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Abstract

The Leonora 1:100 000 Sheet area covers the western limit of the Eastern Goldfields Province of Western Australia, and includes several major gold deposits (eg., Sons of Gwalia and Harbour Lights mines). Detailed mapping by AGSO has identified three major shear zones: the Sons of Gwalia Shear Zone, which formed early (because folded by regional folding), and two north-northwest-striking late shears, the Mount George Lineament and Kilkenny Fault. The latter two are not mineralised. In contrast, the Sons of Gwalia, Harbour Lights, and Tarmoola deposits lie on the northern margin of the Sons of Gwalia Shear Zone. Consequently, significant potential for discovery of large gold deposits in the Leonora area lies in the early higher-strain shear zones of higher metamorphic grade, rather than in the more easily identified late vertical structures of lower strain and metamorphic grade.

The Mount George Lineament and Kilkenny Fault respectively form the western and eastern boundaries of the Keith-Kilkenny High-strain Zone, which separates structurally complex rocks to the southwest from less deformed sequences to the east. The southwest is underlain by a strongly deformed partly migmatitic granitic batholith. Greenstones adjoining the batholith to the east and north are amphibolite-facies metamorphosed mafic igneous rocks. East of the Mount George Lineament, the geology changes to a mixture of felsic and mafic igneous rocks with abundant intercalated sandstone, shale, and conglomerate, intruded by a largely undeformed discordant granite batholith in the northeast. The western margin of the Keith-Kilkenny Zone may represent a reactivated tectonic basin margin separating sequences to the west and east.

The regional pattern of deformation in the area is the result of four major and two minor episodes of deformation. The earliest episode (De) produced gently dipping mylonite, orthogneiss, and schist. Movement directions were usually north-directed. Sedimentary basins and felsic sequences are bounded by regional D_e faults which controlled the location and development of the basins. The second event (D_1) was also largely bedding-parallel, and resulted in structural inversion of the previously deformed rocks. The event is correlated with regional north-south thrusting known throughout the Eastern Goldfields Province. The third episode (D_2) resulted in a widespread north to northwest-striking crenulation of the early schistosity and long-wavelength open upright regional folds. These folds affect the early orthogneiss and other D_e and D_1 structures. Regional northwest-striking strike-slip faults, eg., the Kilkenny Fault on the east margin of the Keith-Kilkenny Zone, with attendant cleavage and subhorizontal stretching lineation, were reactivated as sinistral faults during the third (D_2) and fourth (D_3) deformation events. East-northeast-striking (D_4) faults cross-cut all the earlier structures. In several localities a southeasterly-striking widely-spaced crenulation, commonly gently-dipping, is evidence of a sixth episode (D_5). The well-exposed gently-dipping extensional faults are evidence of an extensional structural event which exerted regionally important structural controls on the development of the stratigraphy and architecture of the greenstone belts.

The boundary of the migmatitic granite in the southwest is the Sons of Gwalia Shear Zone (D_e or D_1), and is earlier than the upright folding. The shear zone dips moderately east at Sons of Gwalia and Harbour Lights Mines, flat at Tarmoola mine, and about 30° north-northwest in the Mount Ross area. S-C fabrics, asymmetric pressure shadows, extensional rotational fractures, and quartz optic axes indicate normal (top-side-north) extensional movement in the west, changing to top-side-east (or east-side-down) in the south, near Leonora township. The batholith appears to be a core complex emplaced in the solid state beneath the Sons of Gwalia Shear Zone, with the top plate moving north or northeastwardswards relative to the granite.

East of the Mount George Lineament, the region is dominated by north-northwesterly-striking faults and folds in a fold-thrust belt.

Introduction

LEONORA[1] lies between 28.5°S and 29°S latitude and 121°E and 121.5°E longitude. The sheet area (Fig. 1) covers part of the Eastern Goldfields Province within the Yilgarn Craton (Gee 1979). Mapping of the area commenced in 1987 with a structural investigation around the township of Leonora. The structural study was extended to cover the whole sheet area in 1989. A preliminary geological map for the area was released in 1990 in hand-drawn form, and a colour compilation and digital files were released in January 1992. The geological compilation was based on mapping carried out by AGSO (then the Bureau of Mineral Resources, BMR) during 1987 and 1988, incorporating information previously collected by Nisbet (1984) and Hallberg (1985) from surveys in the early 1980's.

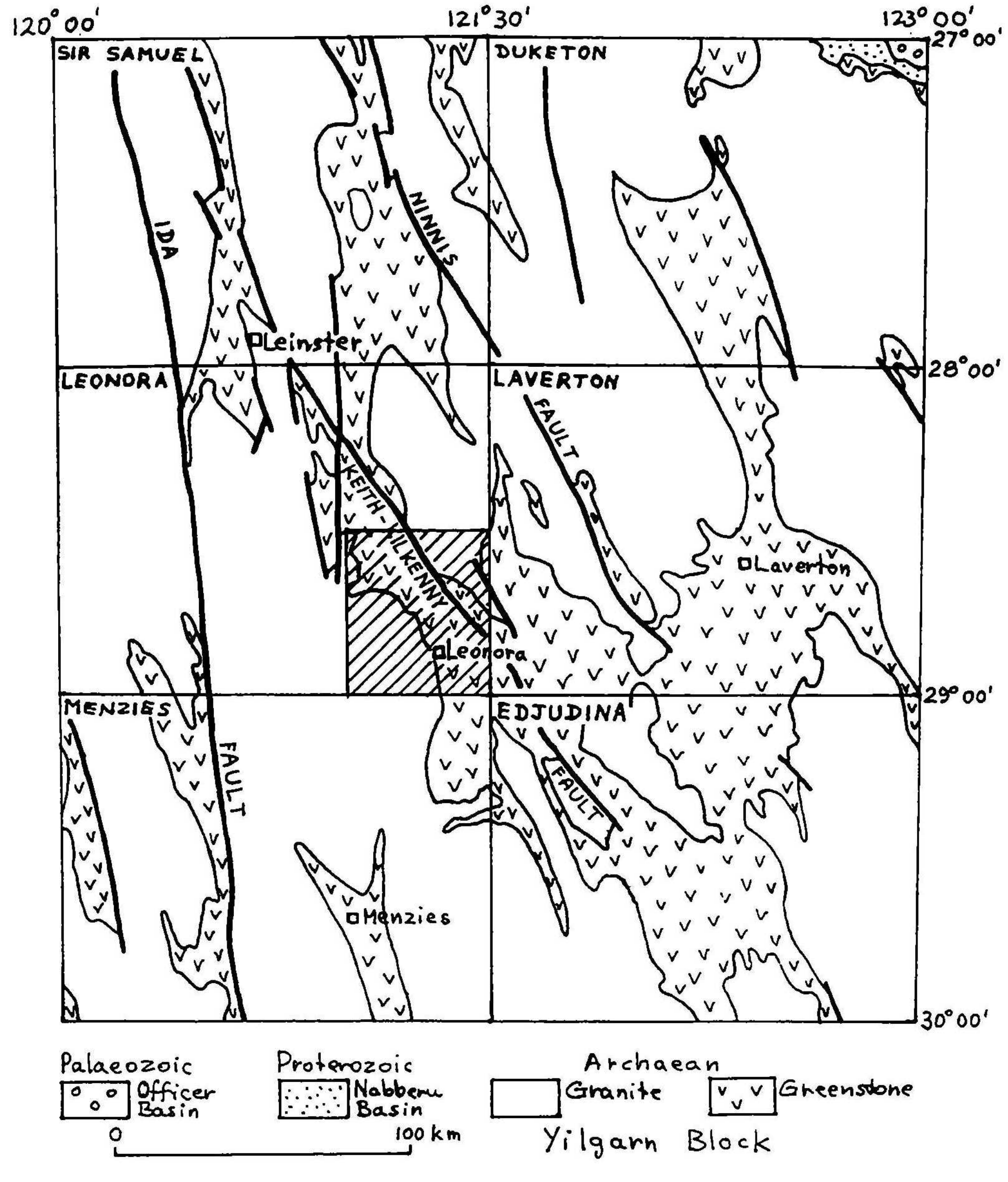

Figure 1. Location of LEONORA in the Eastern Goldfields Province.

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[1] Capitalised names refer to standard 1:100 000 map sheets.

LEONORA covers the western limit of supracrustal rocks of the Eastern Goldfields Province, and includes several major mineral deposits (eg., Sons of Gwalia and Harbour Lights mines). The Keith-Kilkenny High-strain Zone (Passchier 1992), a significant structural break extending well beyond the boundaries of LEONORA, separates structurally complex rocks west of Leonora from apparently less deformed sequences to the east. This deformation zone has been referred to by I. Williams et al. (1973) as the Kilkenny Fault, and by Hallberg (1985) as the western margin of the Keith-Kilkenny tectonic zone.

This report presents a summary and synthesis of the structural information collected in LEONORA, and a description of all the major rock types. The location and structure of the major mineral deposits are also summarised. At the time of mapping, the area was covered by 1.5 km-line spacing aeromagnetic data acquired by BMR. These data are available in digital and processed image form (Anfiloff & Milligan 1989) and as contour maps. Proprietary data were not available to the author at the time of mapping, but AGSO subsequently acquired 400 m line-spacing airborne magnetic and radiometric data over the whole of the Leonora 1:250 000 sheet area. Interpretation of some of these data is included in this commentary.

Locations of all samples mentioned in text are listed in Appendix 1. Locations of all LEONORA whole-rock samples analysed for major and trace elements are listed in Appendix 2; results are stored in AGSO's ROCKCHEM database and are available for purchase.

Previous investigations

The Leonora area was mapped by Thom & Barnes (1977) as part of the regional reconnaissance 1:250 000 geological series, and they summarised the geological studies carried out up to that time. The only later published study of the regional geology was by Hallberg (1983, 1985). Williams et al. (1989) described the structural geology of the region north and east of Leonora. Passchier (1994) described the structural geology of the entire greenstone belt in LEONORA, and concluded that early extension in various directions along gently dipping shear zones was followed by southwest-directed transpressional shortening.

Results of several studies of the mineral deposits of the region have been previously published. Skwarnecki (1987, 1988) discussed the setting and alteration style of the Harbour Lights and Sons of Gwalia deposits, and also provided a summary of the critical geological features of the two deposits (Skwarnecki 1990a, b). Other descriptions of the deposits at Harbour Lights (Dudley et al. 1990), Tower Hill (Schiller & Hanna 1990), and Sons of Gwalia (Kalnejais 1990) are also available. In addition to these published works, there is a large amount of unpublished exploration data available through the Geological Survey of Western Australia M-series open-file database.

Archaean geology

Geological framework

LEONORA can be divided into 16 domains based on differences in the major rock types and structural patterns (Fig. 2). The southwest is underlain by a strongly deformed monzogranite to granodiorite batholith which is migmatitic in places (Raeside Batholith). The batholith is on the eastern margin of a regional gneiss belt (Williams & Whitaker 1993), which extends westwards to the Southern Cross Province, and has a sheared concordant margin with greenstones of the Norseman-Wiluna Belt of the Eastern Goldfields Province. The marginal greenstones are

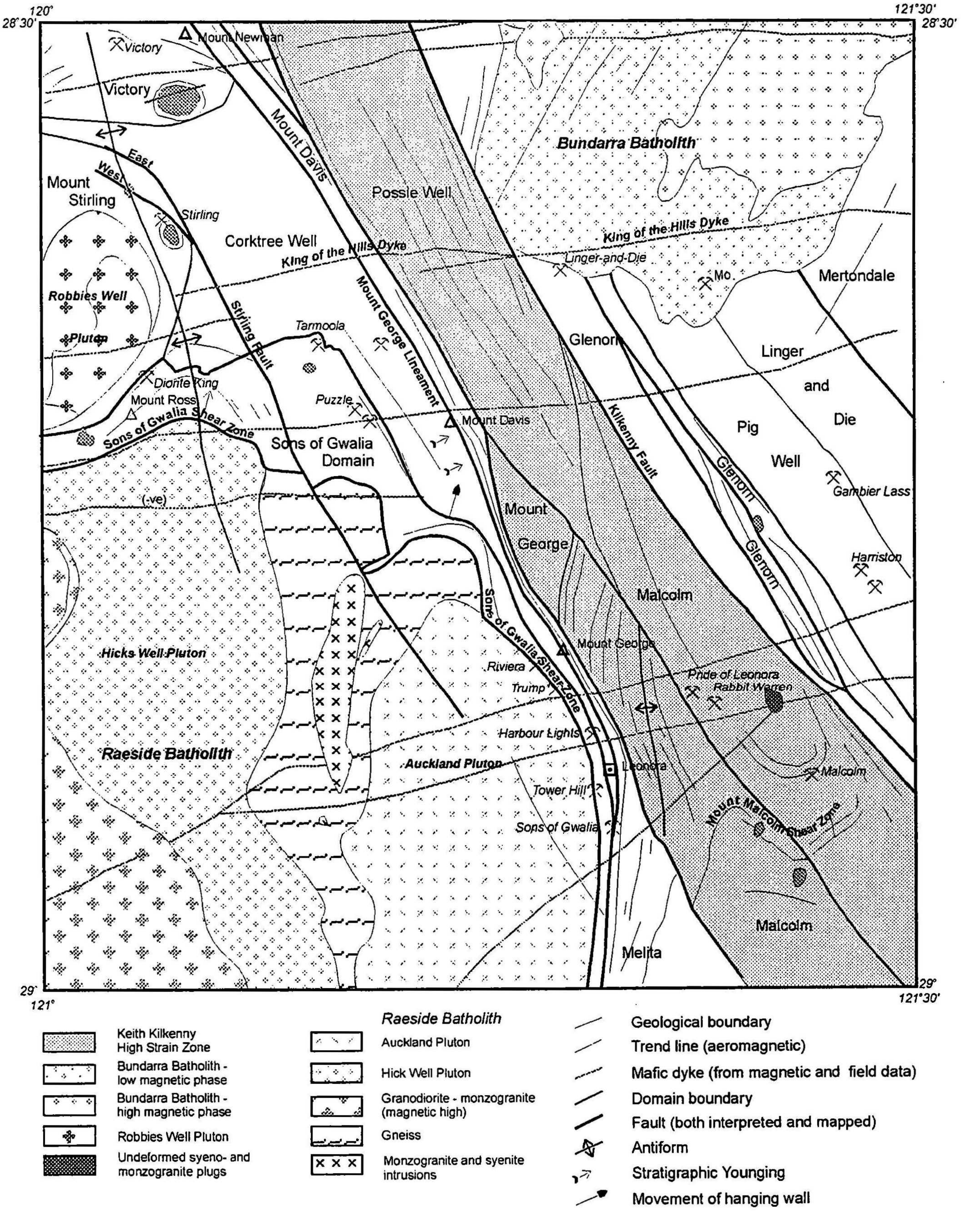


Figure 2. Structural domains and principal structural features of LEONORA, based on field mapping andaeromagnetic interpretation. Interpretation of internal structure of the Bundarra and Raeside Batholiths from 400 m line-spaced magnetic data. Dykes marked by positive magnetic anomaly except where indicated.

amphibolite-facies metamorphic rocks, and are assigned to the Sons of Gwalia Domain. A prominent zone of north-northwest-striking ridges composed largely of chert extends across LEONORA, falling within the Mount Davis Domain. There is a marked change in the geology across this domain. To the east of the ridges, the mafic volcanic rocks are exclusively tholeiitic, whereas in the west pyroxene spinifex texture is common, basalt is commonly pillowed, and interflow sediment is more abundant. Sedimentary and felsic volcanic sequences are present in the east, but not in the west. The eastern domains are intruded by a large discordant granite batholith (Bundarra Granite) which is largely undeformed. A number of smaller intrusions of granite, syenite, and porphyry were mapped during this survey.

The chert ridges within the Mount Davis Domain form a marked topographic lineament (termed the Mount George Lineament) which has been interpreted as a major structural break. Despite the change in geological character across the Mount Davis Domain, the structural information indicates that the major geological break lies to the east of the chert ridges, and that it is not correct to refer to the chert horizons as the site of the structural break or to draw a major shear zone coincident with the Mount George Lineament.

Description of rock units

Ultramafic rocks

Ultramafic rock, undivided or unassigned (Au)

Ultramafic rocks extend from the King of the Hills area (GR210270) to the southeast, and pass into talc-chlorite schist in the Tarmoola Station area (GR195225), within the Sons of Gwalia Domain. Outcrop is poor except in prominent hills east of Tarmoola, which are composed of foliated serpentinised and carbonated ultramafic rocks which show no primary igneous structures.

Ultramafic rocks were intersected in the upper intervals of drill core GWDD4 (Williams & Currie 1993). The rocks include alternating intervals of medium-grained (>1 mm) altered pyroxenite and talc schist. Schist comprises less than 35 percent of the ultramafic rocks, which appear essentially to form a single block transected by relatively minor ductile shears. Thin undeformed felsic porphyry dykes at 68.5 m depth (15 cm thick) and 104.8 m depth (5 cm thick) are parallel to foliation, but show no foliation themselves. The base of the ultramafic interval is strongly sheared and carbonated. The zone of ultramafic rocks structurally overlies less-deformed sedimentary rocks. The talc schist exhibits well-developed S-C fabrics indicating top-side-west movement, which suggests that the ultramafics were emplaced as a thrust slice over the younger felsic volcanic rocks.

