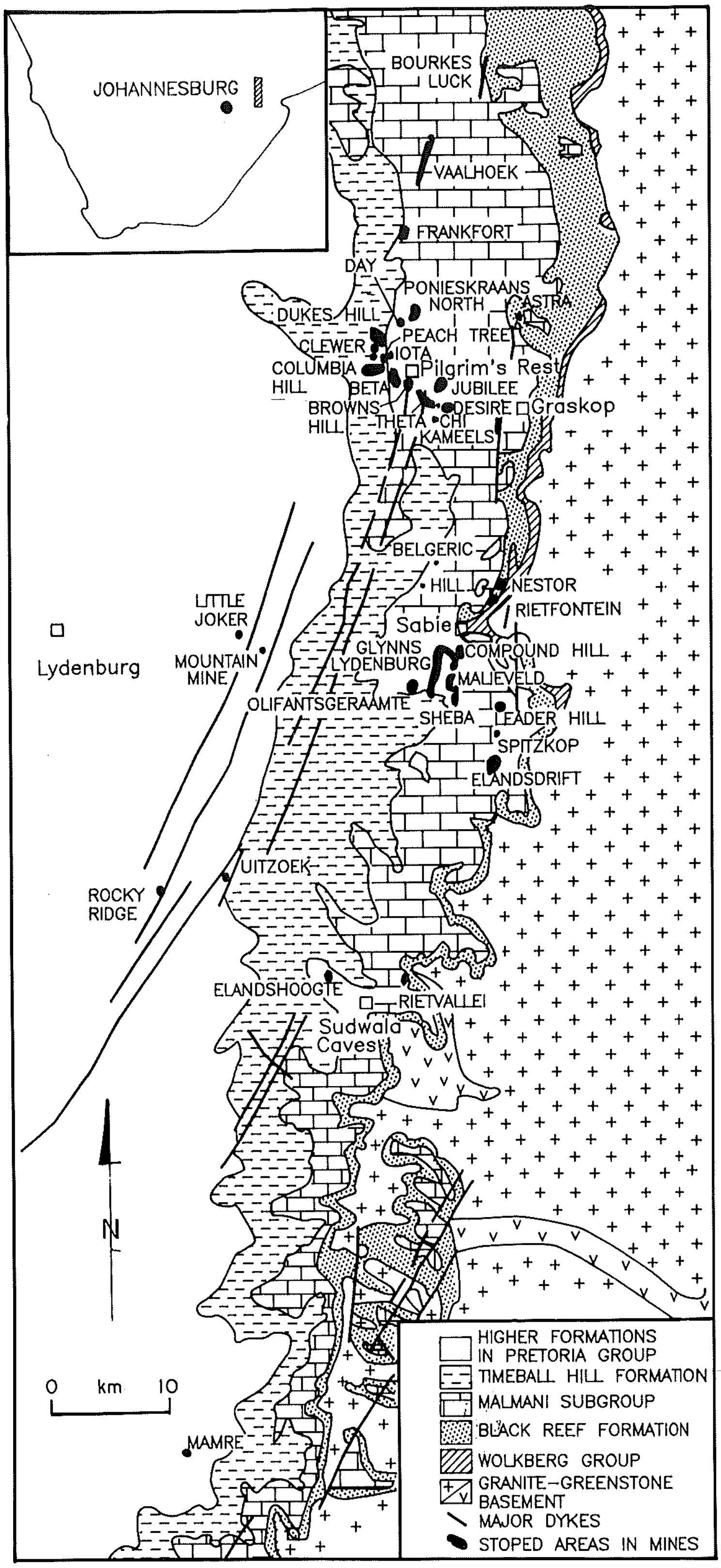

Figure 1: *Geological map of the Sabie-Pilgrim's Rest Goldfield, showing the localities of major gold deposits.*

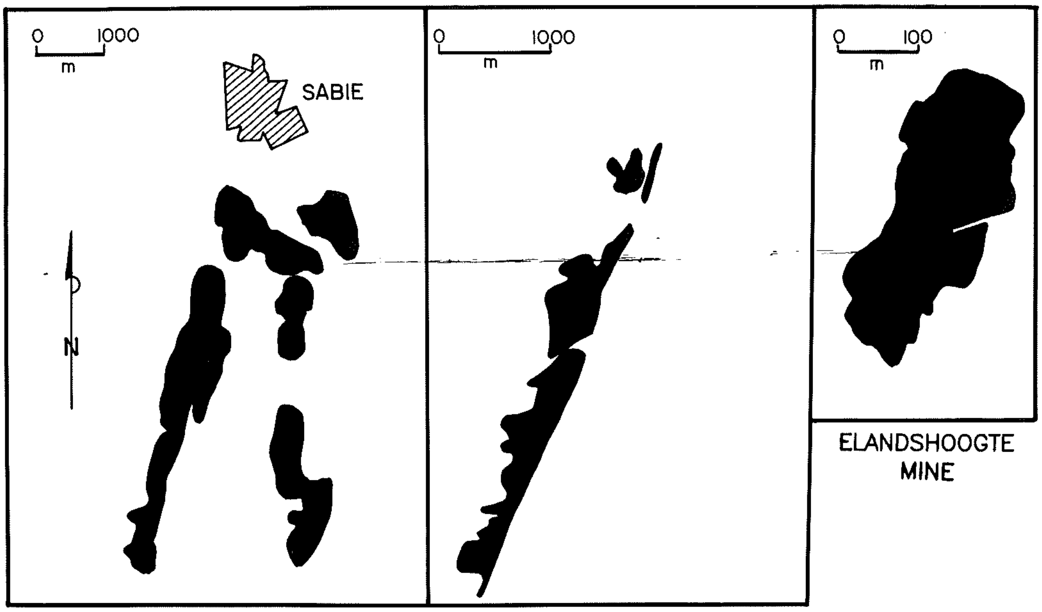

Figure 2: Orientated mine stope plans from selected deposits in the goldfield, showing the NNE directed mineralisation trend.

REEFS AND ORE BODIES WITHIN THE GOLDFIELD

Several styles of mineralisation are present within the goldfield. Initial production was from alluvial deposits developed within the deeply incised juvenile drainage system. Prospecting subsequently located the source lodes exposed on rugged hill slopes overlooking the valleys. These consist of shallowly dipping, bedding-parallel, quartz-sulphide-gold veins, locally termed "flat reefs" (cf Telfer; Goellnicht et al., 1988a). Mineralisation within flat reefs is characterised by a high Cu:Au ratio and preliminary studies of fluid inclusions (Ash and Tyler, 1986) indicated high salinity fluids as well as a complex suite of fluid inclusions (cf Telfer; Goellnicht et al.,1988b). Homogenisation temperatures for fluid inclusions from the Pilgrim's Rest area (Ash and Tyler, 1986) lie between 200 and 400° C, and appear to be similar to those of fluid inclusions from Telfer (Goellnicht et al., 1988b). Fluid inclusions from both areas also contain variable amounts of carbon dioxide.

Flat reefs occur at a minimum of 20 stratigraphic elevations within the goldfield (Fig.3), but the dominant production has been from reefs associated with shale beds intercalated within the dolomitic Malmani Subgroup, and more specifically from the lowermost Oaktree and uppermost Eccles Formations. Minor production has been recorded from flat reefs located within shale beds associated with the underlying arenaceous Black Reef Quartzite Formation. Flat reefs also occur within the overlying Pretoria Group, predominantly within the argillaceous Timeball Hill Formation. Flat reefs range in thickness from 2 cm to 2 m and characteristically pinch and swell, both along strike and down dip. Average thickness for a flat reef is of the order of 30cm. Internally, the reefs may be banded with seams containing pyrite, quartz, and carbonate, and streaky inclusions of chloritic, carbonaceous or shaley material (Visser and Verwoerd, 1960). Angular fragments of wall rock, ranging from specks to blocks up to 80 cm across, are commonly contained within the reef quartz and contacts with the wall rock are usually sharp and display slickensides (Visser and Verwoerd, 1960). Displacement of pre-reef dykes across the plane of the reef has been recorded in the Malieveld and Nestor mines. Flat reefs may occupy similar stratigraphic elevations at

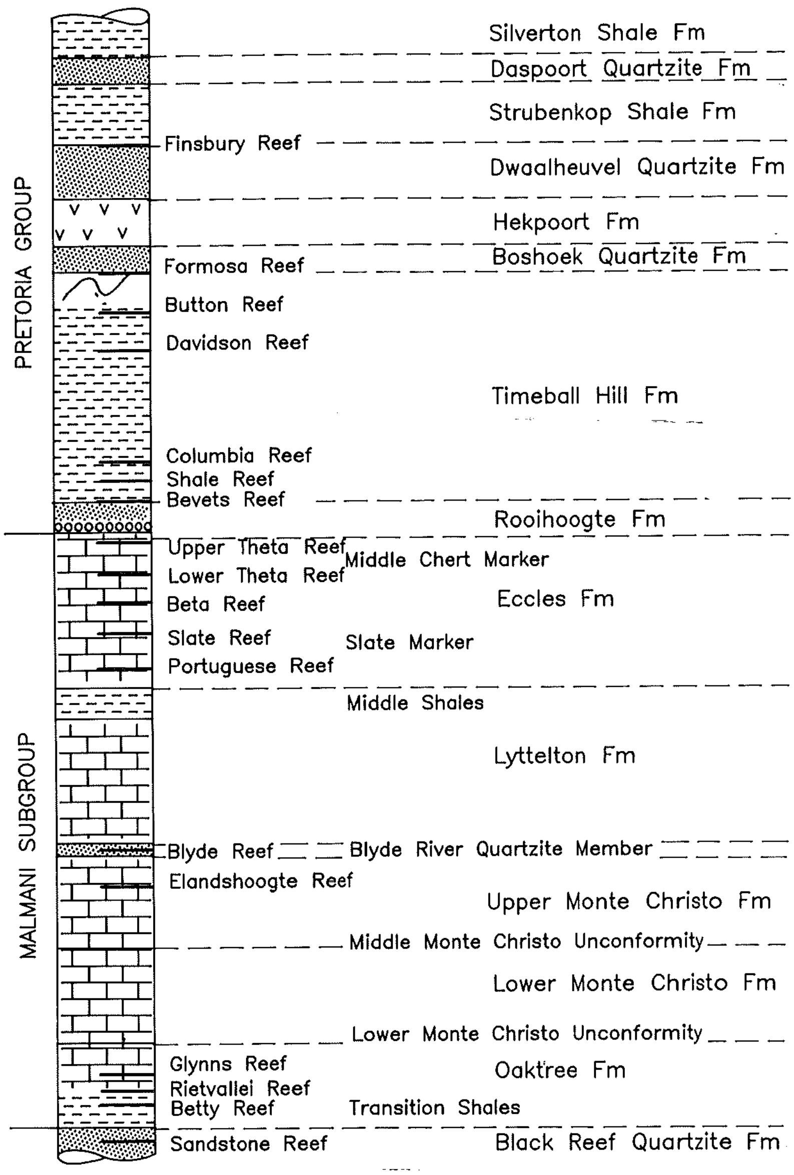

Figure 3: Schematic stratigraphic column for the Transvaal Supergroup. Positions of major veins (reefs) are indicated.

localities many kilometres apart, but have never been traced more than 10 km along strike without interruption. Reefs are commonly developed within, or adjacent to, narrow carbonaceous shale layers in the dolomites and, laterally, the reefs pinch out into fault planes within the shale bands.

Other styles of mineralisation found in the goldfield include steeply dipping to vertical "reefs", narrow transgressive veins associated with flat reefs (termed leaders), and large irregular podiform ore bodies associated with flat reefs termed "blows" and "ore channels" (Visser and Verwoerd, 1960).

The age of mineralisation within the goldfield is unknown. At the Olifantsgeraamte Mine near Sabie (Fig.1), mineralisation is hosted within a dolerite sill (Tyler, 1989) intrusive into the dolomite. Work by Sharpe (1981) and Cawthorn et al.(1981) indicated that the emplacement of similar sills predated the emplacement of the Bushveld Complex (c.2.0 Ga). Syn-Bushveld sills composed of pyroxenite and norite have never been found to host mineralisation and appear to be less altered than pre-Bushveld sills. This rather inadequate evidence restricts the age of mineralisation to syn-Bushveld times.

ELANDSHOOGTE MINE

The Elandshoogte Mine is situated on the northern flank of the southwest-trending Houtbosloop valley (Figs. 1 and 4). Exploration adits have traced the shallowly dipping reef along the valley flank for several kilometres northeast and southwest of the mine, but the northern extensions to the reef are presently unknown. Prospecting adits situated on the southern flank of the valley, due south of the mine, expose a very poorly mineralised reef, the latter possibly indicating the southern limit of the mineralised zone.

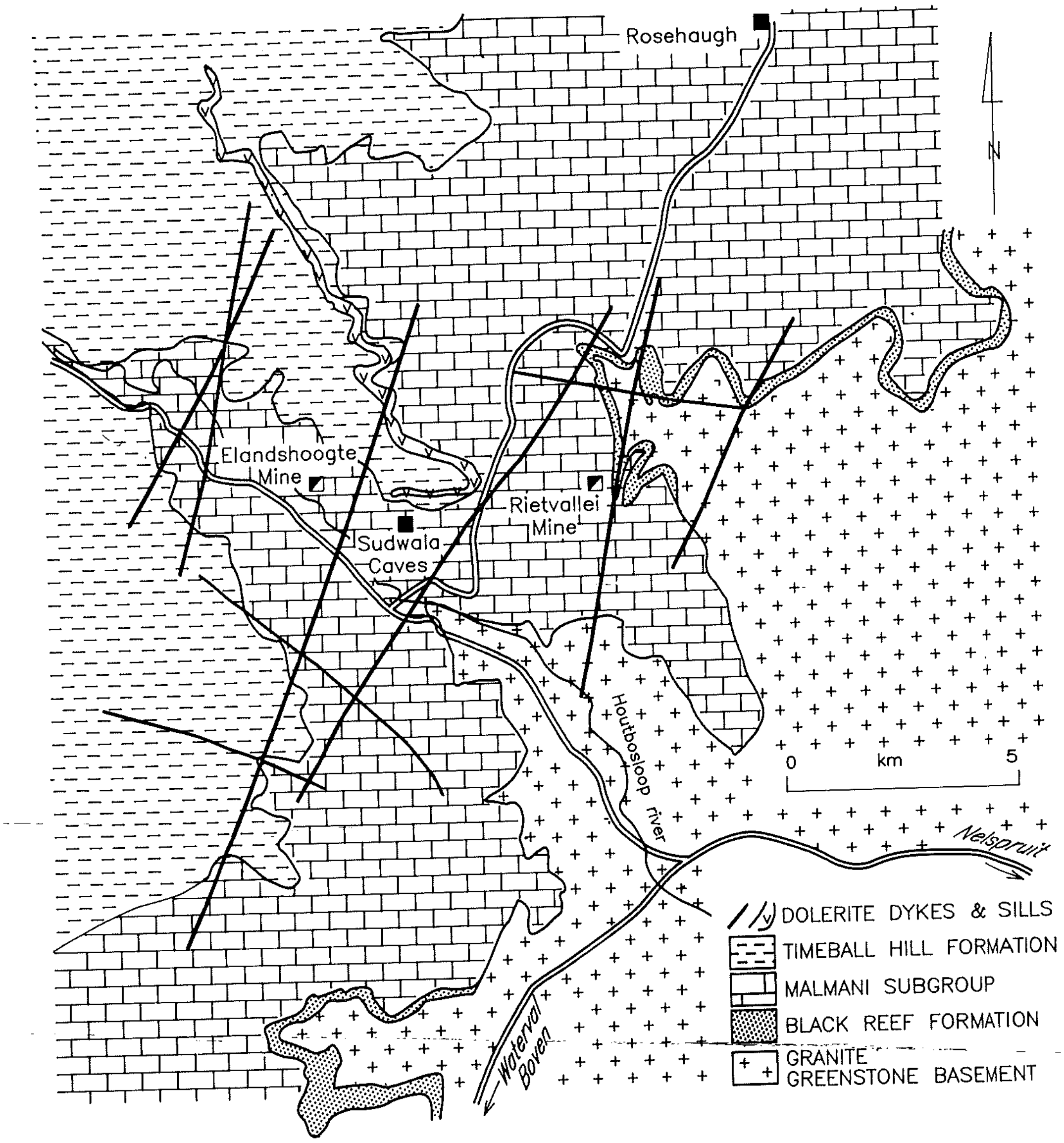

Figure 4: Detailed locality plan of Elandshoogte Mine. Refer to Figure 1 for general locality.