Peridotite (Aup)

Peridotite has been identified in the Victory Domain in the northern part of LEONORA as an extension of the Mount Fouracre body described by Hill et al. (1990). South of White Well, a hill with abundant float of chalcedony and magnesite with some serpentinised peridotite is underlain by peridotite (GR250310). The linear outcrop area is marked by a strong magnetic lineament, and the peridotite has been intersected in diamond drill core. Peridotite was also intersected in the Gwalia Deeps drilling (Sons of Gwalia Domain). In GWDD4, the lower part of the core, dominated by relatively homogeneous basaltic flows and tuffs, includes significant ultramafic intervals (Williams & Currie 1993).

Talc-chlorite schist (Aut, Autg)

These rocks are very poorly exposed in the Sons of Gwalia Domain, but are relatively common in cuttings from RAB drilling programs. They are strongly foliated, with the foliation defined by films of talc and chlorite anastomosing around elongated carbonate porphyroblasts. Altered ultramafic schists have been identified as the host rocks to mineralisation at Tower Hill mine (GR362019, Schiller & Hanna 1990) and also occur throughout the Harbour Lights mine (GR360051). In both areas, alteration to a fuchsite-bearing rock occurred during mineralisation.

Low and medium-grade metamorphic rocks

Rocks of this group are of indeterminate origin.

Amphibolite (Ala)

Amphibolite is confined to the Sons of Gwalia Domain (Fig. 2), and is a dark green to black, fine to medium-grained crystalline rock with conspicuous amphibole crystals normally strongly aligned in a tectonic foliation. In many areas a second population of amphibole crystals is randomly oriented in the foliation, suggesting later growth. No primary igneous structures are preserved, and the rock is characterised by metamorphic textures and mineral assemblages. In the Mount Ross area, strong foliation in the amphibolite is parallel to the boundary of the amphibolite with the Raeside Batholith, and is accompanied by a marked mineral lineation parallel to the stretching lineation in the adjacent mylonitic granite. The foliation is folded and crenulated on mesoscopic and microscopic scales. Sample 87963473A is composed of fine-grained foliated chloritic laminae separating layers of foliation-parallel hornblende grains. This foliation is cut by a strong crenulation cleavage oriented at about 30° to the layering. Clear twinned hornblende crystals are also aligned in the crenulation surfaces. Several grains oriented parallel to the crenulation contain internal inclusion trails which are discordant to the crenulation. Small (0.5 mm diameter) rods of metamorphic quartz are restricted to particular layers in the rock, and represent inhomogeneities during the formation of the early cleavage, which wraps around the quartz rods. Quartz is a minor component of the rock elsewhere. The rods may have originated as amygdales in the parent rock.

In areas of weak crenulation cleavage, the late hornblende grains are randomly oriented and grow across the earlier foliation (eg., sample 87963473b, Fig. 3A and B). Elsewhere, the later fabric is a set of discrete cross-cutting shear zones in which new amphibole crystals have grown. New discrete amphibole crystals in rock surrounding the shears are subparallel to the shears (eg., sample 87963449).

Amphibolite was also encountered in diamond drill holes southeast of Sons of Gwalia mine (Western Mining Corporation [WMC], GWDD1-4, personal communication). Core from one of these (GWDD4) was examined during the present survey. Amphibolite occurred below 1100 m, and was texturally similar to the samples described from the Mount Ross area. The amphibolite is interleaved with quartz-chlorite-amphibole schist in which the well crystallised amphibole causes minor rotation of the matrix foliation and thus formed late in the structural history (eg., sample AB140085). In other examples (eg., WMC sample 140090) amphibole porphyroblasts contain well developed inclusion trails which are concordant with the external foliation but significantly rotated with respect to that foliation (Fig. 4). This relationship also indicates growth of the amphibole (as the peak metamorphic assemblage) late in the development of the early foliation in the amphibolite.

Quartz-feldspar-andalusite schist (Ald)

Andalusite schist has been collected from two localities in LEONORA: near Mount Leonora (Sons of Gwalia Domain, GR378000), and the other in the Mount Malcolm Domain (GR455037). In both areas, narrow andalusite-rich bands are present in quartz-sericite schist and cleaved felsic volcanics. In the Mount Malcolm area (sample 87963498) porphyroblasts are anhedral grains up to 5 mm in diameter with abundant quartz inclusion trails. The rock contains two well defined cleavage surfaces: an earlier strong slaty cleavage, and a later spaced (1-5 mm)

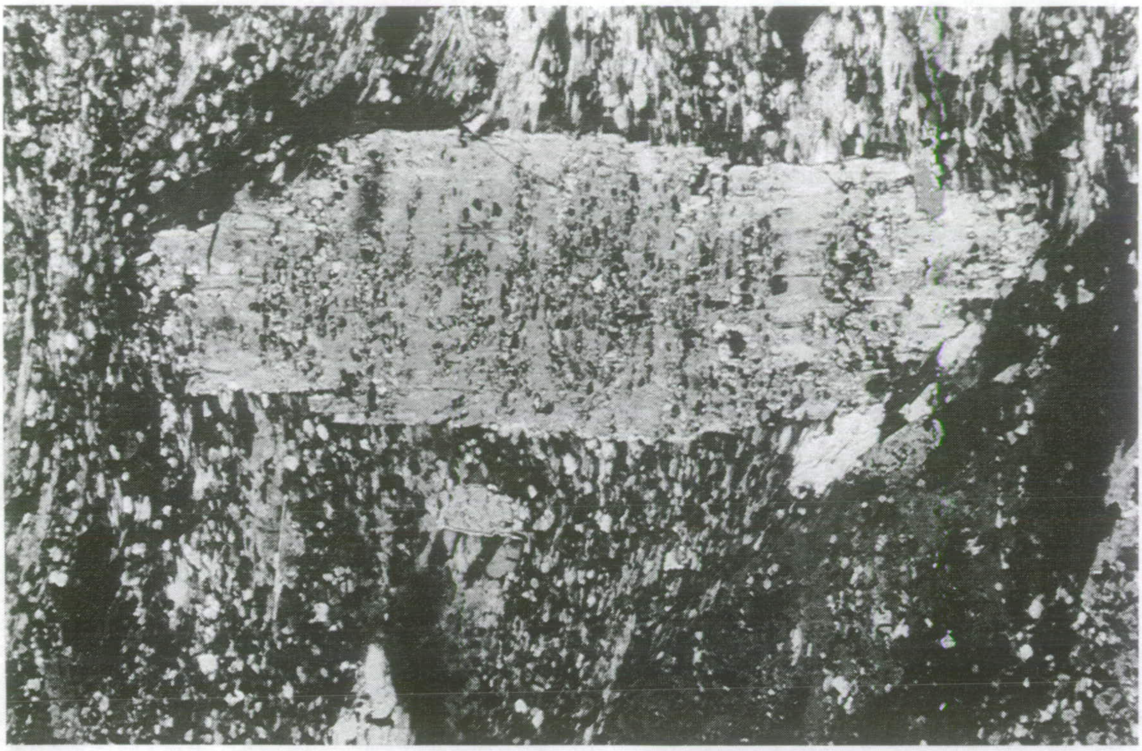


Figure 3A. Amphibole porphyroblasts, Sons of Gwalia Domain. Hornblende growing across the fabric, which is deformed around the porphyroblast.

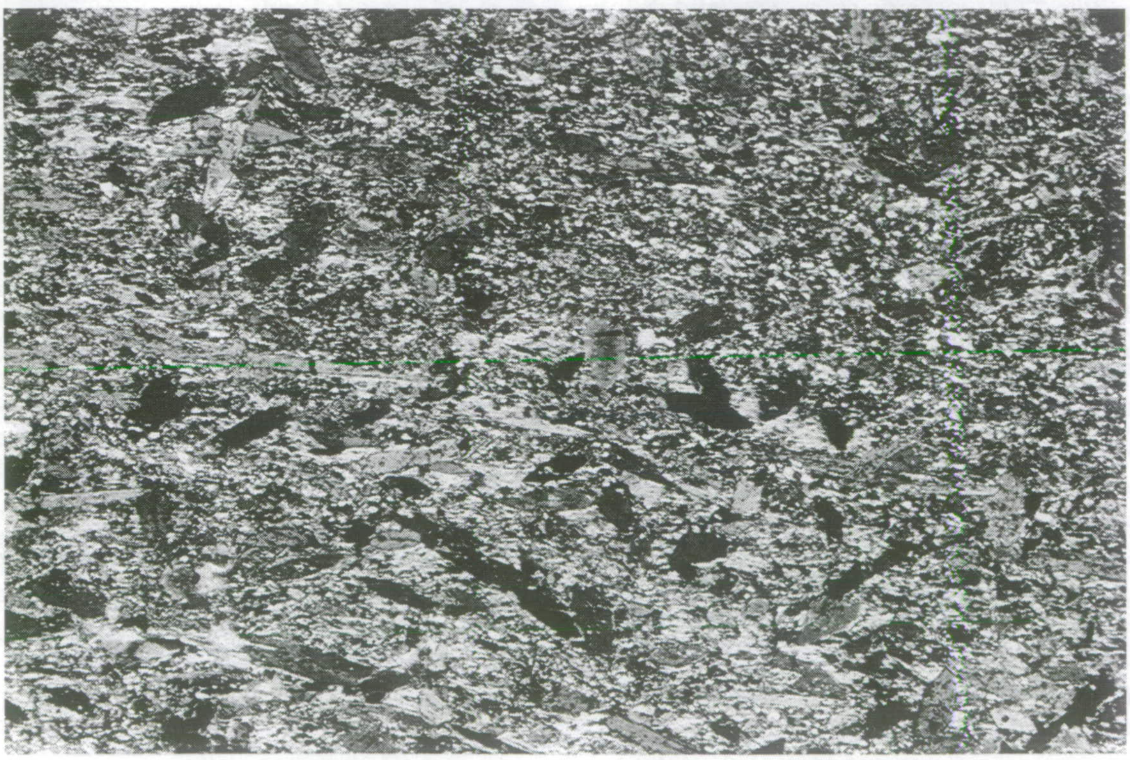


Figure 3B. Amphibole porphyroblasts, Sons of Gwalia Domain. Late random hornblende laths, both within and across the earlier foliation.

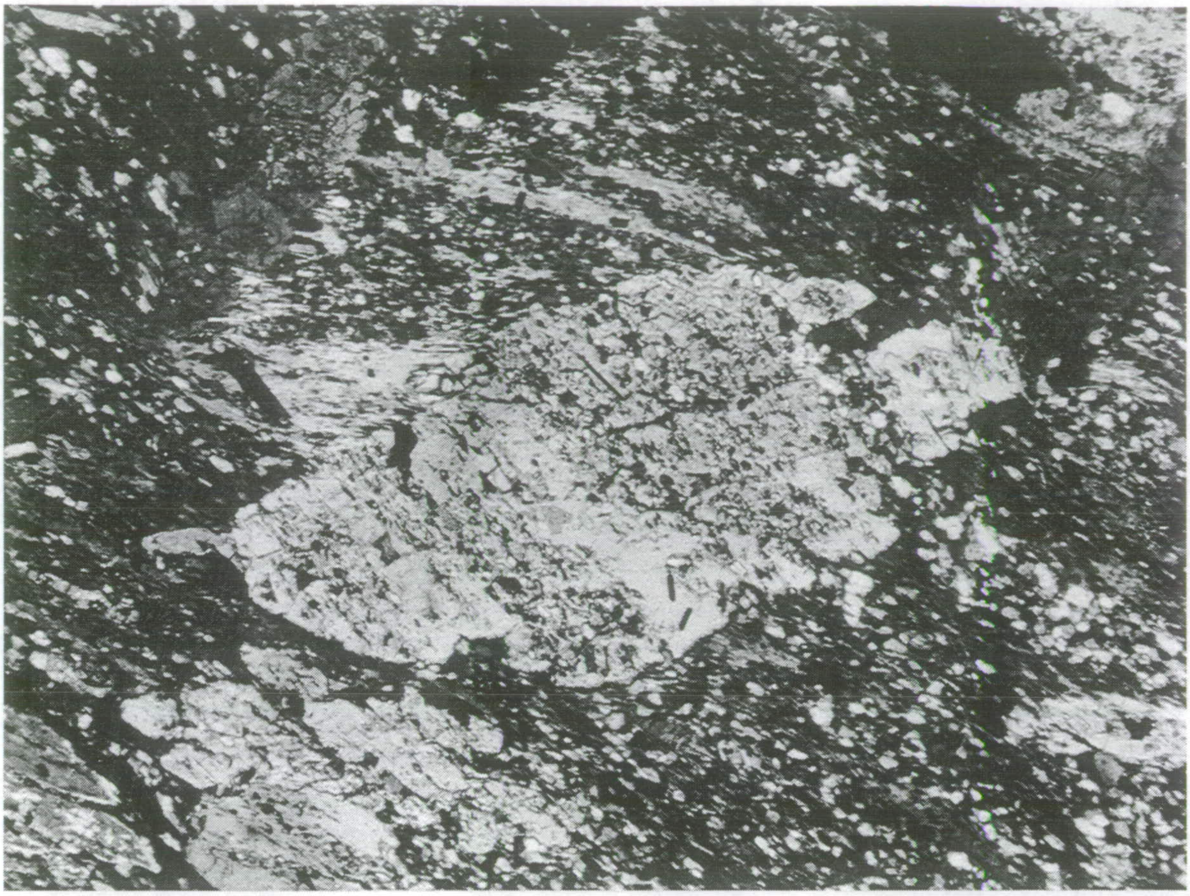


Figure 4. Rotated porphyroblasts with internal inclusion trails, Sons of Gwalia Domain.

crenulation cleavage which defines quartz-rich and mica-rich domains. These mica-rich domains bound andalusite grains in the andalusite- rich layers. The andalusite-rich layers are parallel to the early slaty cleavage.

The quartz inclusions trails within the andalusite grains are commonly straight and strongly aligned to form an internal foliation, which is parallel between adjacent grains, and generally parallel to the external slaty cleavage. The crenulation cleavage deforms the slaty cleavage and anastomoses around andalusite porphyroblasts generating a strong discordance between the internal trails and the later crenulation cleavage. The angle between the internal and crenulation fabrics is about 70°. In a few grains the early cleavage is deflected around the porphyroblasts. These textural relationships indicate that the andalusite grew prior to the crenulation cleavage, but largely overgrew the early slaty cleavage. Minor rotation of the early foliation around the grains suggests that growth commenced late in the early deformation event.

A zone of schistose, mainly felsic rocks extends south from Leonora township and joins with the main ridge of Mount Leonora (Sons of Gwalia Domain). The rocks characteristically contain andalusite porphyroblasts, and at Mount Leonora contain a complex secondary aluminosilicate assemblage described in detail by Hallberg (1985), who also presented convincing evidence that the sequence was derived from a mafic or ultramafic precursor. Andalusite porphyroblasts in schist from just east of Sons of Gwalia mine have a well developed S-shaped internal foliation concordant with the strong external foliation, but strongly rotated. Other porphyroblasts with straight concordant inclusion trails are unrotated, and the external foliation is deflected symmetrically around the grains. These textures are good evidence of synchronous metamorphism and deformation. Tabular opaque porphyroblasts after chloritoid occupy the same textural position as andalusite. On the western flank of Mount Leonora, kyanite porphyroblasts overgrow the dominant foliation, and define a distinct mineral elongation lineation pitching moderately to the south on a moderately east-dipping foliation.

Quartz-mica schist and phyllite (Alqm)

Quartz-mica schist and phyllite form a linear belt of rocks striking north-northwest in the area east of Mount Malcolm (Glenorn Domain). The unit comprises crenulated micaceous schist with abundant quartz augen. Specimen 87963518 contains alternating sericite-rich and quartz-rich bands. Asymmetric polycrystalline quartz augen are present, indicating non-coaxial deformation on the primary cleavage. This cleavage is deformed into a weak crenulation visible in outcrop. Relict angular grains of monocrystalline quartz 2-4 mm across are present in the sericitic layers. The lamination, together with the absence of feldspar, suggests that the rocks may be metasiltstones.

Small outcrops of phyllite (too small to show on the map) are present in the felsic rocks east of the Sons of Gwalia mine (GR374998). The rocks comprise fine-grained quartzite layers with small aligned chlorite flakes, separated by discontinuous laminae of finely interleaved chlorite and biotite. Opaque oxide grains are abundant, and accessory zircon is present. The rocks are strongly foliated. Surface rocks are strongly weathered. The dominant foliation in the phyllite east of Sons of Gwalia is folded into a weak crenulation cleavage. Remnant lozenges of coarser-grained quartz are present, suggesting that the present fine grainsize is due to grainsize reduction during deformation and recrystallisation. The discontinuous nature of several laminae, apparent in thin section, suggests that isoclinal folds are present in the foliation (sample 87963452).

Mafic extrusive rocks

Basalt (Abb)

Basalt west of the Mount Stirling East Fault (Mount Stirling Domain) is typically an equigranular fine-grained bluish rock with rare amygdales. The contrast between the rock types Aby and Abb is particularly marked across the fault boundary between the Mount Stirling and Corktree Well Domains (eg., GR086362). At Mount Cutmore (Mount Stirling Domain, GR112332), the basalt is brecciated, with basalt fragments in a lighter-coloured matrix of epidote with minor quartz; quartz aggregates are present in places. The breccia formed as a result of breakage of chilled flow-top crusts, as brecciated crusts around pillow shapes have been observed in the Mount Cutmore area. The flow-top breccia units are located in linear zones 20-30 m apart on the ridge between Mount Cutmore and Mount Stirling. The formation of ubiquitous epidote-quartz fill between pillows indicates that this material is a metasomatic product resulting from the interaction of sea water with the extruding magma.

West of Mount Cutmore (Mount Stirling Domain, GR098330), excellent exposures of pillow lavas indicate that the Mount Cutmore basalt dips 40° towards 345° and youngs north-northwest. The pillow sequences are largely free of amygdales. Farther west, between Mount Cutmore and the main Meekatharra Road, units showing abundant flow-top brecciation are interbedded with pillowed basalts. Silicification of flow-top breccias is common on the ridge south of Mount Cutmore (eg., GR114315, GR105300), and in these areas there is a particularly strong pattern of layering trend lines visible on the aerial photographs.

The basalt is hornfelsed in a zone approximately 500 m wide around the Mount Stirling granite stock. The indurated basalt forms a ring of hills around the stock, which includes Mount Stirling and Mount Cutmore. There is also some associated alteration of the basalt resulting in the formation of epidote haloes around clear undeformed quartz grains.

Mafic schist (Abf)

Mafic schist is a common rock type in strongly deformed zones throughout LEONORA, generally adjacent to through-going north-northwest-striking faults. No primary igneous structures are preserved, and the rocks are characterised by metamorphic textures and mineral assemblages. The region immediately west of the chert horizons at Mount Davis is dominated by mafic schist. The rock type is also present 2.5 km east of Pig Well Bore (GR468157) and in the Mount Stirling Fault Zone. Numerous small areas of schistose basalt are present, but these do not form major bodies and are also clearly formed by deformation of the surrounding basalt. Mafic schist is also a common rock type in the main open cuts in the Leonora area. At Harbour Lights, chloritic schist is composed of lozenges of carbonate separated by alternating chlorite and quartz laminae (eg., Harbour Lights diamond drill core HL3, 173.5 m).

High-magnesium basalt (Abm)

Rocks assigned to this unit crop out west of the Mount Davis Domain within the Cork Tree Well Domain. They are in fault contact with basalt of the Mount Stirling Domain. The unit is characterised by rounded hills covered with float of pale green basalt, which has acicular amphibole needles up to 20 mm long. The float boulders are well rounded, and weather to a distinctive buff colour in marked contrast to the dark angular float characteristic of the other two basalt types. Igneous layering is common in outcrops of this unit, and pillow structures have also been observed at several localities (eg. Arboyne open pit; GR204268). Flow tops are characterised by a pale rim 10 to 15 mm thick above a zone of amygdaloidal basalt. The amygdales comprise an outer coating of clear silica around a filling of milky quartz. East of Mount Stirling (eg., Corktree Well Domain, GR140330) individual basalt flows can be identified by the position of pillowed flow tops. The flows range from 100-300 m thick, and vary in grainsize from gabbroic in patches to glassy at the flow margins. The bulk of the flow is medium-grained and equigranular; the rounded float is derived from this material. Southwest of Mount Davis there are numerous thin discontinuous chert horizons in the basalt sequence, usually less than 1 m wide. These are interpreted to be interflow chemical sediments. Pillow structures in the sequence suggest that the top of the sequence is to the northeast. Northwest of Mount Davis, the basalt is schistose in discrete shears which separate undeformed basalt cores (GR 240240). The cores show well-developed radiating acicular hornblende aggregates which appear to overgrow pale coloured (epidote-rich?) spherulitic patches which were probably ocelli. Similar ocelli are present sporadically throughout the basaltic rocks of the Corktree Well Domain. Quartz-prehnite veins have also been observed in basalt of the Mount Davis area.

Vesicular Basalt (Aby)

East of Balkan Well in the Mount Stirling Domain, a unit of vesicular basalt preserved between the two major branches of the Mount Stirling Fault shows prominent layering trends on airphotos. In outcrop, a pronounced planar fabric is defined by the alignment of amygdales and by a weak but marked lamination in the rocks, which is parallel to the airphoto trends. The laminated zones are restricted to the upper parts of cyclical units approximately 1.5 m thick (Fig. 5). Other outcrops in the same area show pillow structures, in which the vesicular layers are restricted to the pillow margins. The laminated units probably represent the deformed margins of larger pillows.

Mafic intrusive bodies

Dolerite (Aod)

Dolerite and metadolerite are common throughout the greenstone sequence. They appear to be conformable, but boundary relationships are rarely exposed. East of Balkan Well (Mount Stirling Domain), a basalt unit displays considerable grainsize variation resulting in exposures which

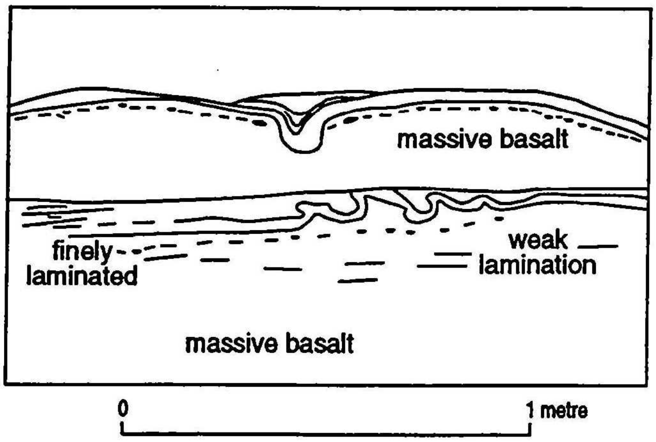


Figure 5. Deformed flow top in the Mount Stirling area.

could be classified as dolerite (GR085385). However, the coarser-grained parts are discontinuous at the map scale, and no discrete intervals of dolerite can be mapped out. Where exposure is adequate, the variation between basaltic and doleritic texture is gradational, and the doleritic parts are interpreted to be slowly cooled sections of thick basalt flows. There are also clearly intrusive dolerite and gabbro dykes ranging in width from 1 m up to about 30 m. Intrusion of a thick gabbro near Balkan Well has resulted in the formation of a zone of silicification of the host fine-grained basalt adjacent to the dyke margin (GR096380).

Dolerite dykes northwest of Mount Davis form a linear topographic high (GR240240). The western intrusion is coarse-grained dolerite to gabbro (grainsize up to 4 mm) which rapidly fines eastwards. At the eastern margin of the intrusion, a xenolith of fine-grained basalt has been observed. A suite of three dolerite intrusions has been mapped. They are most likely to be sills, as they are parallel to the strike of the surrounding acicular basalt (Abm), are weakly differentiated, and the thicker units are fine-grained to the east, implying a top to the east, in agreement with the way-up determined for the stratigraphy from pillows in the nearby basalt.

East of Malcolm Dam, a poorly exposed sequence of metadolerite and metagabbro is interlayered with discontinuous intervals of chert (GR520065). The chert layers are flanked by concordant slate bands, suggesting that the chert is the result of surface silicification of the slate. The presence of these thin bands of sedimentary rock within the dolerite suggests that the dolerite was emplaced as concordant sills into the least competent stratigraphic horizon. The mafic rocks vary from weakly metamorphosed pyroxene-bearing rocks to strongly foliated chloritic schist, in which the foliation wraps around lineated residual mafic cores. The cleavage contains a strong gently plunging stretching lineation, and is silicified in places. Elsewhere gabbroic rocks in this unit are brecciated and carbonated. The fresher rocks from (sample 87963519) contain twinned augite crystals, variably replaced with amphibole, in a saussuritised plagioclase matrix. Unaltered cores of pyroxene in amphibole crystals are pale pink and slightly pleochroic, and larger grains of hypersthene are common. Epidote, visible in hand specimen also, is an abundant secondary phase.

East of Braemore Station (Mount George Domain, GR387080), a number of dolerite and quartz dolerite intrusions into felsic volcanic rocks form prominent air photo patterns. The major intrusion, Braemore Dolerite, is folded concordantly with the Rifle Range Anticline in the surrounding strongly foliated volcanics. The dolerite is weakly deformed along its margins. The discontinuous form and irregular thickness of the body, and the presence of an undeformed dyke stockwork at a high angle to the strong cleavage, strongly suggest that these dolerites were intruded late in the formation of the shear fabric in the surrounding felsic volcanic rocks. The sigmoidal form of the intrusion is consistent with emplacement during dextral shearing. Epidote and chlorite are abundant around the margins of pale green hornblende grains (sample

87963412). Patches of quartz with thin carbonate veins are probably secondary, but there are also abundant quartz grains intergrown with plagioclase. Plagioclase in areas associated with the quartz is andesine, suggesting that the quartz dolerite in these post-depositional and late tectonic intrusions may have calc-alkaline affinities, and be unrelated to the stratigraphically concordant units (described in following section). The rock is lower in Ca, V, and Ni, and higher in K than basalt units in LEONORA with a similar SiO_2 value. Similar late discordant dolerite has been mapped to the east, in MINERIE (Williams et al. 1995).

Gabbro (Aog, Aogl)

Small areas underlain by gabbro have been identified at GR270210 south of Mount Davis, at GR100360 north of Mount Stirling, and at GR270320 east of White Well. The unit north of Mount Stirling is part of a differentiated intrusion, and is preserved in the fault-bounded wedge within the Mount Stirling Fault Zone. A cross-section of the rock units within the fault slice is shown in Figure 6. The lowest unit in the fault slice is a variably deformed dolerite (Aod, Abf)

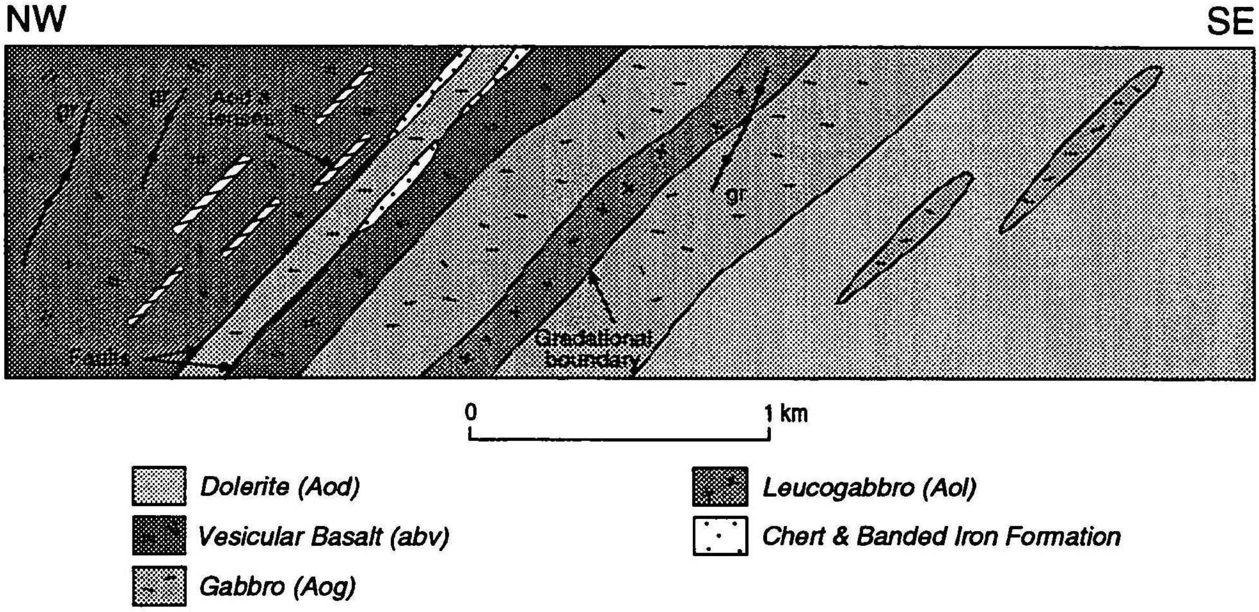


Figure 6. Cross-section through a differentiated sill, Mount Stirling.

which includes thin lenses of gabbro (Aog). These lenses probably represent more slowly cooled horizons in the dolerite sill, rather than a separate intrusion. The dolerite is overlain by a gabbro sequence approximately 1000 m thick. The lowermost gabbro is melanocratic, composed of amphibole with minor interstitial plagioclase. The plagioclase content increases progressively in the sill to a zone which contains a number of leucogabbro lenses, made up of amphibole laths in a feldspathic groundmass. It was not possible to map a distinct band of leucogabbro, but leucogabbro float is abundant. The zone of leucogabbro is about 300 m thick, and is overlain by coarse-grained gabbro (sample 88963087) in which plagioclase has been completely saussuritised to a felted mass of fine-grained chlorite with abundant grains of Fe-rich epidote and clear quartz. This assemblage is interstitial to amphibole grains, which in places pseudomorph pyroxene. Abundant microveins of calcite are present. The coarse gabbro is overlain by vescicular basalt (Aby) 300 m thick. North of these intrusive units, an isolated gabbro has a lower (southern) margin marked by a deformed cherty horizon with bedding-parallel cleavage. The northern margin is coincident with lenses of strongly foliated banded iron formation ranging from 0.4-4 m thick. Foliation in the BIF is parallel to the margin (dip 68° to 330°), but steeper than the inferred bedding direction (dip 50° to 320°). A number of intrafolial folds are present, plunging 35° towards 035° and a stretching lineation also plunging north-northeast has developed. The movement direction in these zones is parallel to that determined for the early layer-parallel movement event (see Structure section), which suggests that the northern gabbro layer may be allochthonous, possibly a thrust slice of the gabbro intrusion to the south.

The gabbro south of Mount Davis is pegmatitic in patches which are dominated by prehnite and minor quartz. The prehnite also occurs in late veins with prehnite fibres perpendicular to the vein walls. The gabbro body is in sharp contact with the surrounding basalt.

A linear outcrop of gabbro (sample 87963492) composed of clinopyroxene partly converted to amphibole, and plagioclase in a very fine-grained matrix of dominantly feldspar and minor quartz has been identified at GR 130423 adjacent to the chert horizon north of Victory Corner Well. The gabbro may represent a cumulate phase of the overlying basaltic flow, as it appears to be only a thin interval.

Felsic volcanic rocks

Felsic volcanics are abundant east of the Mount Davis Domain, but less common west of the domain.

Undivided felsic rocks, commonly schistose (Af)

These rocks crop out in three main areas: around Mount Malcolm in the southeast, in a north-trending belt east of Leonora (Malcolm Domain), and in small areas adjacent to the Mount George Lineament in the Mount Davis and Mount George Domains. The rocks are fine-grained platy strongly foliated quartz and quartz-sericite schist, and range from equigranular to inequigranular, where they contain quartz augen which probably represent remnant porphyroblasts. In the Mount Davis Domain (Fig. 2), the rocks of this unit are felsic schist with a well developed stretching lineation (plunging gently north). A thin unit trending southeast of Mount Georgecontains some less deformed horizons of well bedded felsic tuff (GR342110). At one location (GR371085, sample 87963532), a finely laminated bed is truncated by a thin crystal-rich unit with abundant randomly-oriented fractured feldspar crystals in a fine-grained siliceous matrix. The beds are probably part of an air-fall tuff deposit. The stratigraphic younging direction in this area, based on the truncated laminae, is to the west.

Porphyry (Afp)

Porphyry intrusions are common in several areas of LEONORA. A dyke swarm in ultramafic rocks north of Jasper Hill mine forms an *en echelon* suite of undeformed quartz and quartz-feldspar porphyries (GR266181, Sons of Gwalia Domain). Elsewhere in this domain, Nisbet (1984) described highly deformed quartz-feldspar porphyry with a strong stretching lineation and foliation defined by sericite plates and elongate aggregates of sericite and quartz. In some rocks the foliation is refracted through the phenocrysts. An area of undeformed porphyry in the northeast at GR530375 (Linger and Die Domain) is a subconcordant intrusion in dolerite.

South of the Bundarra Batholith (see below), large areas of subcrop and angular float mapped as Afp in the Linger and Die Domain are underlain by buff deeply weathered equigranular to quartz (± feldspar)-phyric undeformed fine-grained rocks. In the Bundarra Batholith area, these rocks appear to be interbedded with the felsic tuff described above; they may be high-level porphyry intrusions into the tuff sequence or they may be weathered crystal tuffs. The association of the sheet-like granodiorite intrusion with abundant high-level porphyries intercalated with tuff suggests that the area south of the Bundarra Batholith may be a discrete felsic volcanic centre.

Similar porphyritic rocks are present in the east (Mertondale Domain, around GR530190). The rocks are poorly exposed, feldspar-phyric, and weakly foliated. Two cleavage surfaces are commonly present, indicating that the rocks may be part of the stratigraphic succession and not later intrusives. The earlier surface is relatively gently dipping and concordant with the early cleavage in the adjacent Pig Well Domain. Sericite beards are well developed around angular opaque grains (formerly pyrite?) and quartzite grains (samples 87963570a, b). Large angular sericite-rich grains are probably altered feldspar; in sections cut parallel to the lineation these are irregularly shaped and elongated parallel to the sericite beards, defining the extension direction in this area. Opaque grains are abundant along fractures and grain boundaries, and are probably of secondary origin. The matrix of the rocks is very fine-grained. The porphyries may have originated as either subvolcanic intrusives or as extrusives, but appear to be part of the stratigraphic succession. They are probably correlative with the felsic rocks south of the Bundarra Batholith.