The Elandshoogte Reef is unusual in that it occurs within the upper Monte Christo Formation (Maske et al., 1986). No equivalent reefs exist at this stratigraphic elevation elsewhere within the goldfield.

Mine Geology

A NNE-trending normal fault downthrows the western block approximately 6m relative to the eastern one and divides the mine into two sections. The reef is developed within a thin carbonaceous shale bed in the dolomites and dips at 5° to the west. Small domical stromatolites, ripple-marked grainstones, and inversely graded oolite beds are present in both the hanging wall and footwall dolomites. Preliminary ore-microscopy studies (Maske et al., 1986) have indicated a complex multi-stage process of reef development, which is confirmed by this work. Within the shales, a well-developed subhorizontal planar fabric, comprising a close-spaced cleavage is developed. Cleavage surfaces commonly bear slickensides as evidence of early shearing and fine-grained euhedral pyrite occurs as fabric hosted layers within the shales. Mineralogically, the shale consists almost entirely of fine-grained sericite, very minor quartz (confirmed by XRD analysis), and up to 2% organic carbon (assay by Geological Survey of South Africa Laboratory).

A broad zone of silicification extends up to 1m from the reef in both the footwall and in the hanging wall. Field evidence, however, indicates that this alteration zone predates the emplacement of the reef. Thin, steeply inclined, quartz-carbonate pyrite veins cut the alteration zone, yet are themselves transgressed by the shallowly dipping reef. Disseminated pyrite occurs within the silicified zones, but gold is not significantly enriched. Carbonate, which is a common constituent of many reefs within the goldfield (Swiegers, 1949), is virtually absent from the Elandshoogte Reef. The reef consists of a complex quartz-pyrite-arsenopyrite chalcopyrite-gold vein, which characteristically pinches and swells and contains fragments of shale and silicified dolomite which may be sufficiently abundant to form localised breccias. Thicknesses of the reef range from 2cm to 1,2 m, but averages 30cm. Thin quartz-sulphide veinlets and mineralised fractures project from the reef in some localities and cut the fabric within the shales (Fig.5) and long tapering tensional veins project from the reef into the silicified hanging wall. These veins consistently strike between 010 and 030° and dip steeply to the east. In

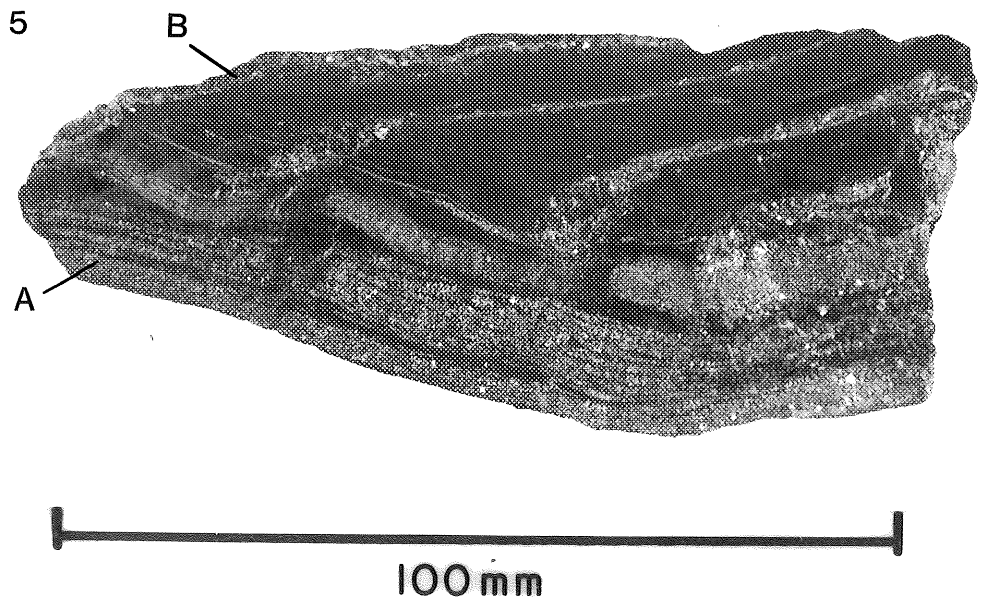

Figure 5: *Hand specimen photograph of mineralised shale from the reef foot wall, Elandshoogte Mine. Note the cleavage-parallel pyrite layers (A) and the transgressive pyrite veins (B).*

extreme cases veins curve into subhorizontal attitudes at their tips. The hanging wall contact of the reef is markedly planar, while the footwall contact is gently undulose.

Stage One Mineralisation

Early mineralisation within the reef is dominated by pyrite with lesser arsenopyrite and locally abundant chalcopyrite. Coarse arsenopyrite and pyrite aggregates occur and individual striated, cubic pyrite crystals may reach 1 to 2 cm across. Commonly, sulphide precipitation is seen to have occurred on vein margins, or around inclusions, such as shale fragments within the reef.

Several generations of sulphide minerals within the first paragenesis have been recognised by polished section microscopy.

Pyrite 1: This occurs as small euhedral to subhedral grains, commonly as fabric-parallel layers within the deformed carbonaceous shales.

Pyrite 2: is characterised by an abundance of small inclusions coupled with a subhedral form. This coarse-grained pyrite is invariably associated with reef material and generally occurs overgrowing pyrite 1 along the reef margins and around reef inclusions (Figs. 6 and 7).

Arsenopyrite occurs as coarse-grained, equant crystalline forms, *not* as acicular or rhombic forms common to Archaean lode deposits. Arsenopyrite partially overgrows pyrite 2, and grain boundaries of the two minerals are straight, indicating equilibrium growth without replacement.

Pyrite 3: is coarse grained and inclusion-poor. Large crystalline forms may enclose arsenopyrite as well as pyrite 2. In some cases pyrite 3 occurs intergrown with arsenopyrite and is interpreted as being coeval with the arsenopyrite. Gold and chalcopyrite occur as small (5-40 microns), discrete rounded inclusions within pyrite 3 (Fig. 8). Tetrahedrite and rarely bismuthinite are also present as rounded inclusions within pyrite 3.

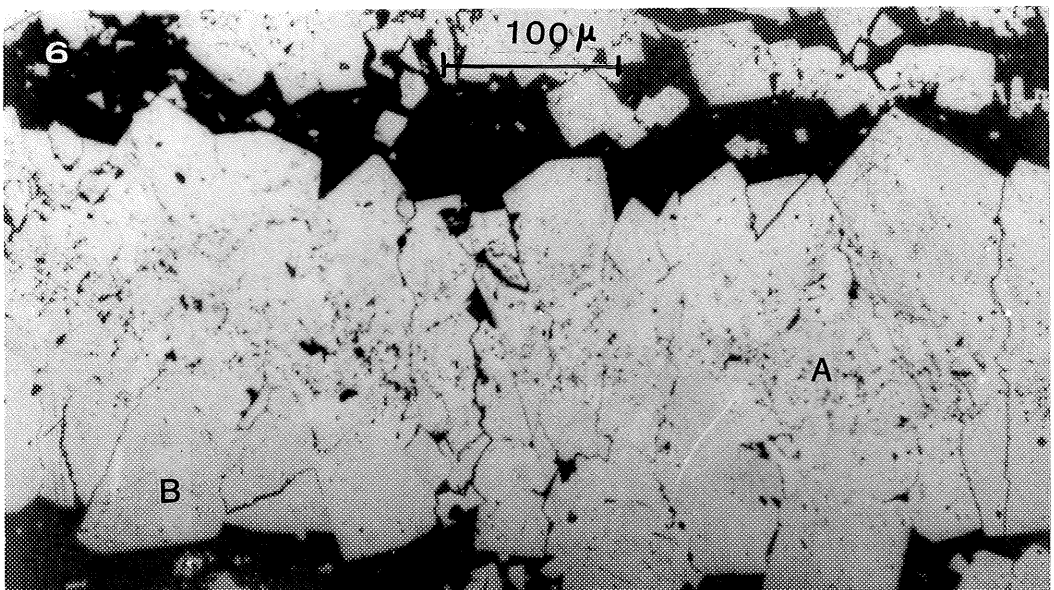

Figure 6: Photomicrograph of coarse pyrite (B) overgrowing an earlier generation of fine-grained, euhedral pyrite (A).

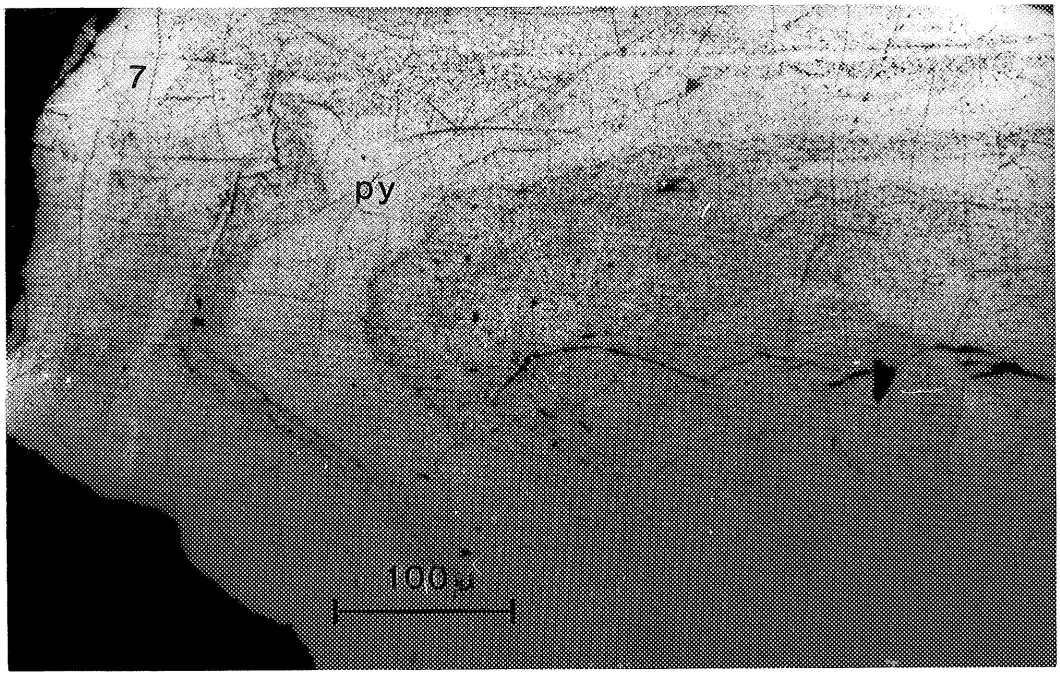

Figure 7: *Tightly folded, pyritic shale, replaced by a later, coarse-grained pyrite phase.*

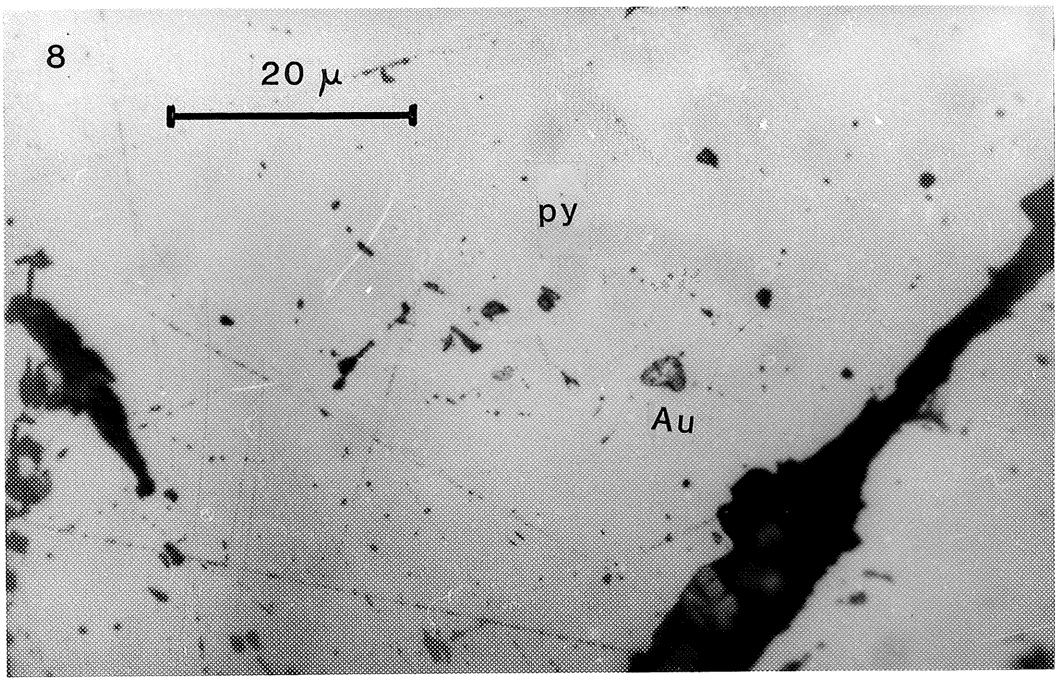

Figure 8: *Small, rounded inclusion of gold (Au) in a large, fractured pyrite grain (py).*

Pyrite 4: is an anhedral, inclusion-bearing phase which partially overgrows pyrite 3. This phase, however is very sporadically developed within the mine.

Stage Two Mineralisation

A second stage of gold mineralisation constituting about 70% of the gold within the Elandshoogte Mine ore belongs to this later generation.

Gold is accompanied by a complex suite of rare minerals including native bismuth, bismuthinite, the tetrahedrite tennantite species, sphalerite, and chalcopyrite and is sited within quartz-filled cracks and fractures within the stage one sulphides, predominantly pyrite 3 (Fig.9). These later minerals may passively fill broad fractures and also replace pyrite, and, less commonly, arsenopyrite around narrow fractures. It is unusual to see all minerals of the late paragenesis together as this situation occurs only where small cavities within the pyrite are intersected by fractures. The cavities are generally partially filled with later sulphides and in one example all components of the late-stage paragenesis, and their inter-relationships, were identified. Native bismuth occurs as small irregular grains, often with no visible crystalline form. Sphalerite overgrows and partially replaces bismuth, in places forming an enclosing envelope around it. Bismuthinite is a major component in the late generation of minerals and totally overgrows and envelopes the bismuth-sphalerite grains. Chalcopyrite is volumetrically dominant and occurs as a complex intergrowth with bismuthinite.