Felsic pyroclastic rocks (Aft)

These rocks form a discrete stratigraphic zone trending south-southeast from east of Ironstone Well (GR414100, Glenorn Domain). The unit forms a marked topographic high, and is readily mapped on airphotos. It is approximately 200 m thick, and is regarded as an informal stratigraphic unit with type locality from GR415093 to GR417096. Similar rocks have been identified at GR465125, 6 km northeast of the type locality. In the central part of the outcrop belt (where it crosses the Leonora-Nambi road), the dominant rock type is volcanic breccia, with angular felsic clasts up to 20 cm in length in a dark fine-grained matrix. The clasts are aligned parallel to bedding, which is well defined by changes in clast abundance and size. The breccia becomes finer-grained to both the northwest and southeast. In the northwest, the breccia is intercalated with fine-grained felsic tuff, clastic sedimentary rocks, and thin hematitic chert lenses, with the tuffaceous and sedimentary rocks becoming more abundant and the breccia unit becoming thinner. In the south, the unit is composed of laminated siltstone interbedded with thin tuffaceous intervals. The unit hosts the Mount Germatong mine (GR420070). Hematitic chert horizons are also abundant south of the Mount Germatong deposit at the top of this unit. The unit appears to represent a small felsic vent centred at the breccia deposits and flanked by finer-grained tuffaceous and sedimentary rocks. The hematitic chert may be a chemical deposit associated with the volcanic vent activity.

Felsic volcanic and volcaniclastic rocks (Afv)

The volcanic sequence east of Leonora (Rifle Range volcanics, Hallberg 1985) is composed dominantly of strongly foliated felsic rocks with an original fragmental nature. The preserved fragmentals and interbedded non-fragmental, strongly siliceous, commonly porphyroclastic felsic rocks have been grouped into this classification. Airphoto trends reflect well defined bedding observed in the unit, which also forms a topographically positive feature. Outcrop is good throughout the unit. The unit forms the core of the Rifle Range Anticline (Skwarnecki 1987), which is clearly visible on the air photographs.

The rocks are strongly deformed quartz-sericite schist (eg., sample 87963410) composed of abundant sericite grains aligned parallel to a banding defined by aligned flattened quartz augen and small untwinned albite crystals with abundant inclusions. Hematite is abundant. The cleavage surfaces wrap around both the quartz augen and the albite grains, indicating that the porphyroclasts probably represent recrystallised primary phenocrysts. Other more quartz-rich rocks with larger phenocrysts retain their original volcanic character (eg., samples 87963419, 87963429, 87963434). Large quartz phenocrysts have not been recrystallised, but strain lamellae have formed, and asymmetric pressure shadows have developed around the porphyroblasts. The fine-grained matrix has been completely recrystallised to quartz and sericite with thin hematite bands, and is well foliated with the foliation deflected around the larger phenocrysts. In sample 87963419, sericite is concentrated in thin laminae. In sample 87963429, plagioclase crystals are abundant, and some recrystallised quartz augen are present. Plagioclase crystals are commonly fractured, and phenocrysts are also commonly aggregated. Carbonate alteration is present, but restricted to specific clasts, indicating that these may have been a lithic component of the original tuff. The presence of both quartzite and quartz clasts suggests that the quartzite clasts may have been lithic fragments rather than recrystallised quartz phenocrysts. Equigranular components of the sequence are typified by sample 87963420. The rock is a fine-grained recrystallised quartz-phengite schist with well crystallised phengite flakes defining an S-C fabric. Thin laminae dominated by very fine-grained mica are discontinuous on the thin section scale, and have the appearance of randomly stacked platelets. These may be recrystallised pumice fragments aligned and flattened in the strong foliation. Thus, an interpretation of this unit as a sequence of pyroclastic flows and crystal tuffs is consistent with thin section and field evidence.

The rocks south of the Bundarra Batholith in the Linger and Die Domain are fine-grained quartz-phyric and equigranular felsic tuffs. The equigranular rocks are laminated in places. Outcrop is poor, but outcrops in creeks south of the granite comprise lithic lapilli tuff interbedded with siltstone and very coarse-grained sandstone. Agglomerate, with some granodiorite porphyry clasts and abundant quartz crystals, and thin (20-30 mm) chert horizons are also present in the sequence. Cross-bedding and graded bedding indicate the stratigraphic younging direction in the sequence is to the south, away from the granite margin.

Other felsic volcanic occurrences

Probable quartz-feldspar porphyry has been described from the Trump Mining District, and similar deformed porphyritic rocks are present near Horse Paddock Well (GR220210), composed of quartz, K-feldspar, and plagioclase phenocrysts in a fine-grained quartz-sericite matrix. The foliation is well developed, and in places asymmetric around the phenocrysts. Movement direction indicated by the asymmetry is top-side-south (Nisbet 1984). The exposures are too small to show on the map.

Metamorphosed sedimentary rocks

Chert (Ac)

Chert crops out at several localities in LEONORA as long thin ridges. The prominent range of hills in the Mount Davis Domain, extending from Mount Newman in the north (GR132456) to Mount George in the south (GR340107) is characterised by parallel ridges of chert interbedded with sedimentary and felsic volcanic rocks. The form of the outcrop and the lateral continuity of the chert horizons suggests that the chert represents original stratigraphic units. At Mount Newman the chert is microcrystalline, with laterally continuous laminae about 1 mm thick, and is greater than 100 m thick. Directly southwest of Mount Newman, four lenses of chert strike north-northeast. In this area, the hills are capped with laterite surrounding residual chert outcrops. The chert dips 50° north in outcrops up to 2 km west of Mount Newman, but closer to Mount Newman the bedding rotates to a more northerly orientation, dips become steep to vertical, and the chert units become increasingly brecciated. Parallel zones with strongly developed fracturing strike 150°, and numerous quartz veins with the same orientation have been noted in these zones. Bedding has been rotated into parallelism with the fracture zones, but is undisturbed to gently folded outside the zones. The brittle deformation of the chert with abundant quartz veining indicates that the chert pre-dates deformation and cannot be of more recent origin (Williams et al. 1989). The breccia zones are interpreted as zones of brittle faulting. In the Mount Newman area, the chert is interbedded with slate and schist, which are of sedimentary origin. On the western side of Mount Newman, folded chert beds can be traced into the north-northwest-striking fault zones. The folds in the chert become tighter and the fracture cleavage more pronounced close to the fault zones. There is considerable transposition of the bedding into the fault zones. On the eastern side of the fault, mafic schist (Abf) and laminated metasedimentary rocks (Ash) are preserved, and graded bedding in the metasedimentary rocks indicates that the sequence is younging to the west. This is consistent with synclinal folding of east-striking chert bands into to a north-northwesterly trend.

A unit of chert southwest of the sedimentary sequence (Ash) near Victory Corner Well (Victory Domain, GR145415) is highly brecciated, and contains isolated isoclinal folds in a well-defined layering. The chert is cut by brittle faults which have been infilled by recrystallised silica. The unit has the same north-northeasterly orientation as the chert lenses west of Mount Newman, and appears to have been rotated into this orientation by sinistral shear on the Mount George Lineament.

Between Mount Newman and Sullivans Creek (GR190378), chert and interbedded slate crop out as elongate discontinuous lenses in a matrix of felsic schist (Asfv). At the southern part of this zone the chert is well exposed, and is cut by abundant fracture surfaces separating open to tightly folded chert beds. The chert contains a weak stretching lineation and also a lineation defined by the intersection of bedding with quartz veinlets. There is abundant evidence for the primary nature of chert in this area. Figure 7 is a photomicrograph of chert from this area, and shows a number of siliceous clasts with well defined but disoriented cleavage surfaces. These clasts are separated by a continuous matrix of metamorphic quartz grains, and both the clasts and matrix are cut by late post-tectonic quartz veins. Clearly, the brecciation and silicification of the main chert bands are syntectonic and therefore the chert is of Archaean age. The late metamorphic quartz veins are themselves disrupted by irregular zones of dark grey microbreccia or cataclasite which may have been molten (pseudotachylite?, Fig. 8), although conflicting timing relationships between the two suggests that vein formation and microfaulting may have been contemporaneous.

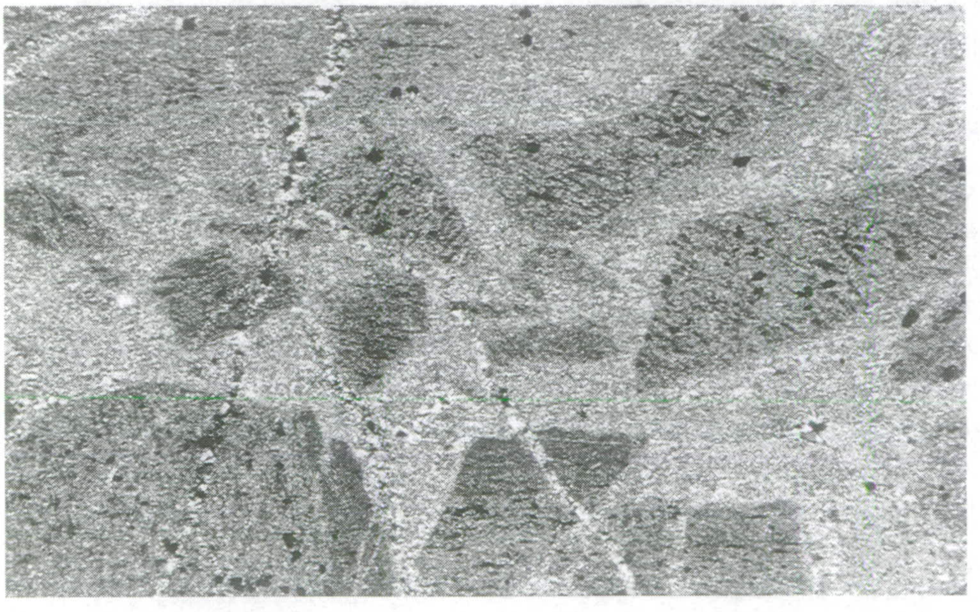


Figure 7. Two stages of quartz veining in the Mount George chert horizon. Foliated ?shale disrupted by a wide fine-grained vein, which are both cut by later metamorphic quartz veins. The shale was brecciated during the early phase to produce the disoriented foliated fragments, cut by the later metamorphic veins. Structures demonstrate the complex deformation history recorded in the chert horizons.

South of Mount Davis, the two main chert horizons pass westwards into a chert breccia with clasts of grey silicified siltstone and jaspilite up to 80 mm long in a finely brecciated siliceous matrix (GR295200). The breccia passes laterally into a brecciated region containing several disoriented coherent blocks 3-4 m long. In the chert horizon, bedding surfaces are studded with pyrite pseudomorphs and spherical framboidal cavities lined with silica. Bedding is marked by fine differently coloured laminae 0.5-1 mm thick. Rocks between the two chert horizons also include chert breccia. The breccia includes fragments of the finely laminated chert characteristic of the main ridges, indicating that the laminated chert is a primary sedimentary unit and that the chert breccias are probably locally-derived fault breccias. The breccia also contains metasandstone blocks.

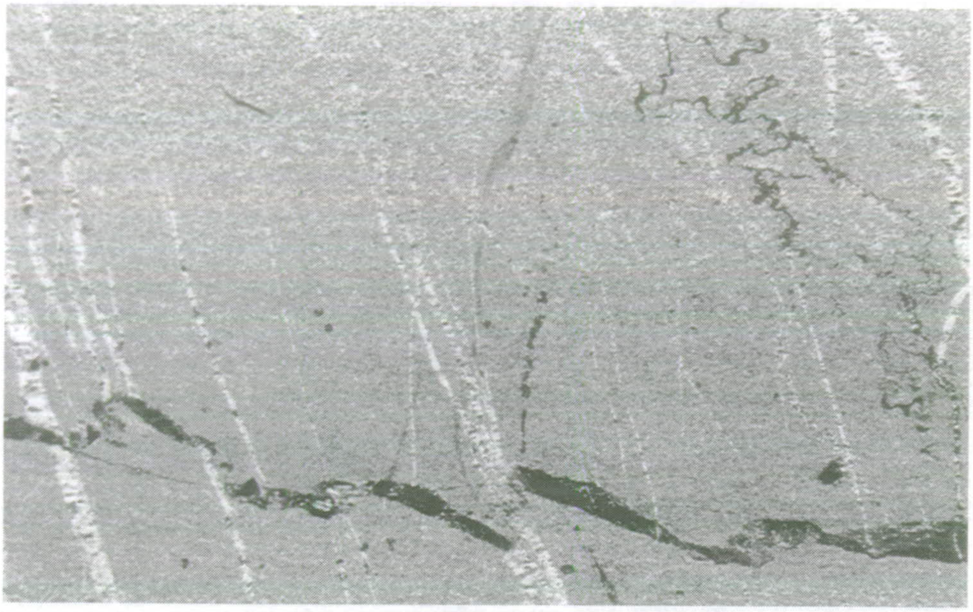


Figure 8. Cataclastic veins, possibly pseudotachylite, disrupting chert beds at Mount Newman, and cut by late metamorphic quartz veins which infill along faults.

Between Station Creek (GR325121) and Mount George (GR340107), the two chert horizons are interbedded with strongly deformed slate and metabasalt, and can be traced continuously in low outcrops. A large fold in the unit has been mapped north of Mount George, where the chert contains spectacular folded lineations and rotated planar structures. South of Mount George the sequence becomes strongly attenuated and swings to a north-south trend. The chert horizons become much more strongly deformed, with tight folding (Fig. 9a) and abundant rootless isoclinal folds (Fig. 9b), and are also much more strongly recrystallised. Layering is defined by variations in the grainsize of the quartzite (Fig. 10a). The metamorphic granoblastic texture of the coarser layers is apparent, providing further evidence that the chert and quartzite lenses are of primary sedimentary origin. Chert forms boudins within silicified slate horizons, and the rotation of boudins in the chert ridges indicates that there has been sinistral movement in the horizons (Fig. 10b). Quartz-axis orientation in this part of the formation is well defined, with largely symmetrical cross-girdle patterns with strong maxima (Fig. 11). Slight differences between fabric patterns for the finer-grained matrix (Fig. 11A) and the coarser-grained layers (Fig. 11B) may indicate changing deformation flow patterns during deformation.

Chert mapped to the east of the Mount George Lineament is similar to the rocks mapped in the lineament. They occur in the Mount Malcolm area (GR488028), where they define a regional antiformal closure, and also adjacent to the Pig Well Domain. The presence of chert at GR410060, at the margin of the sedimentary rocks near Pride of Leonora, and at GR470084 northwest of Sunset Well suggests that these two sedimentary units may correlate across the regional synform in that area.

West of the Mount George Lineament, three main horizons of chert or quartzite have been mapped. The most southerly of the horizons extends around the margin of the Raeside Batholith, and defines a marker horizon in the largely mafic and ultramafic sequence on that margin. The unit has been described by Williams et al. (1989) as a quartzite composed of metamorphic quartz grains with stylolitic grain boundaries tending towards triple junctions (Fig. 12D, E). Layering is defined by thin hematite bands parallel to the main foliation. The unit forms the Auckland Hills.

Figure 9. Folded chert horizons, Mount George. A. Close folds, possibly related to F_1.

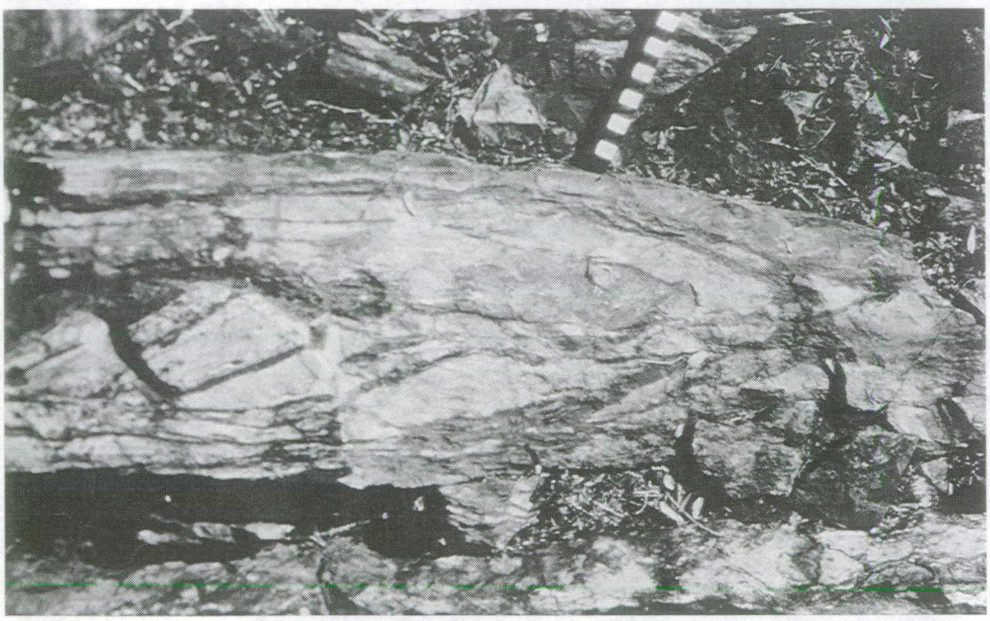


Figure 9B. Remnant ?F_1 isoclinal fold.

Identical quartzite units crop out at GR200219 near Tarmoola Station, and in the Mount Ross area. The quartzite is deformed by isoclinal folding with axial surfaces parallel to the layering, and these folds are rotated around a regional upright north-plunging antiform in the Auckland Hills area. The quartzite is characterised by a strong linear fabric developed on the bedding surfaces, caused by alignment of quartz grains and aggregates. Thin sections cut perpendicular to the foliation and parallel to this lineation show a strong quartz optic-axis alignment indicating recrystallisation in a non-coaxial stress environment (Fig. 12A and B).

In the northwest, a thin band of chert extends for 8 km along strike, and marks the boundary between a vesicular basalt unit (Aby) and a more homogeneous basalt unit (Abb). The unit dips about 45° north and is parallel to layering in the surrounding basalts and interflow sediments. The horizon varies in thickness from a few metres up to about 50 m, and contains abundant isoclinal folds with axial surfaces parallel to the layering. The quartz optic-axis fabric of this horizon (sample no 88963028, Fig. 12C) also shows an asymmetric cross girdle structure, which

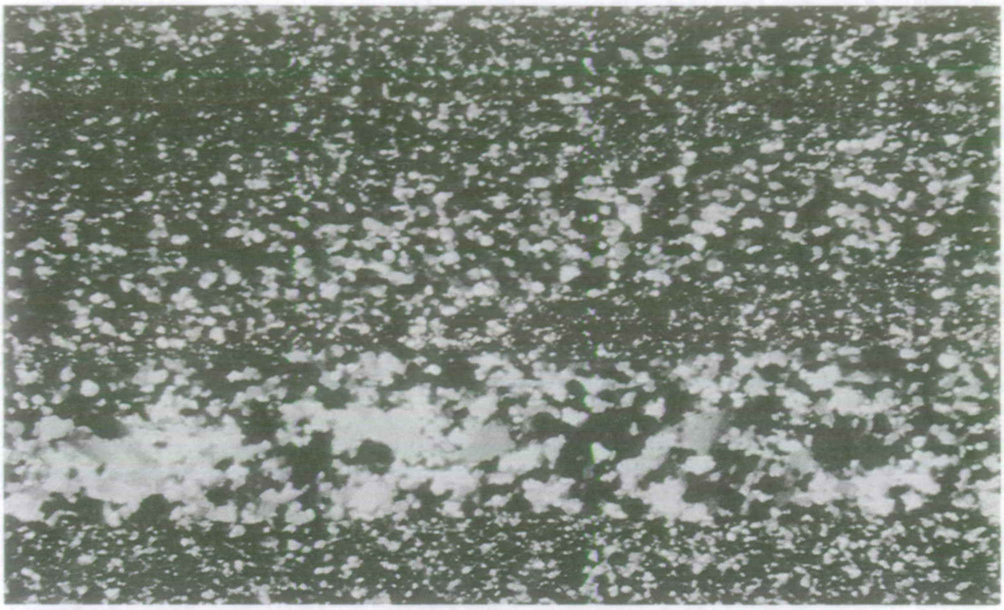


Figure 10A. Photomicrograph of metamorphic banding in chert, Leonora reservoir.

Figure 10B. Deformed brecciated chert lens, with block rotation indicating sinistral shear. Leonora town water reservoir.

indicates recrystallisation of the quartzite in a non-coaxial shear environment under greenschist facies conditions. The chert is finely laminated in places, and diapiric structures, probably caused by dewatering, are present. At its eastern extremity, this unit is truncated by faults parallel to the Mount George Lineament.

A similar interval of shale and chert has been mapped close to the northern margin of LEONORA in the Victory Domain (GR087452). The chert occurs on the margin of a dolerite sill (Aod), and has a mylonitic foliation. Stacked lozenges of quartzite are preserved in a strongly foliated shaly hematitic matrix. The foliation is parallel to bedding, and is overgrown by randomly oriented very fine-grained phengite crystals (Fig. 13A). A north-plunging stretching lineation is well developed. The rock is interpreted to be a metamorphosed hematitic chert with interbedded thin-bedded iron formation. Between these two units are discontinuous undeformed chalcedonic lenses. In these rocks (eg., sample 88963011), metamorphic quartz layers are present

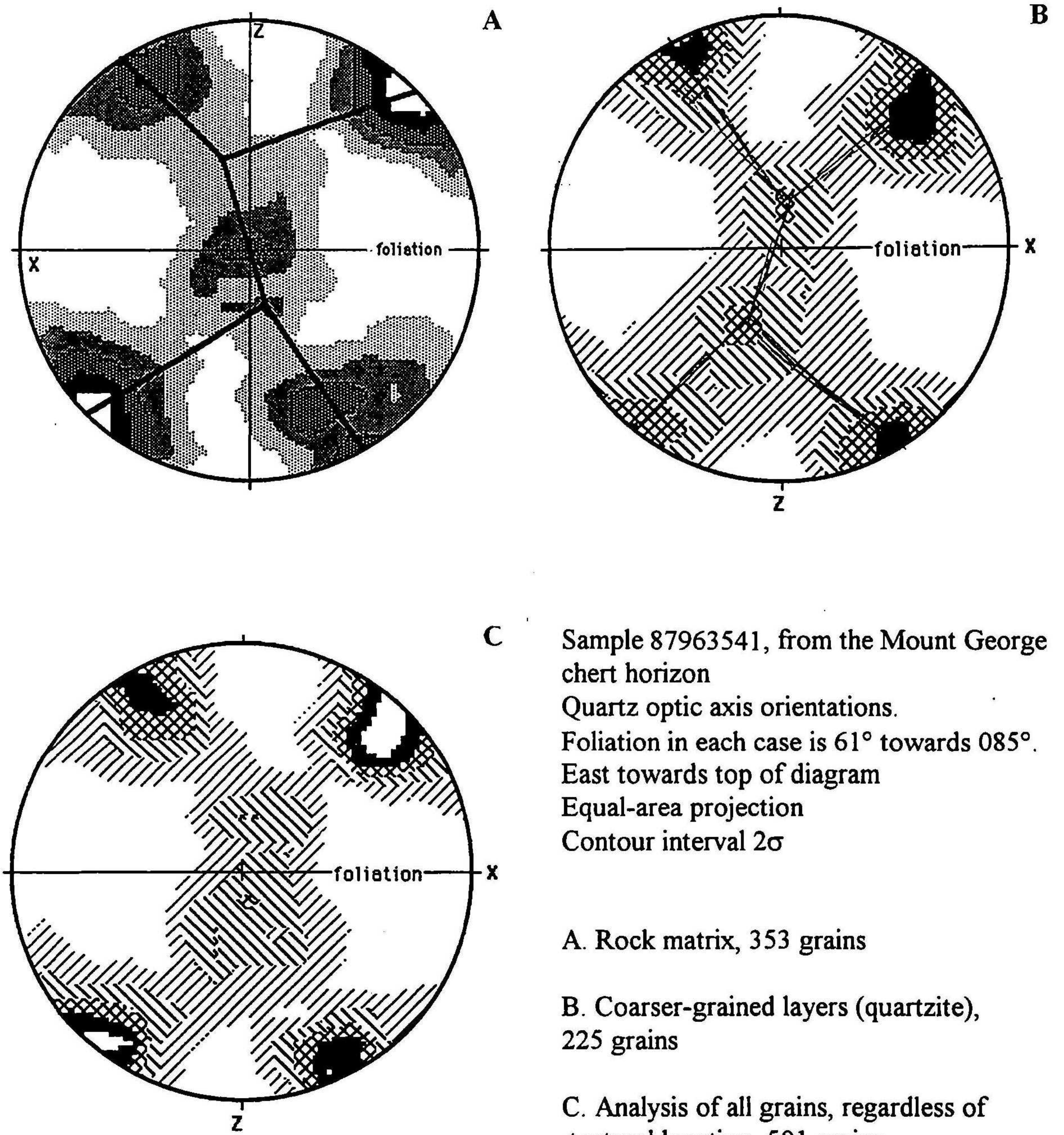
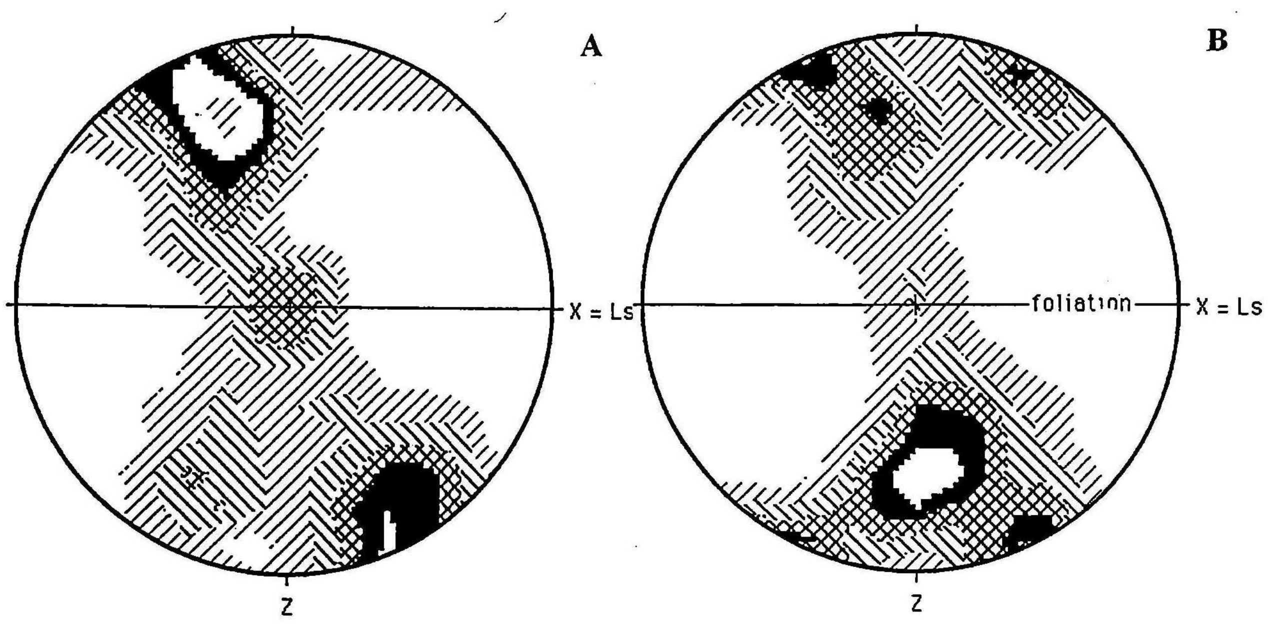
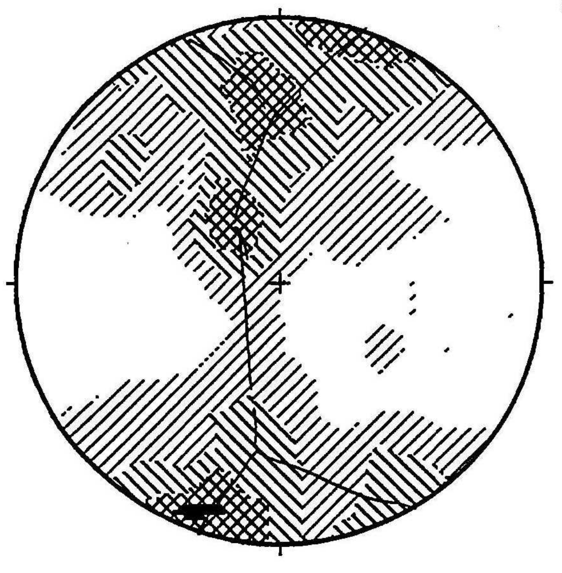


Figure 11. Quartz optic-axis fabrics, Mount George chert horizon, Leonora reservoir.

in a granular felted chloritic matrix which has a remnant cumulate texture (Fig. 13B). The metamorphic quartz layers are overprinted by large spherulites of chalcedonic silica. These textures are probably the result of multiple phases of serpentinisation of ultramafic rocks, initially during low-grade metamorphism and later at low temperature to form the spherulitic texture.

In most instances, deformation has been concentrated in the chert and shale zones, as all show marked dynamic recrystallisation and mylonitic structures. The surrounding rocks, particularly the basalt sequences in the north, show very little deformation parallel to layering. This observation is used to imply that the earliest bedding-parallel deformation has been strongly





C Quartz optic axis fabrics of quartzite in western domains.

Equal area projection.
Contour interval 2 sigma

A: Auckland Hills quartzite horizon 262 grains.
Foliation 60 towards 010,
stretching lineation (X=Ls) plunges to 010.

B: Auckland Hills quartzite horizon, 251 grains.
Foliation 60 towards 010,
stretching lineation (X=Ls) plunges to 038.

C: Victory Domain, sample 88963028,
325 grains. Foliation 70 towards 010,
stretching lineation (horizontal on diagram)
down-dip.

Figure 12. Metamorphic quartz optic-axis fabrics, Auckland Hills quartzite horizon. A and B. Repeated analyses from the same horizon, confirming the fabric pattern. C. Similar pattern from a chert horizon in the north of LEONORA.

partitioned into shear zones which are now characterised by linear chert and chert/hematite-rich zones.

Banded Iron Formation (Aci)

Banded iron formation (BIF) crops out as thin stratigraphic units in the Sons of Gwalia Domain. BIF is particularly abundant in the Auckland Hills area (GR260166) adjacent to the Auckland Pluton (eg., GR245155). East of the Mount George chert, BIF is present in the Mount Malcolm Domain, where BIF beds define a megascopic fold, and on the western margin of the Pig Well Domain. In the Sons of Gwalia Domain, BIF extends from the Gwalia North area (GR347078) north-northwestwards towards Trevors Bore (GR281170), where two BIF units have been

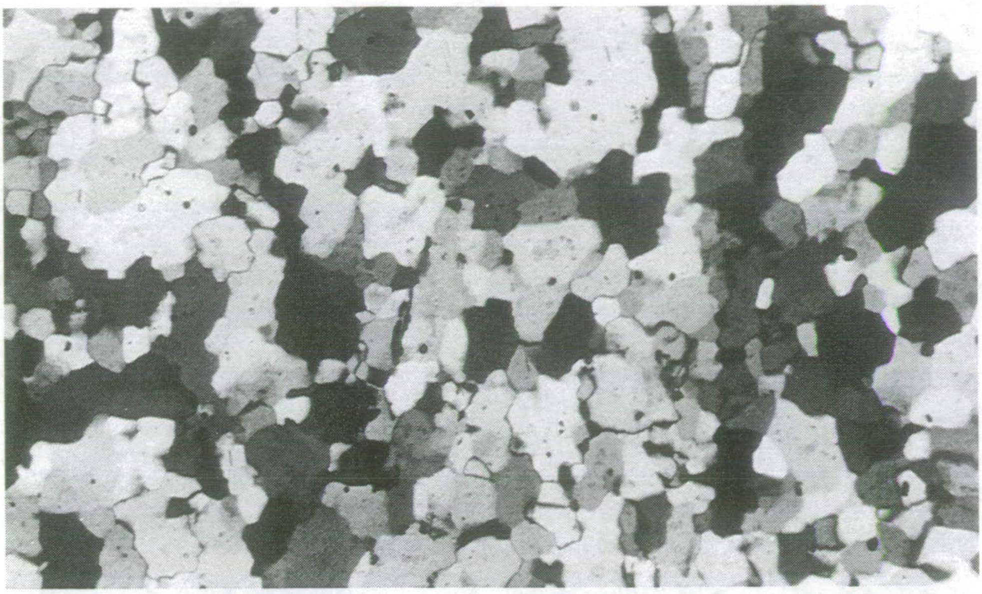


Figure 12 continued. Metamorphic quartzite textures, Auckland Hills quartzite. Grainsize ca 0.1 mm, photomicrographs in polarised light with crossed nicols. D. Stylolitic grain boundaries with incipient triple junctions.

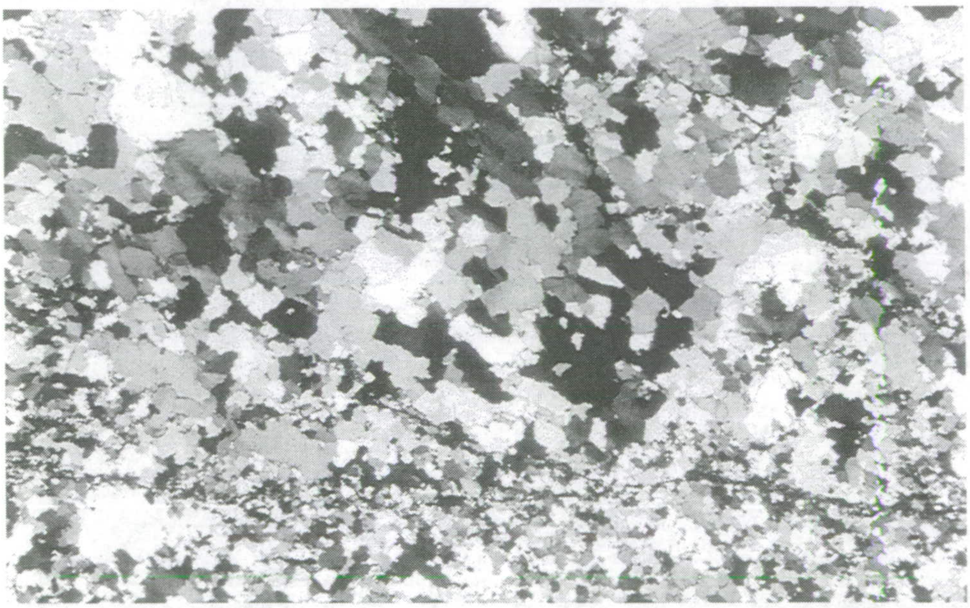


Figure 12 continued. E. Triple junctions, and grain-size reduction and recrystallisation along a post-metamorphic shear zone (bottom of photograph).

identified west of the bore (Nisbet 1984). In rocks surrounding the BIF there is a strong foliation parallel to bedding in the BIF, and numerous isoclinal folds in the BIF have axial surfaces parallel to foliation. A strong stretching lineation is oriented down-dip. Numerous lenses of BIF with short strike length are surrounded by amphibole schist at GR245155. They strike at about 150° and have a well developed stretching lineation plunging 10° south. In the west,a 1-2 m-thick BIF can be mapped around the northern margin of the Hick Well Pluton at Mount Ross, and can probably be correlated with the BIF in the Auckland Hills and Riverina areas. The unit is intensely deformed into isoclinal folds and asymmetric parasitic folds. The vergence of adjacent parasitic folds is commonly opposite, and sheath folds are present (Fig. 14), suggesting fold development during non-coaxial deformation. The BIF overlies a discontinuous metamorphosed interflow sediment horizon, which is also folded into a series of tight to isoclinal folds with axial surfaces parallel to the bedding direction (cf. Fig. 15A). The BIF in the Sons of Gwalia Domain is composed of a medium to fine-grained hematite-magnetite-actinolite-quartz assemblage.