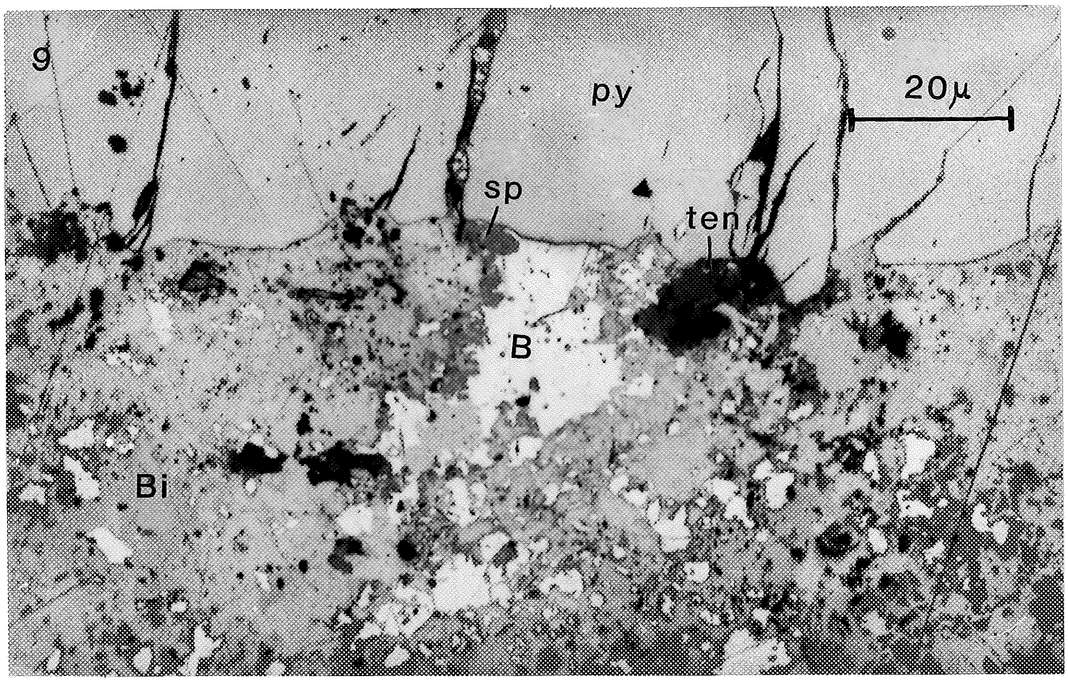

Figure 9: *Complex intergrowth of late-generation sulphides, which occur in fractured pyrite (py). Native bismuth (B) occurs in contact with sphalerite (sp). Tetrahedrite-tennantite (ten) is a minor phase, while bismuthinite (Bi) encloses all other phases.*

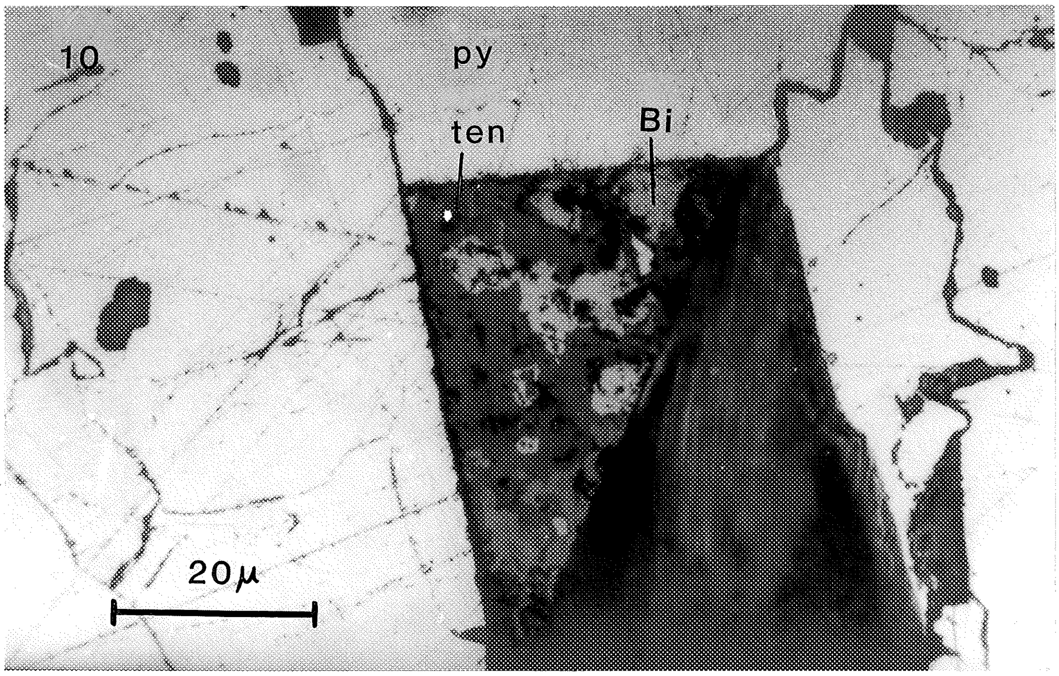

Figure 10: *Complex intergrowth of tetrahedrite-tennantite (ten) and bismuthinite (bi), in contact with quartz gangue and pyrite (py).*

Tetrahedrite-tennantite is also intergrown with bismuthinite, but is very sporadically developed (Fig.10). Gold occurs as small anhedral inclusions in the bismuthinite. Where only chalcopyrite and bismuthinite accompany gold in fractures, gold commonly occurs along the grain boundary between the two minerals, or is totally enclosed in the bismuthinite. Stage two gold grains range from 2 to 40 microns in size (Figs.11 and 12). Late stage fracture-hosted gold mineralisation, similar to that at Elandshoogte has also been described from deposits around Pilgrim's Rest (Swiegers, 1949; Meyer et al., 1986), although no reference was made to the origin of the fractures. The fractures in the early reef sulphides constitute a cataclastic texture. Fractures range from hairline cracks to microfaults with visible offsets, and transgressive relationships can be seen with some cracks offset by microfaults. Fractures present in the sulphides are filled with quartz, which is in places intergrown with coarse hydrothermal muscovite (Fig. 13) and can be traced to the enveloping quartz gangue. The

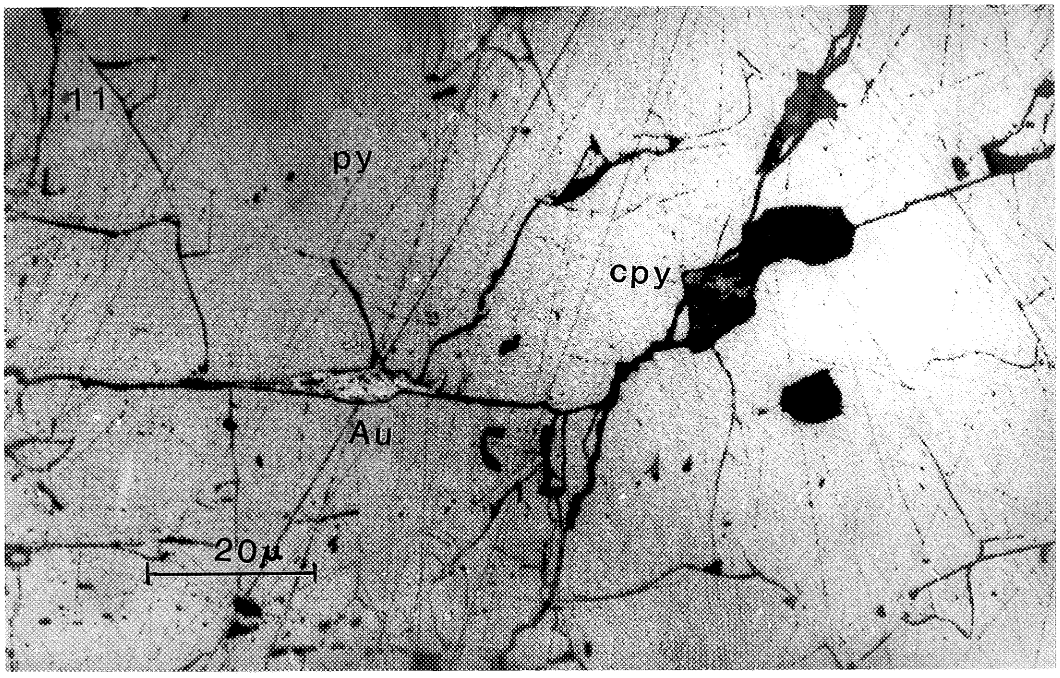

Figure 11: *Late stage gold (Au) and chalcopyrite (cpy), hosted along, and within fractures respectively, in pyrite (py).*

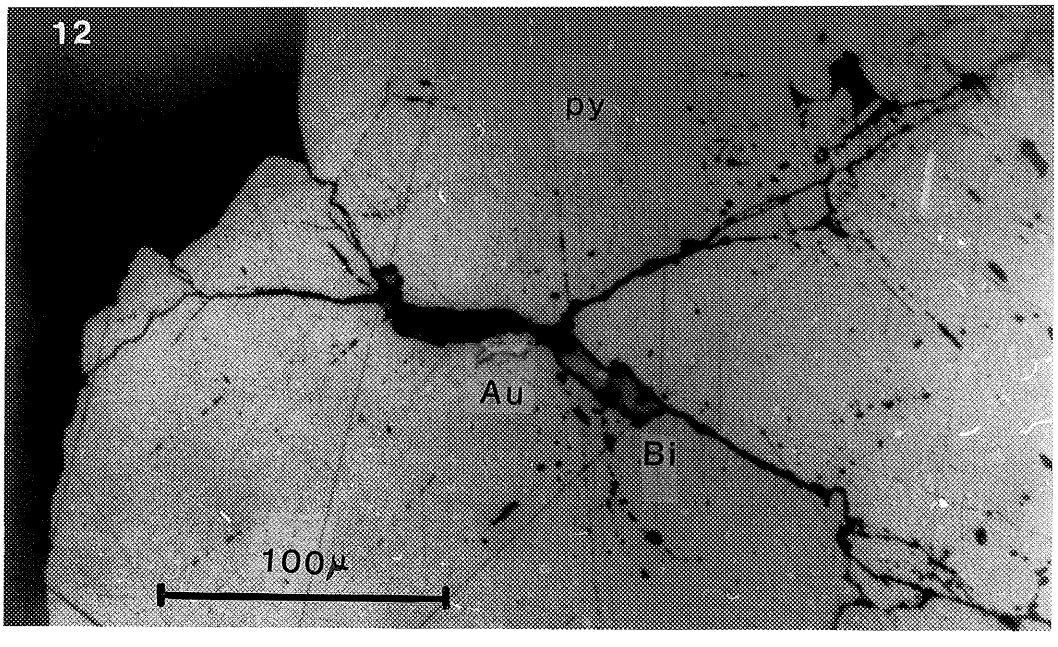

Figure 12: *Late stage gold (Au), closely associated with bismuthinite (Bi), located in cataclastically deformed pyrite (py).*

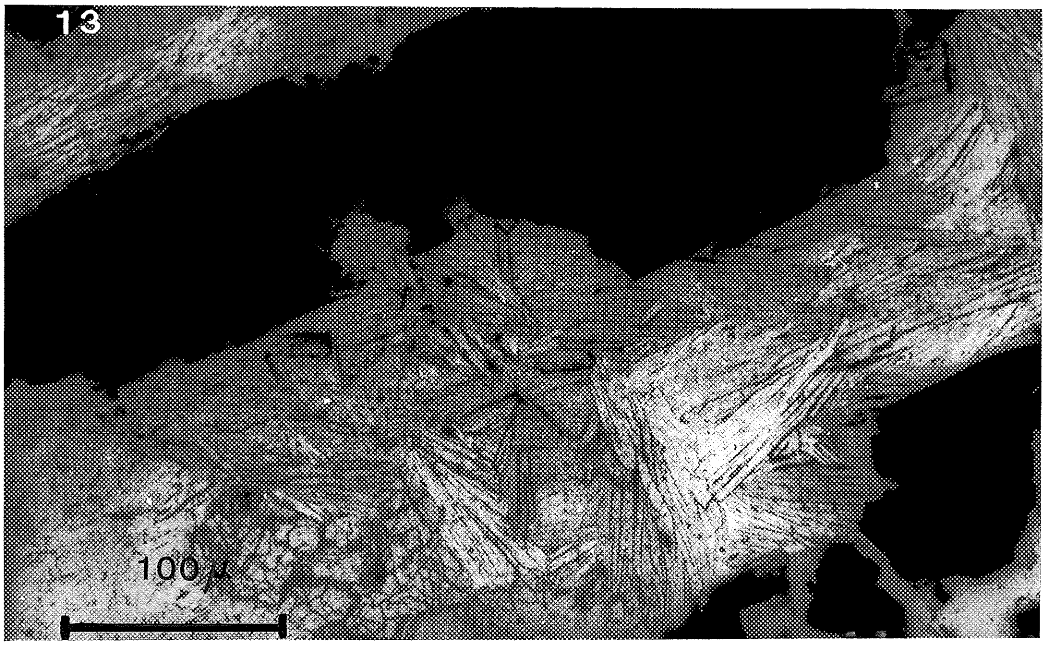

Figure 13: *Coarse-grained hydrothermal muscovite, intergrown with quartz, developed in fractured pyrite. Plane polarised light.*

occurrence of stage two mineralisation, within the quartz-filled fractures in the stage one sulphides suggests that the later phase accompanied the quartz emplacement. The quartz shows extreme undulose extinction, sutured grain boundaries, and pressure solution in veinlets, coupled with microfractures as evidence of post reef deformation. No gold mineralisation occurs in the quartz, but coarse-grained crystalline chalcopyrite occurs as aggregates in quartz.

Early Deformation and Quartz Emplacement

The orientation of dilated riedel and conjugate riedel fractures and mineralised fractures associated with the main phase of reef emplacement are consistent with simple shear deformation. Broadly ESE-verging, bedding-parallel thrust faulting, characterised by small-scale duplexes, S-C cleavages (Figs.14 and 15), ramp structures, and asymmetric folds, took place in the mineralised carbonaceous shale and fractured the pre-existing sulphides. The importance of high fluid pressure accompanying

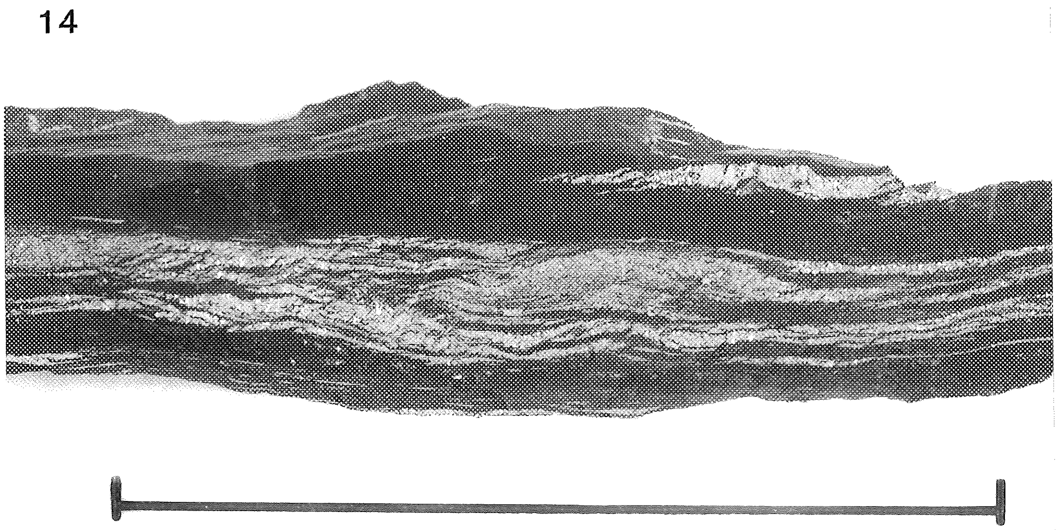

Figure 14: *Complex microstructures in sheared, pyritic shale, from the vein hanging wall.*