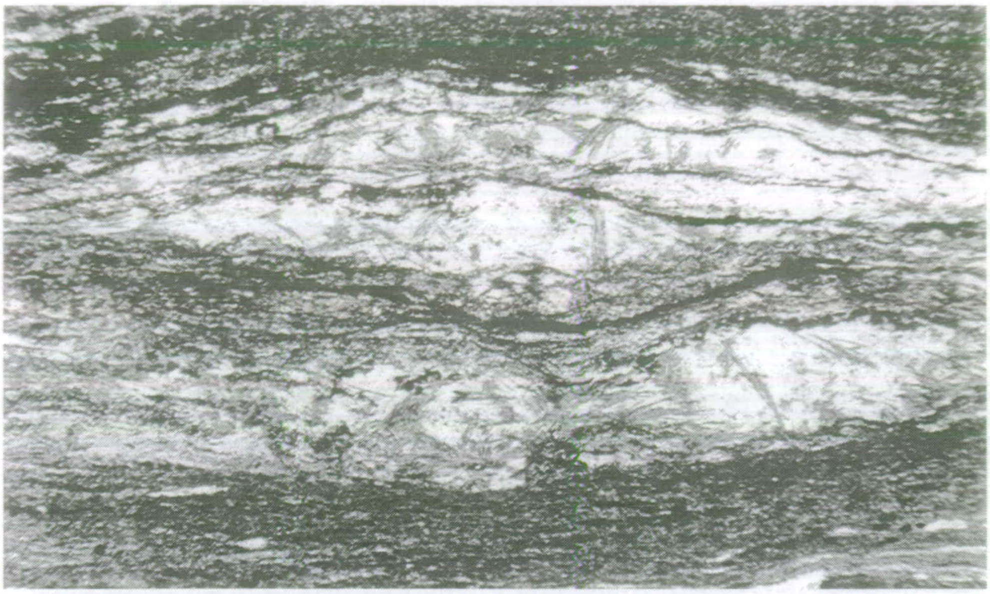


Figure 13. Textures from other silicified zones. A. Quartzite lens in shale, mylonitic foliation overgrown by phengite crystals, sample 88963033.

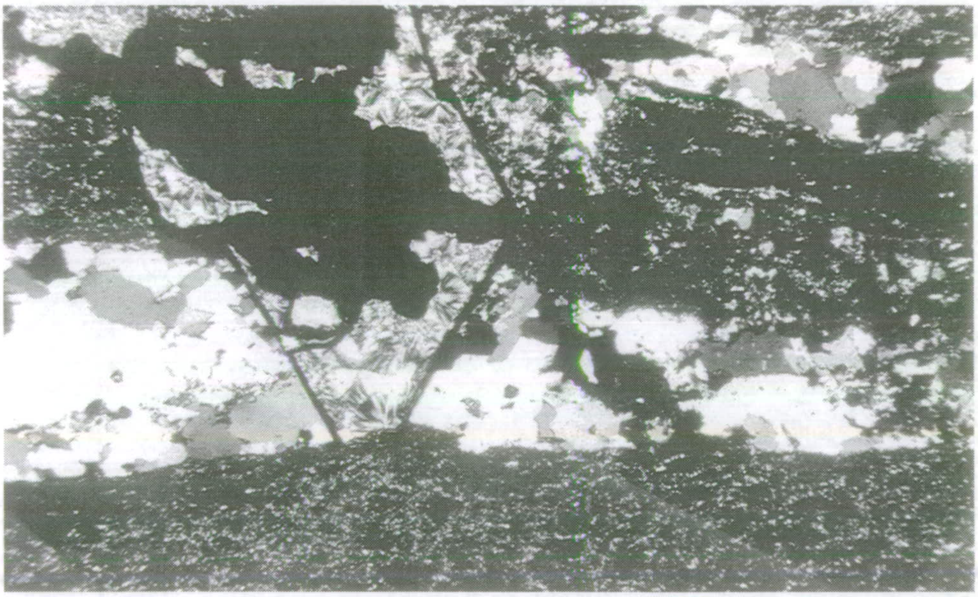


Figure 13 continued. B. Chalcedonic structures in chert formed within ultramafic rocks, sample 88963011.

East of the Mount Davis Domain, BIF units are generally intimately associated with chert and quartzite. The units are strongly deformed and commonly boudinaged (Fig. 15B). The boudins are made of chert, indicating that the chert was more competent than the hematite-rich laminae at the time of deformation. In the Mount Malcolm Domain, the BIF defines megascopic isoclinal folds (GR506020, 485027).

Polymict conglomerate (Asc)

Thick units of polymict conglomerate are preserved in the Pig Well Domain, and form the major component of the sequence there. Conglomerate is also exposed in the southern part of the Linger and Die Domain, where the conglomerate is strongly deformed and composed largely of porphyry clasts in a sandy matrix. The porphyry clasts are cleaved concordantly with the conglomerate matrix. The dominant cleavage is gently dipping in this area.

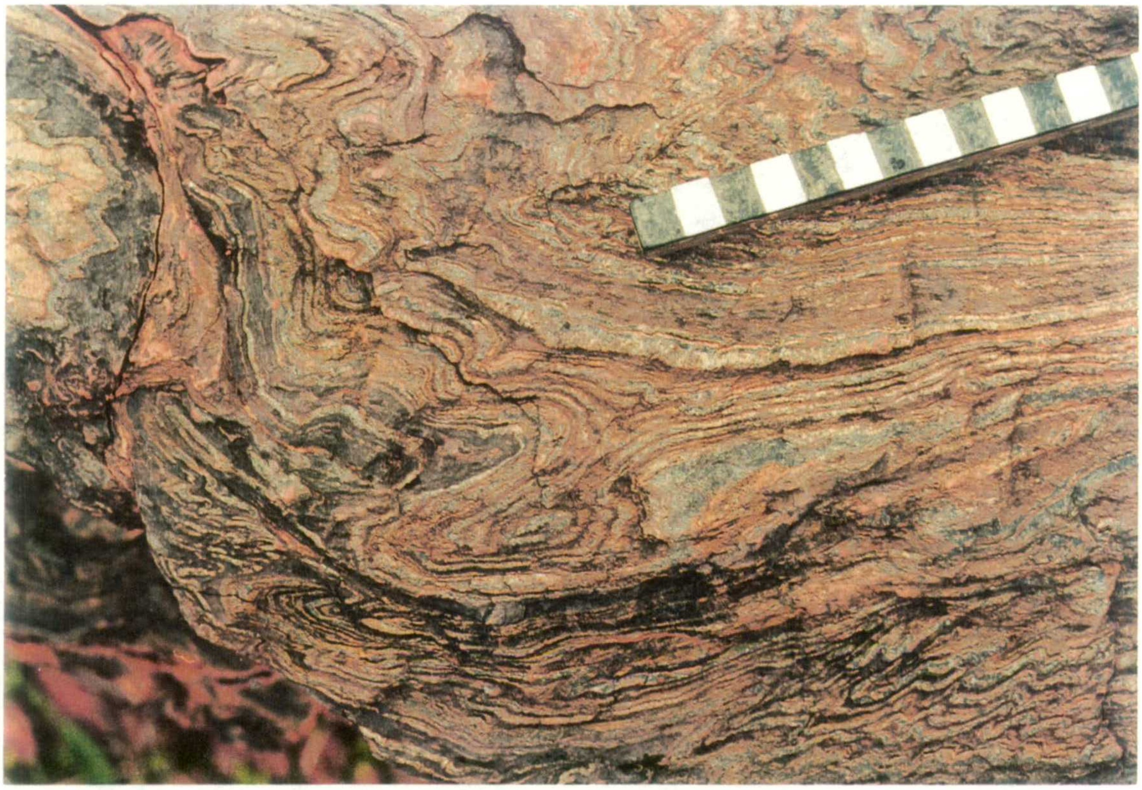


Figure 14. Sheath fold developed in BIF at Mount Ross.

Figure 15A. Deformed sedimentary rocks beneath BIF in the Mount Ross area.

The most extensive outcrop area for the unit is between Gambier Lass (GR500192) and Harriston (GR519136) Mining Centres in the east. At Harriston, sandstone with a gently dipping cleavage is cut by a silicified breccia zone composed of pale yellow to brown silcrete with equidimensional angular quartz fragments. The conglomerate is interbedded with sandstone and siltstone, which form the dominant component of the clastic sequence in the Domain. The

Figure 15B. Boudins in chert and fractured chert, Mount Malcolm Domain.

conglomerate is composed mainly of felsic clasts, including felsic volcanic rocks. At GR519166, the felsic volcanic clasts are up to 30 cm long. On the western side of the trough, the conglomerate contains mainly ellipsoidal granitoid boulders up to 1 m long. Some of the clasts are foliated, but there is only a poor alignment of clasts in any except plan section. This indicates that the clasts define a strong linear fabric plunging gently to 350°. This fabric gives surface scrapes an apparent vertical cleavage which is not evident in sections perpendicular to the lineation. It is not clear whether this fabric is of tectonic or sedimentary origin. Rocks close to the edges of the domain are more strongly deformed than elsewhere. On the western margin, strongly deformed conglomerate with granitoid clasts up to 70 mm diameter has a steeply dipping cleavage deflecting around the granitoid clasts. Lineation defined by clast elongation is approximately horizontal.

Oligomict conglomerate (Ascb)

Two small areas of conglomerate composed of well rounded cobbles and boulders of basalt up to 0.3 m in diameter in a dark chloritic matrix have been identified close to the Mount Davis Domain (GR330130 and GR320140). These outcrops may be part of a 'conglomerate marker horizon' identified here by Hallberg (1985). Continuity of the unit was not confirmed during the current survey.

Undivided sedimentary and felsic volcanic rocks (Asfv)

The chert units between Mount George and Mount Newman (GR129456) form a relatively small percentage of a package of slate, quartz-sericite phyllonite, chlorite schist, and felsic volcanic rocks which have been mapped as Asfv. Outcrop is generally very poor, most commonly occurring adjacent to the chert or chalcedony zones. Slate adjacent to chert is commonly strongly silicified.

Southwest of Mount Newman, felsic rocks are strongly pitted, because of weathering of feldspar laths from a fine-grained silicic matrix. The rock was probably a rhyolite. At thislocality, deeply weathered fine-grained clastic rock and interbedded pencil slate crop out adjacent to the volcanic rocks. Exposures on the hills are composed of breccia/conglomerate with angular to rounded clasts of vein quartz, hematitic siltstone, felsic volcanics, basalt, and chert, in a vein quartz matrix. The rock is interpreted as a locally derived fault breccia.

The sequence within the Mount Davis Domain, surrounding the Mount George Lineament, probably ranks as an informal formation, and is composed dominantly of slate, pyritic shale, and siltstone with two major horizons of chert formed as rhythmically layered chemical sediments. Felsic volcanic rocks are sudsidiary, and laterally discontinuous. The formation extends over at least 65 km and is about 800 m thick, but is structurally thinned south of Mount George.

Shale, slate and interflow sediment (Ash)

Rocks belonging to this unit are generally areally insignificant, and form linear marker horizons and small outcrop areas. In the north, east of Victory Corner Well (GR160420, Victory Domain) a sequence of interbedded medium to coarse-grained sandstone, slate, and subsidiary chert dips about 30° north. Cleavage within the unit dips more gently north (20°), indicating that the sequence here is inverted. Sandstone beds are 10-50 mm thick, and the siltstone in laminated units up to 80 mm thick. Most chert is undeformed and in thin discontinuous lenses within the siltstone; it may be the result of surface silicification. The unit is fault-bounded to the west. At the western edge of the outcrop area, an unusual hematitic breccia is composed of chert fragments in a red siliceous matrix with abundant small clear well-rounded quartz grains. Some fragments of mudstone and felsic volcanics (70 mm long) are also present. The reddish matrix forms continuous lenses, and very similar material occurs as clasts. Yellow angular fragments are strongly aligned, and bedding is defined by the reddish chert laminae. The lenses of reddish chert are deformed around angular green chert clasts, which are fractured at right angles to the bedding lamination. Beds dip 35° north. The origin of this rock is not known, but the presence of felsic volcanic detritus, clear rounded quartz grains in the matrix, and the poor distinction between chert clasts and matrix suggests an origin as a slumped mass of partially consolidated chemical sediment in a region of felsic volcanic activity.

In the Mount Malcolm Domain, east-northeast-striking slate crops out between ridges of BIF south of the railway line for a strike length of about 5 km (GR510986). The zone is about 10 m thick, and is doubly folded (Williams et al. 1989). The earlier folds are isoclinal, with axial surfaces parallel to bedding. The later folds are upright, with a weak axial planar cleavage. The slate contains abundant framboidal pyrite spheres which are mantled by asymmetric quartz fibres in pressure shadows to the north (Fig. 16). The orientation of the fibres with respect to cleavage indicates their development in a non-coaxial stress field produced by northwards movement of the upper plate. Surface outcrop of the slate in this area is quite hard, which suggests that near-surface silicification of the unit has taken place.

Interflow sediments are present in basalt units (Aby) in the northwest (Corktree Well Domain, GR115427). The sediments are typically fine to medium-grained sandstone, and rarely show sedimentary structures. At the above locality, graded bedding and ripple marks in units 20-50 mm thick indicate that the basalts young northwards. Deformed and metamorphosed sedimentary rocks are also present beneath BIF in the Mount Ross area (Sons of Gwalia Domain, Fig. 15A), and in the Mount Malcolm Domain a number of discontinuous cherty horizons apparently within basalt and dolerite units are likely to be silicified pyritic shale deposited between extrusive events (Fig. 15B).

Quartz-rich siltstone and slate (Ass)

Quartz-rich sediment and slate have been identified in the east, in the Malcolm and Pig Well Domains. Bedding in the slate is a fine lithological banding, and bedding surfaces are commonly

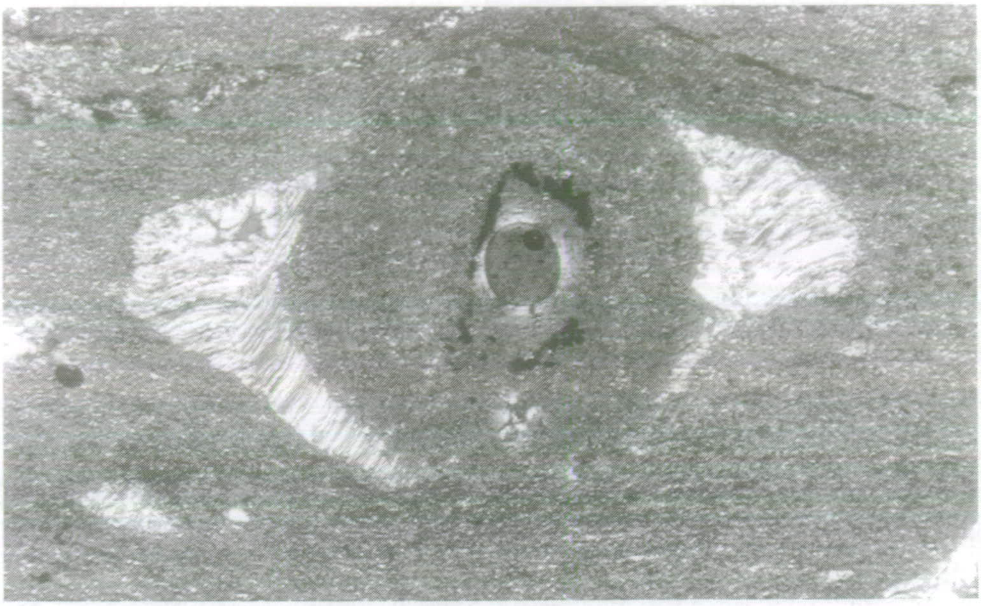


Figure 16. Quartz fibre fringes around pyrite framboids (Ash).

micaceous. The cleavage is at a high angle to the bedding, and produces a crenulation lineation on the micaceous bedding surfaces, indicating that the dominant cleavage may be a second (or later) surface. A strong cleavage subparallel to bedding is present in places. The sedimentary rocks host a large number of quartz veins, which have been extensively prospected. A gently dipping cleavage is visible in the siltstone, commonly dipping more gently than bedding. These rocks are inferred by Hallberg (1985) to have been deposited in a graben, which he named the Pig Well Graben.