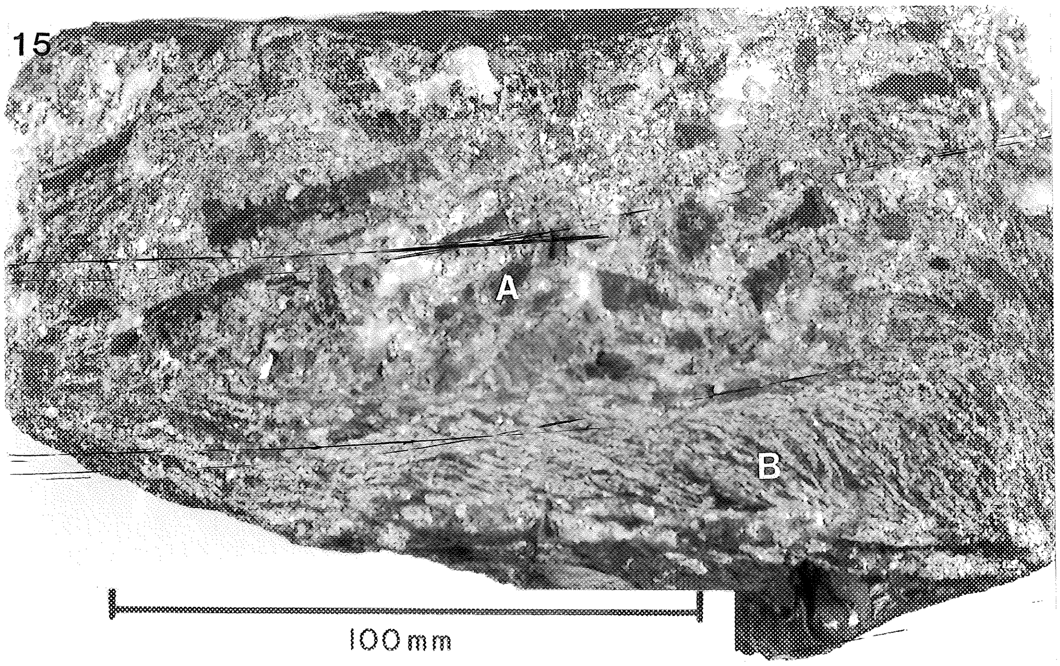

Figure 15: *Hand specimen of well-mineralised vein material from Elandshoogte Mine. Note the contrasting styles of deformation displayed. Brecciated silicified dolomite (A) and sheared, imbricated pyrite laminae in the shale of the vein footwall (B).*

thrust faulting has been emphasised by Hubbert and Rubey (1959), Gretener (1969; 1972), and Sibson (1989). Deposition of the dominant phase of quartz and the second stage of gold mineralisation occurred from the fluid which accompanied early reef deformation. Restricted development of hydraulic breccias and tensional veins indicate high pressures present at the time of emplacement. No major gangue phase is recognised accompanying stage one mineralisation. It is possible that minor quartz veining took place, but most evidence of this within the reef has been obliterated by the main phase of quartz deposition. Minor ribboned selvages of early quartz and sulphide are, however, thought to be preserved in places.

Post Reef Deformation

A complex suite of related structures characterises the main phase of post-reef deformation at Elandshoogte Mine. Reef emplacement was a multiple-stage process and one of the final stages of reef formation was a complex thrust-faulting event. The carbonaceous shale, which is commonly preserved along the reef footwall and hanging walls is a preferred site of deformation and localises the sole and roof thrusts of a blind thrust system (Fig.16). These thrusts occur as zones of intense deformation within the carbonaceous shale: individual fault planes occur in subparallel sets, and minor splays interconnect to form complex anastamosing fault patterns, up to 30 cm wide. Small (cm to 10s' of cm scale) duplex structures are commonly developed within the thrust zones together with isoclinal recumbent folds. Asymmetric to recumbent folding and complex faulting also occur elsewhere within the shale units. Ramps occur as carbonaceous, slickensided fault planes which cut upsection from footwall to hanging wall, indiscriminately through all reef components, forming large (10s to 100s of cm scale) duplex systems. Antiformal stacks also occur on several scales within the thrust system (Fig.17). Ramps consistently dip shallowly to the west, duplex structures have hanging wall-ramps underlying their eastern flanks, and leading branch lines within antiformal stacks occur on the eastern sides of these structures. Axial planes of microfolds also dip westwards. These kinematic indicators were

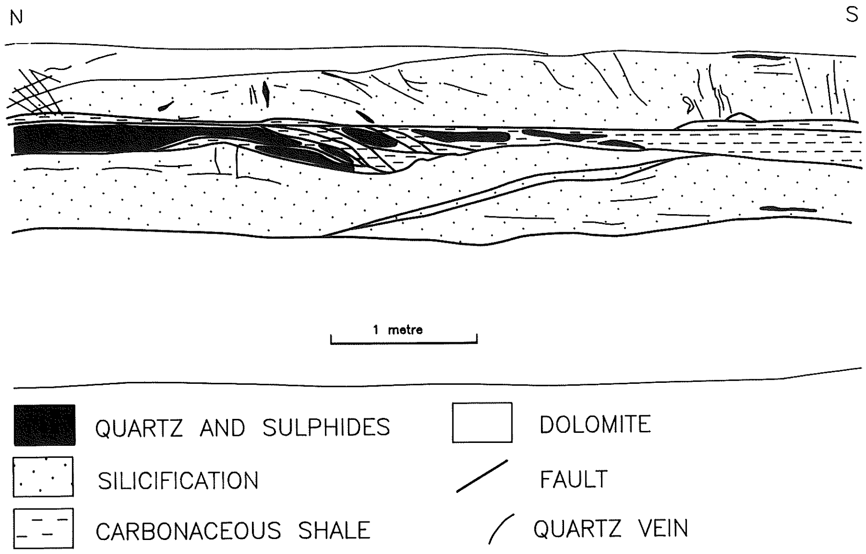

Figure 16: *Sidewall map of a part of the Elandshoogte Mine showing the complex post-reef structures associated with the blind-thrust system.*

combined with slickenside data from fault planes to obtain the overall sense and direction of thrust motion, which is towards the ENE. Analysis of geometries of structures within the reef also shows that thrust faulting occurred both by progressive footwall failure and by out-of-phase thrusting.

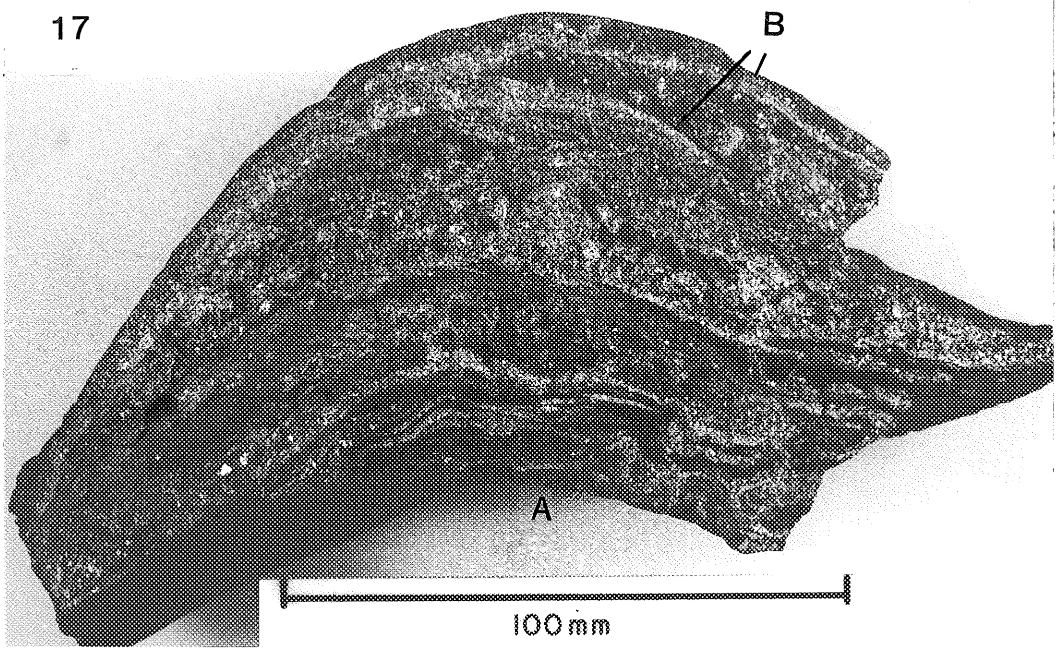

Figure 17: *Hand specimen showing an antiformal stack of vein material from Elandshoogte Mine. Note the folded pyritic-shale (A) in the footwall of the structure and the folded fault planes (B).*

DISCUSSION

It is possible that the post-reef thrusting is the termination of a progressive deformation event, which commenced with the emplacement of the main quartz reef. Crystallisation of the quartz from the fluid accompanying early deformation increased the competency of the deformation zone and led to a change in deformation style, from bedding parallel thrusting in shales, to the formation of thrust duplexes in the quartz reef. Kinematic indicators for both deformational events also indicate very similar transport directions in both cases.