In drill core from south of Leonora (GWDD4, GR390987), the sedimentary rocks consist of fine-grained thinly laminated meta-siltstone to very fine-grained sandstone which pass transitionally into banded chert very similar to surface outcrop of chert in the Mount George Lineament. Black shale, commonly pyritic, in units about 1 m thick, is interbedded with the chert. Original sedimentary features (scours, flutes, grading) are common, and distinctive colour banding in shades of black, white, beige, and green forms marker horizons. The upper part of the section lacks volcanic rocks, but below 166 m, felsic tuffs, cyclic air-fall feldspathic crystal tuffs, and probable ignimbrites are interbedded with the sedimentary rocks. Distinctive brown porphyritic felsic sills or dykes, which petrographically resemble the surrounding felsic volcanic rocks, parallel the cleavage, but are not deformed. This relationship suggests that felsic magmatism accompanied and outlasted deformation in the region.

Granitoids

Two major granite bodies are exposed in LEONORA. In the southwest, a deformed composite body of gneiss, coarse-grained granite, and numerous minor intrusions of aplite, pegmatite, and sparse mafic dykes, makes up the Raeside Batholith. This batholith has concordant margins with the adjacent supracrustal rocks. In the northeast, a large area of granite comprising at least two intrusions is markedly discordant with surrounding greenstones, and is termed the Bundarra Batholith. Other small granite intrusions include: two bodies in the Mount Ross area (GR063215, 090255); granite and associated dykes in the Mount Stirling area (GR114338); some small bodies near Victory Well (GR132415); and an area of syenite dykes east of Pig Well Bore (GR475138).

Granodiorite (Agg)

An intrusion of granodiorite was identified by Hallberg (1985) south of Linger and Die Well (GR360305) in the Linger and Die Domain. The intrusion is a wedge-shaped body adjacent to the

Bundarra Batholith, and intrudes felsic volcanics, subvolcanic porphyry, and tuff in a semi-concordant form. The granodiorite is medium-grained, equigranular, contains both hornblende and biotite, and is strongly cleaved. It may be a subvolcanic equivalent of the surrounding tuff. The granodiorite plots in the granodiorite fields in Figure 17A and B.

Monzogranite (Agm)

Bundarra Batholith

Granitoids in the northeast are very poorly exposed, and are assigned to the Penzance Pluton of the Bundarra Batholith. A continuous arcuate breakaway marks the edge of a silcrete-capped plateau covered with granite-derived Cainozoic detritus (Czg). The only outcrops of granitoid were located west and south of the breakaway. Most outcrops are deeply weathered. Exposure on the western margin of the Batholith consists of pinkcoarse-grained equigranular to slightly quartz-phyric biotite monzogranite intruded by fine to medium-grained biotite granite dykes up to 4 m wide. Exposures on the margin of the granite show a strong foliation which is parallel to cleavage in the surrounding felsic volcanic rocks. The intensity of deformation decreases rapidly away from the margin, and within 100 m is defined by a weak alignment of quartz grains. Exposures distant from the margin are strongly jointed.

Aeromagnetic data over the Bundarra Batholith indicate two rock types. The western part of the batholith (to which the description above refers) has a moderate magnetic susceptibility with dominant north-northeasterly-striking linear fractures with slightly higher susceptibility. In the east, a region with much higher susceptibility and angular boundaries with the surrounding rocks is apparent (Fig. 2). The boundary of this intrusion is parallel to the northeasterly fracture pattern evident in thewestern part of the intrusion, suggesting that the western rocks are the older and were fractured during emplacement of the eastern body. No samples of the eastern body were collected during the present survey. The western body was sampled by D.C. Champion (AGSO) in 1992.

Robbies Well Pluton

The Robbies Well Pluton is a porphyritic biotite (± hornblende) monzogranite cut by numerous aplite, pegmatite, and microgranite veins exposed on the northwestern margin of the apophysis of amphibolite at Mount Ross (eg GR090240). Analyses of the monzogranite and comagmatic dykes confirm that the Robbies Well Pluton has a different composition from the nearby Hick Well Pluton, plotting as a granite in the normative plot (Fig. 17A) and as a trondhjemite close to the granodiorite-trondhjemite boundary in Figure 17B. The Robbies Well Pluton is only weakly deformed away from the boundary with the amphibolite at Mount Ross. In the boundary zone, anastomosing sinistral shear zones are present, but the overall pattern of the pluton margin, consisting of a number of stepped segments cross-cutting the mylonitic foliation in the adjacent amphibolite, indicates the intrusive nature of the pluton (Fig. 18). Comagmatic microgranite dykes (analyses 21 and 22) are slightly folded and post-tectonic (Fig. 18), further supporting the view that the granite is a late-tectonic intrusive post-dating the Raeside Batholith.

Structure of the Robbies Well Pluton

In the granite at the boundary zone between the Robbies Well Pluton and the amphibolite at Mount Ross, a well developed foliation is defined by aligned biotite. However, there is only a weak foliation in the K-feldspar megacrysts. The biotite foliation can be traced into microgranite veins which are oriented at a high angle to the foliation. The veins are only slightly folded (Fig. 18), indicating that there was only limited flattening deformation of the pluton after vein emplacement.

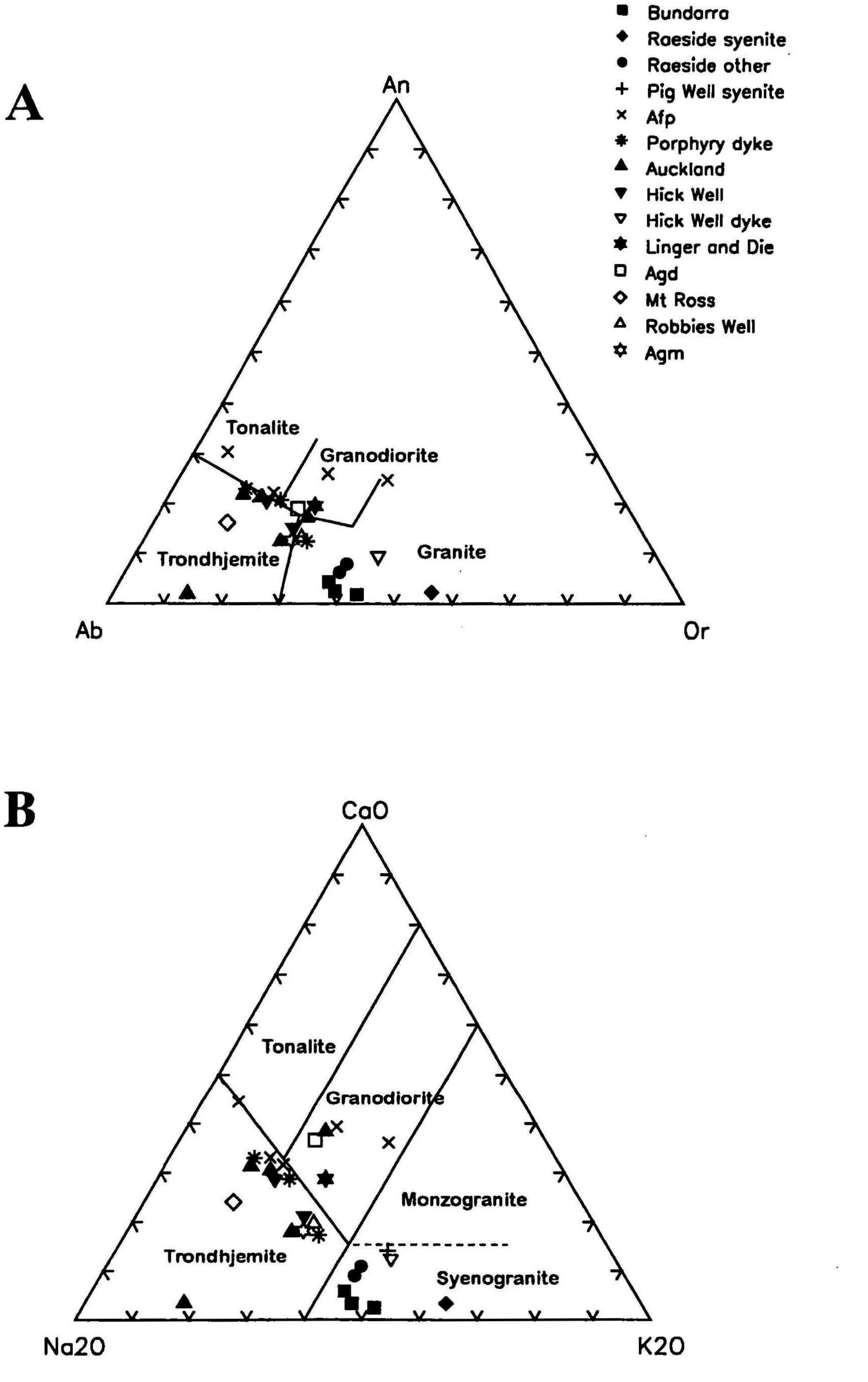
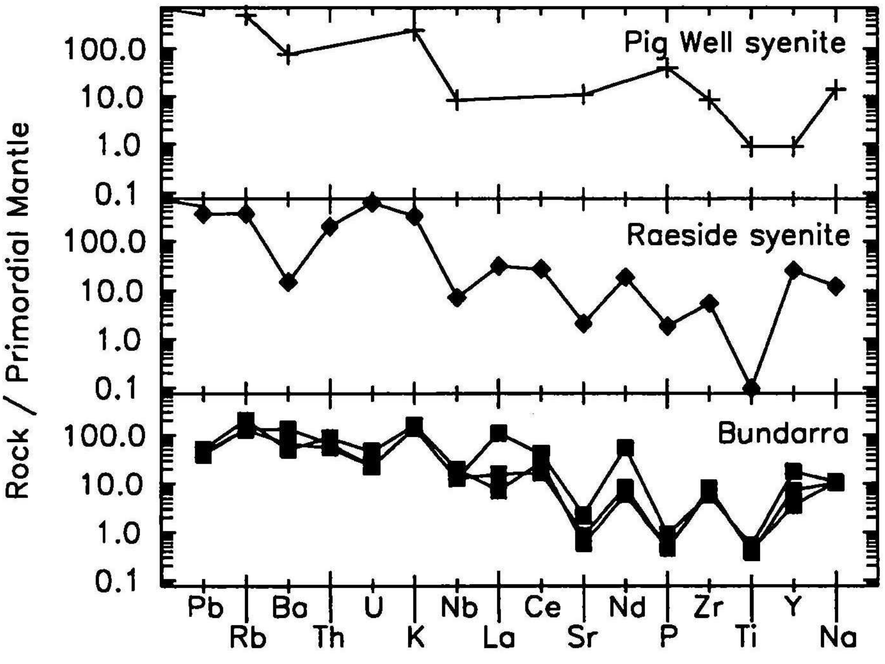


Figure 17. Petrological diagrams for granitoids, LEONORA. A. Normative Ab-An-Or diagram, and B. Na_2O-CaO-K_2O diagram. Note the sodic character of most of the intrusive rocks.

C



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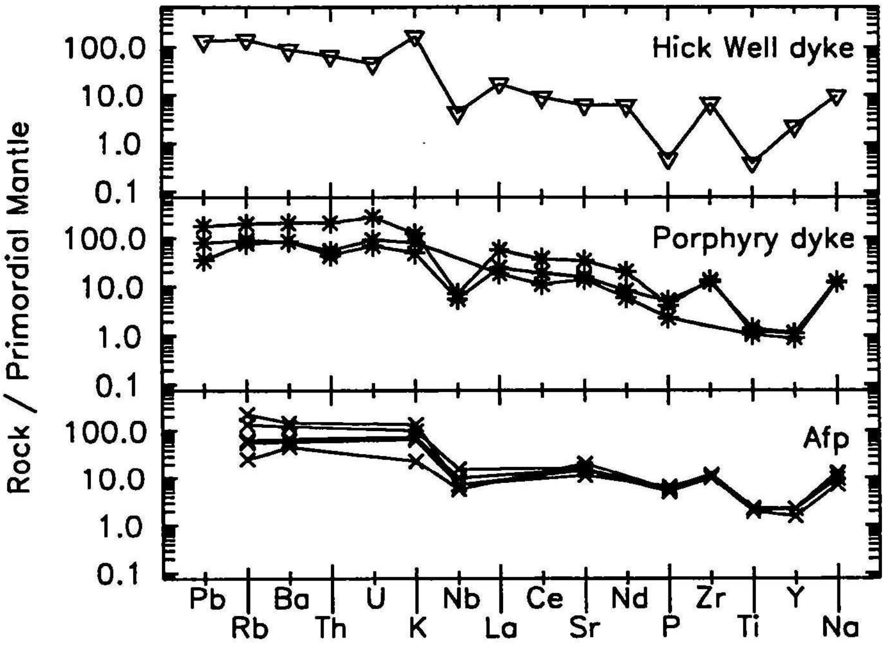
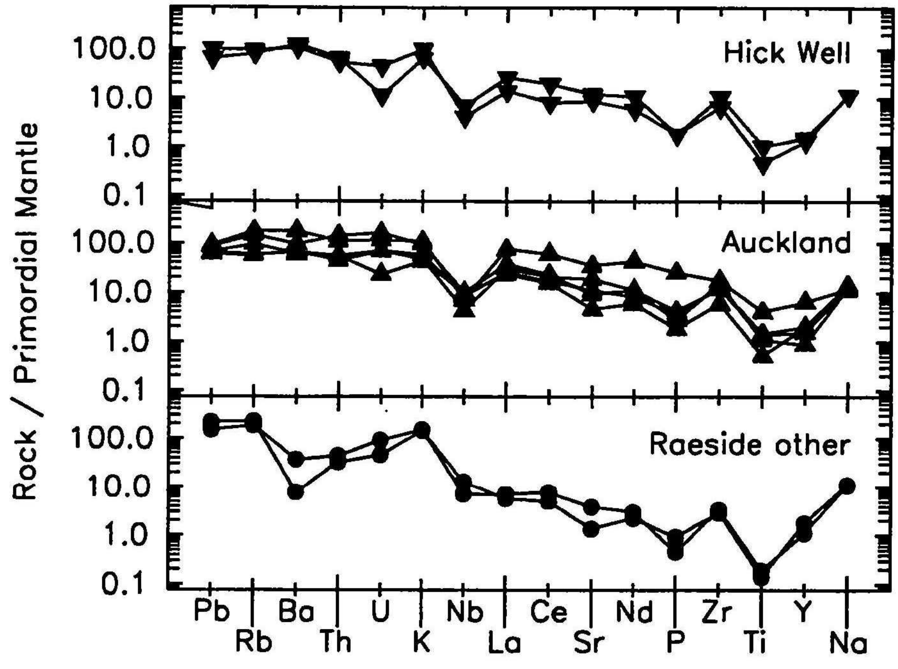


Figure 17 continued. C. Primordial mantle-normalised abundances of minor and trace elements, syenite near Pig Well, syenite in Raeside Batholith, granitoids in Bundarra batholith. D. Granitoid dyke in Hick Well Pluton, porphyry dykes in Robbies Well Pluton and Abb basalt, Afp porphyry in Gambier Lass area.

E



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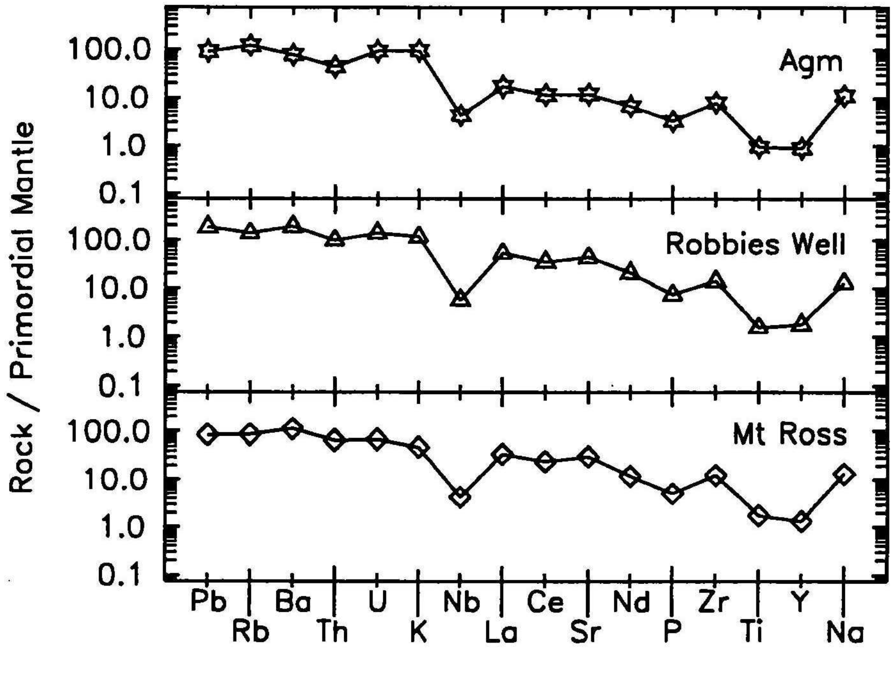


Figure 17. Primordial mantle-normalised abundances of minor and trace elements continued. E. Granitoids in Hick Well Pluton, granitoids in Auckland Pluton, other granitoid samples of Raeside Batholith from near White City Well. F. Agm granitoid at Mount Stirling, granitoid from Robbies Well Pluton, granitoid from Hick Well Pluton near Mount Ross.