Regionally, preliminary investigations reveal similar deformation and mineralisation styles at many of the mines in the Sabie-Pilgrim's Rest Goldfield (e.g. Nestor, Malieveld, Mountain, Little Joker, Dukes Hill, Frankfort, Rietvallei). The causes of this deformation, as well as the source of mineralisation are unknown at present.

The similarities between the gold deposits of the Sabie Pilgrim's Rest Goldfield and the Telfer deposit of Western Australia have been indicated in the text and also by Goellnicht et al.(1988a). Goellnicht et al. (1988b) demonstrated that lead isotope data from the Telfer deposit are consistent with partial derivation of fluids from a local granitic source. The preferred genetic model proposed by Goellnicht et al.(1988b) involves the syn- to post-deformational infiltration of magmatic, auriferous fluids along favourable beds and structures in the sedimentary sequence. Both Telfer and the Sabie-Pilgrim's Rest deposits are characterised by high salinity fluid inclusions and a Cu:Au association, features common to mineralisation styles unequivocally related to granitoid magmatic-hydrothermal systems, such as porphyry-copper and tin-tungsten deposits (Goellnicht et al.,1988b).

In terms of the Sabie-Pilgrim's Rest area no intrusive granitoids have been identified within the goldfield; the Bushveld granite bodies being located 80 to 100km west of the goldfield. However, there is abundant evidence for igneous activity in the goldfield with both pre- and post mineralisation dolerite intrusives, and Tyler (1986) suggested that the gold mineralisation may be genetically related to magmatism, which is expressed as dyke and sill emplacement. The possibility of there being unexposed granitoids intrusive into the Archaean basement also cannot be discounted and such intrusives may be responsible for the mineralisation in the Sabie Pilgrim's-Rest Goldfield, analagous with the situation proposed for Telfer by Goellnicht et al.(1988 a, b).

CONCLUSIONS

Stage two gold mineralisation was deposited in fractured sulphides during massive fluid influx accompanying thrust faulting. The fractures and microfaults formed during thrust deformation and created permeability in the crystalline sulphides, allowing fluid access to the interior of the thrust-bound fragments of reef. Gold deposition occurred, not in the major thrust faults, but in secondary structures created by thrust deformation. Reef formation was a complex, multi-stage process in which structure played an important role in preparing the sites for mineralisation. The implications of this model are that reefs in the mine which do not show evidence of early deformation are not prospective gold hosts. Similarly, reef material that is devoid of sulphide is also unlikely to host significant gold. Definition of the origin of the deformation and the fluids will also allow demarcation of areas of high prospectibility, and refinement of a genetic model for the goldfield.

ACKNOWLEDGEMENTS

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REFERENCES

Ash, J.P. and Tyler, N. (1986). A Preliminary Investigation of Fluid Inclusions in the Pilgrim's Rest Goldfield. Inf. Circ. Econ. Geol. Res.Unit., Univ Witwatersrand, Johannesburg, 180, 21pp.

Button, A. (1976). Transvaal and Hamersley Basins-Review of Basin Development and Mineral Deposits. Minerals Sci.Engng., 8, pp 262-293.

Cawthorn, R.G., Davies, G., Clubley-Armstrong, A. and McCarthy, T.S. (1981). Sills Associated with the Bushveld Complex, South Africa: an Estimate of the Parental Magma Composition. Lithos 14, 75-83.

Fowler, A.R.C. (1968). Mining at Transvaal Gold Mining Estates Limited, 1872-1967. J. S. Afr. Inst. Min. Metal., February 1968, 291-335.

Goellnicht, N.M., Dimo, G., Groves, D.I. and McNaughton, N.J. (1988a). An Epigenetic Origin for the Telfer Gold Deposit. In: Bicentennial Gold 88, Extended Abstracts, Oral Programme. Geol. Soc. Aust., Abstr 22, 79-94.

Goellnicht, N.M., Groves, I.M., Groves, D.I., Ho, S.E. and McNaughton, N.J. (1988b). A Comparison between Mesothermal Gold Deposits of the Yilgarn Block and Gold Mineralization at Telfer and Miralga Creek, Western Australia. Indirect Evidence for a Non-magmatic Origin for Greenstone-Hosted Gold Deposits. In: Ho, S.E. and Groves, D.I. (eds) Geol.Dept. and Univ. Extension, Univ. W.A. Publication 12, pp 309-319.

Gretener, P.E. (1969). Fluid Pressure in Porous Media - its Importance in Geology: a Review. Bull. Can. Petroleum Geology, 20, 255-295.

Gretener, P.E. (1972). Thoughts on Overthrust Faulting in a Layered Sequence. Bull. Can. Petroleum Geology, 20, 583-607.

Hubbert, M.K. and Rubey, W.W. (1959). Role of Fluid Pressure in Mechanics of Overthrust Faulting. Geol. Soc. America Bull., 70, 115-166.

Maske, S., Maiden, K.J. and Clendenin, C.W. (1986). Gold Mineralisation at the Elandshoogte Mine, Eastern Transvaal Basin. In: Geocongress '86: Johannesburg. Geological Society of South Africa. 531-534

Meyer, M. (1988). Environment of Ore Formation in the Sabie-Pilgrim's Rest Goldfield, South Africa. In: Geocongress '88: Durban. Geological Society of South Africa, 427-430.

Meyer, M., Welke, H.J. and Robb, L.J. (1986). Mineralogical and Geochemical Characteristics of Flat Reefs in the Sabie-Pilgrim's Rest Goldfield. In: Geocongress '86: Johannesburg. Geological Society of South Africa, 535-540.

Sharpe, M.R. (1981). Petrology and Geochemistry of Pre-Bushveld and Waterberg Mafic Sills. Trans. Geol. Soc. S. Afr. 84, 75-83.

Sibson, R.H. (1989). High-angle Reverse Faulting in Northern New Brunswick, Canada and its Implication for Fluid Pressure Levels. J. Struct. Geol., 17, 873-877.

Swiegers, J.U. (1949). Gold Deposits of the Pilgrim's Rest Gold Mining District, Transvaal. Trans. geol. Soc. S. Afr., 51, 81-132.

Tyler, N. (1985). The Origin of Gold Mineralisation in the Pilgrim's Rest Goldfield, Eastern Transvaal. Inf. Circ. Econ. Geol. Res. Unit., Univ. Witwatersrand, Johannesburg, 179, 34pp.

Tyler, R. (1989). Cyclic Sedimentation and Gold Mineralisation in the Pilgrim's Rest Sabie Goldfield, Eastern Transvaal. Unpublished M.Sc Thesis, University of the Witwatersrand, Johannesburg, 146pp.

Visser, H.N. and Verwoerd, W.J. (1960). The Geology of the Country North of Nelspruit. An Explanation of Sheet 22 (Nelspruit). Geological Survey of South Africa, 128pp.

Zietsman, A.L. (1967). The Relationship Between Mineralisation and Structure in the Pilgrim's Rest-Sabie Goldfield. Unpubl. D.Sc. Thesis. Univ. of the Orange Free State, Bloemfontein, 198pp.

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