Two sets of shear zones are present in the granite. An earlier set striking 020°-040° is marked by narrow mylonite bands. The mylonite zones have sharp margins with the surrounding granite, and form narrow anastomosing zones 10-60 mm wide. Within the zones, quartz has been recrystallised to form 1-2 mm-thick mylonitic laminae. The foliation within the zones has an elongate sigmoidal pattern (Fig. 19a) and is consistently oriented clockwise to the shear zone margin, indicating formation by sinistral shear. The S-fabric within the mylonite bands is concordant with the external biotite foliation, and is probably related to the same deformation event. The second set of shears strikes southeast (130°) and consistently offsets the north-northeast shears with sinistral displacement. Vein quartz is present along some of these shears, and the structures formed during a much more brittle deformation event.

The earlier shear zones cause apparent dextral offset of the microgranite veins (Fig. 19b). The microgranite veins range in thickness from 20-30 mm up to 150 mm. They narrow gradually along strike, and strike at approximately 90° to the shear zones (strike 125°). They have sharp boundaries with the shear zones. Interpretation of these structural features was provided by Passchier (1994). Despite the apparent dextral offset on the horizontal outcrop surface, the internal fabric in the shear zones between dextrally offset segments (Fig. 19b) is clearly sinistral (Fig. 19a).

Minor monzogranite intrusions

A small plug of medium-grained equigranular biotite granite about 20 m in diameter is exposed at GR090384 east of Balkan Well). A large number of quartz porphyry, feldspar porphyry and aplite dykes are also present in this region, suggesting a relationship between the small granite plug and the minor intrusives.

Porphyritic monzogranite (Agmp)

Mount Ross Stock

An intrusion of coarse-grained equigranular to feldspar-phyric granite is located within the wedge of amphibolite west of Mount Ross (GR063215). The amoeboid pattern of the body is due to the large number of porphyry dykes which form offshoots from the main body. The main body is undeformed, and undeformed leucogranite veins oblique to the main foliation have been mapped by Passchier (1992). Porphyry dykes with no foliation but with schist xenoliths have also been observed. There is widespread static recrystallisation of hornblende in the region surrounding the intrusion (Fig. 20), probably due to the thermal effects of the main granite body. These observations indicate that the monzogranite stock post-dates the main foliation, and is therefore the latest granitoid intrusion in the Mount Ross area.

Strongly foliated monzogranite (Agn)

Raeside Batholith

The Raeside Batholith (Raeside Granitoid Complex of Witt 1994) is poorly exposed away from the margins with the main greenstone belts. Magnetic images of the Batholith (Fig. 2) depict its main components in LEONORA as two north-trending elliptical plutons, both with a low even magnetic signature. A belt of rocks with higher more irregular susceptibility separates the two domal bodies, and represents a later intrusive phase in the batholith. The pluton boundaries are defined from the magnetic image (Fig. 2). The plutons are defined here as the Hick Well Pluton (western body) and the Auckland Pluton (eastern body).

Auckland Pluton

South of Auckland Hills, rocks of the Auckland Pluton are medium-grained equigranular to slightly feldspar-phyric fairly dark biotite granodiorite with some pegmatitic patches (eg., sample 87963482). The rock is composed of quartz, plagioclase as zoned phenocrysts with diffuse albite twinning and altered cores, and also as groundmass oligoclase, sericitised K-feldspar (coarser

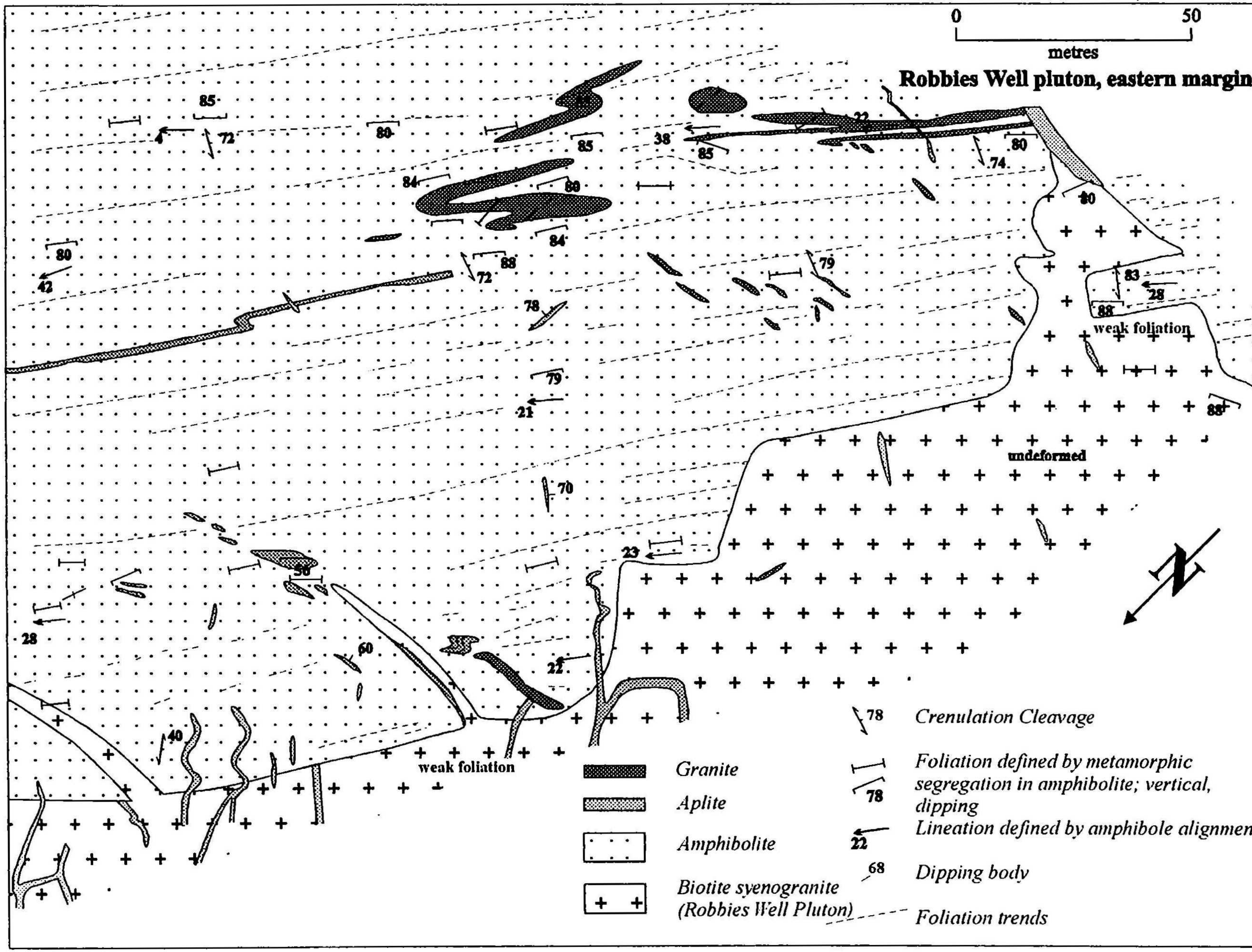


Figure 18. Intrusive nature of the Robbies Well Pluton, indicated by transgressive boundaries. Isolated folded granite inclusions in the amphibolite are probably dismembered syntectonic granite dykes. The composition is similar to the Hick Well pluton (Fig. 17F).

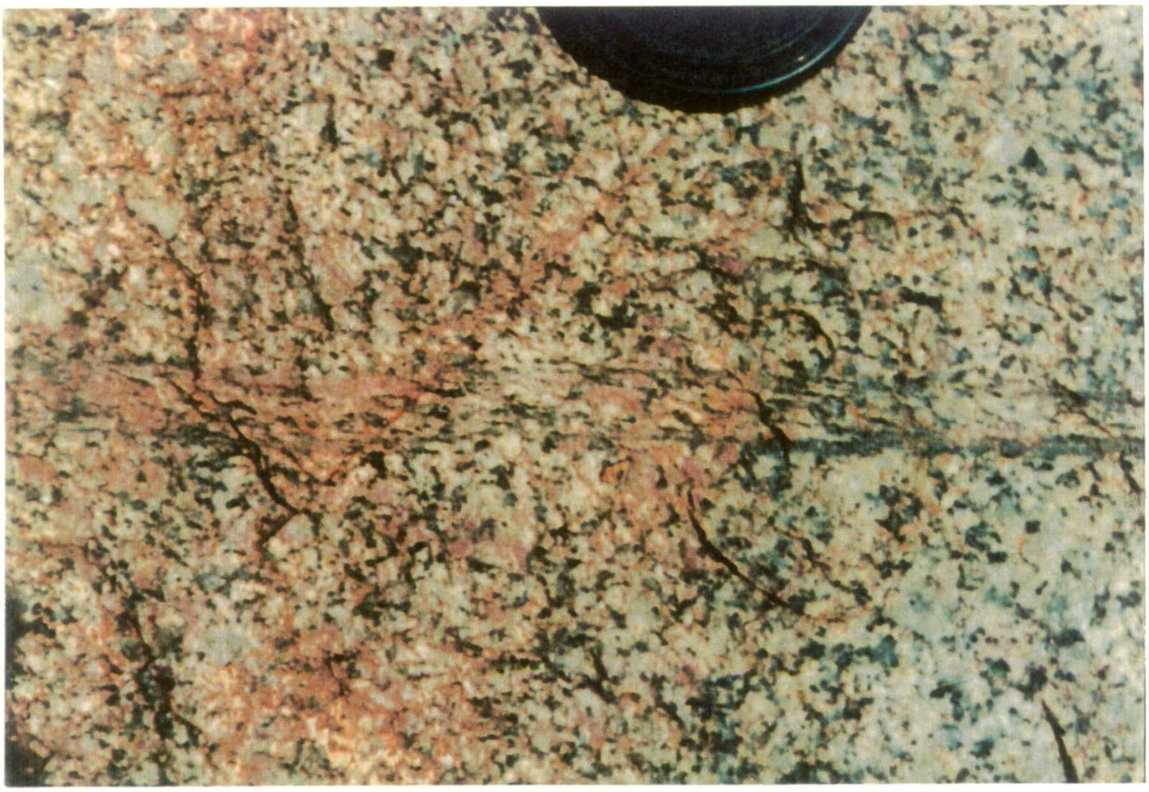


Figure 19A. Sigmoidal internal fabric to shear zone, indicating sinistral shear sense, Robbies Well Pluton.

Figure 19B. Apparent dextral offset of vein along the same shear shown in Figure 19A. See text for explanation.

than groundmass plagioclase), biotite (7%) altered to and intergrown with chlorite associated with accessory epidote, muscovite (with the K-feldspar), and accessory clear zircon and apatite. In this region, the pluton displays two foliations. The earlier is an alignment of biotite-rich laminae parallel to discrete quartz-rich veins or laminae, and contains a mineral elongation

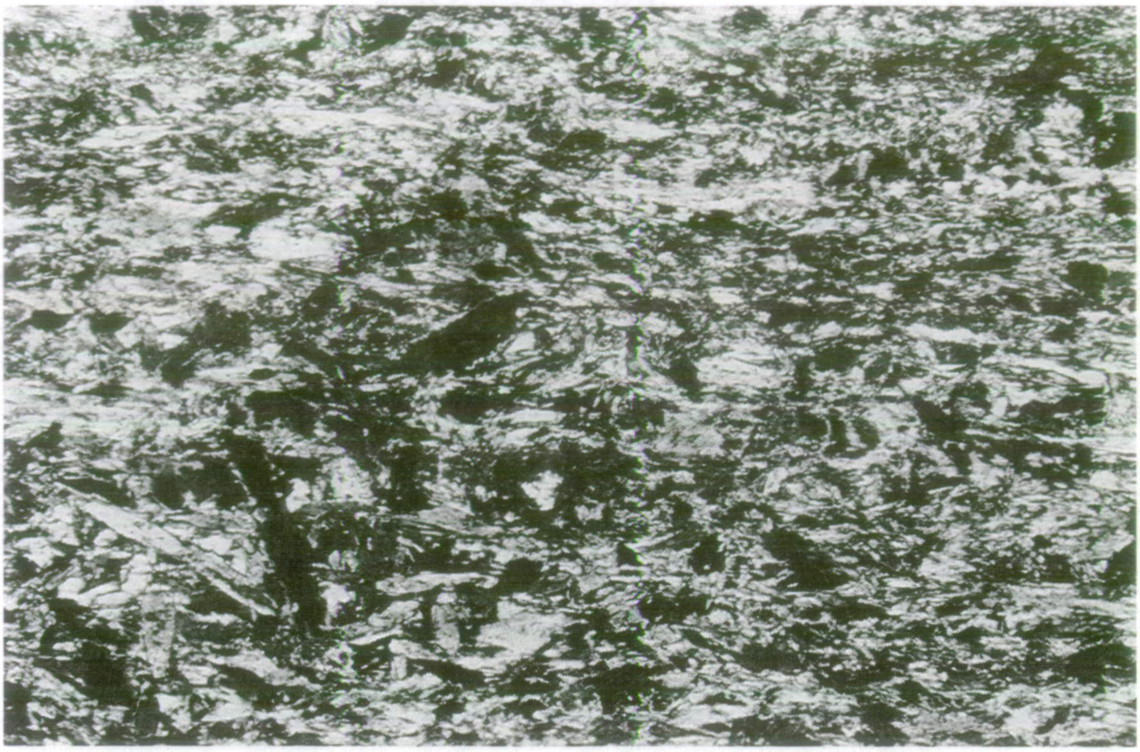


Figure 20. Random amphibole laths overgrowing the main fabric in amphibolite, Mount Ross.

lineation plunging 50° to the north-northeast. The later foliation is a spaced stylolitic cataclastic fabric. The fabric in the quartz veins is a recrystallised, well defined triple-

junction granoblastic texture, markedly coarser-grained than the stylolitic fabric of the granite matrix. Several exposures of the pluton occur in the region between Trump and Tower Hill mines on the eastern margin of the pluton. At Trump mine, the main body of granodiorite is strongly deformed and similar in appearance to the rocks in the Auckland area. There are a number of finer-grained units at Trump mine with a strong fabric and a subvolcanic texture (Fig. 21). It is probable that several of the exposures of felsic rocks in the Trump area are deformed porphyry dykes. At Tower Hill mine, the margin of the Auckland Pluton is exposed in the main open cut, where it consists of a very leucocratic saccharoidal medium to fine-grained sodic granite. The texture, lack of a mafic component, and siliceous nature suggest that there has been intense hydrothermal alteration on the margin, not observed in other areas.

Hick Well Pluton

Boundary exposures of the Hick Well Pluton south of Mount Ross (GR072210) are much more strongly deformed than those of the Auckland Pluton. The rock has a fine-grained recrystallised matrix of quartz, biotite, epidote, and accessory titanite wrapped around porphyroclasts of albite and minor K-feldspar. The composition of the porphyroclasts suggests that the rock was originally a granodiorite (sample 87963440). Quartz fibres are present in laminae adjacent to the porphyroclasts. Away from these inhomogeneities, matrix quartz forms fine-grained aggregates with granoblastic texture. The quartz crystallographic axes are strongly aligned in an asymmetric girdle (Fig. 22A), indicating formation at a high metamorphic grade in a non-coaxial stress field (Williams & Currie 1993). Sample 88963180A, also from the Mount Ross margin, contains abundant large porphyroclasts of K-feldspar and minor matrix microcline grains, suggesting the original rock was a monzogranite.

Between the western margin of LEONORA and Hick Well (GR152181), strongly deformed banded granitic gneiss is cut by thin leucogranite veins 10-20 mm wide. The gneiss contains concordant bands of foliated amphibolite composed of hornblende and plagioclase with

Figure 21. Subvolcanic textures in foliated granite in the Trump mining district.

subsidiary quartz. The banding is defined by leucocratic layers greater than 100 mm wide in coarse-grained foliated granodiorite. The banding is cut by felsic porphyry dykes and by pegmatite. Feldspar porphyry dykes which have a strong mylonitic foliation at an angle to the main foliation are also present. In sample 88963283 the foliation is defined by the alignment of biotite flakes and some differentiation into biotite-rich laminae. The quartz has been recrystallised to a granoblastic texture. K- feldspar grains form remnant porphyroclasts, and plagioclase is present both in the matrix and as porphyroclasts. Epidote is abundant as subhedral and euhedral grains, usually associated with the biotite-rich laminae. It appears to be a retrograde metamorphic mineral.

A stretching lineation defined by porphyroclast elongation and quartz fibres is present throughout this region, but the lineation is weaker than that developed close to the pluton boundary. The dominant gneissic foliation is also folded into open upright folds with a northerly plunge. The stretching lineation and a fold hinge are both north-plunging immediately west of Hick Well. The orientation of structural elements in the Raeside Batholith is shown in Figure 22B.

In the Hick Well Pluton south of Lake Raeside, several exposures of coarse-grained equigranular biotite granodiorite are present in a north-trending zone of subcrop between Metzke Bore (GR127027) and White City Well (GR205926). The granodiorite is weakly to strongly foliated and has a low magnetic susceptibility (10-30 x 10^{-5} SIU). Pegmatite zones and patches are common, and there are abundant fine-grained equigranular biotite monzogranite and aplite veins. The monzogranite veins commonly have pegmatitic cores, suggesting that the pegmatite and monzogranite veins are coeval. Rare foliated mafic dykes are also exposed (eg., at GR138024, GR144019), and chlorite schist and diorite enclaves have been observed.

No stretching lineation has been observed in the region south of Lake Raeside, and the foliation is weaker and more variably oriented than in the area north of the Lake. The Hick Well and Auckland Plutons are deeply weathered south of Lake Raeside; silcrete capping and areas of kaolinitic soil are common.

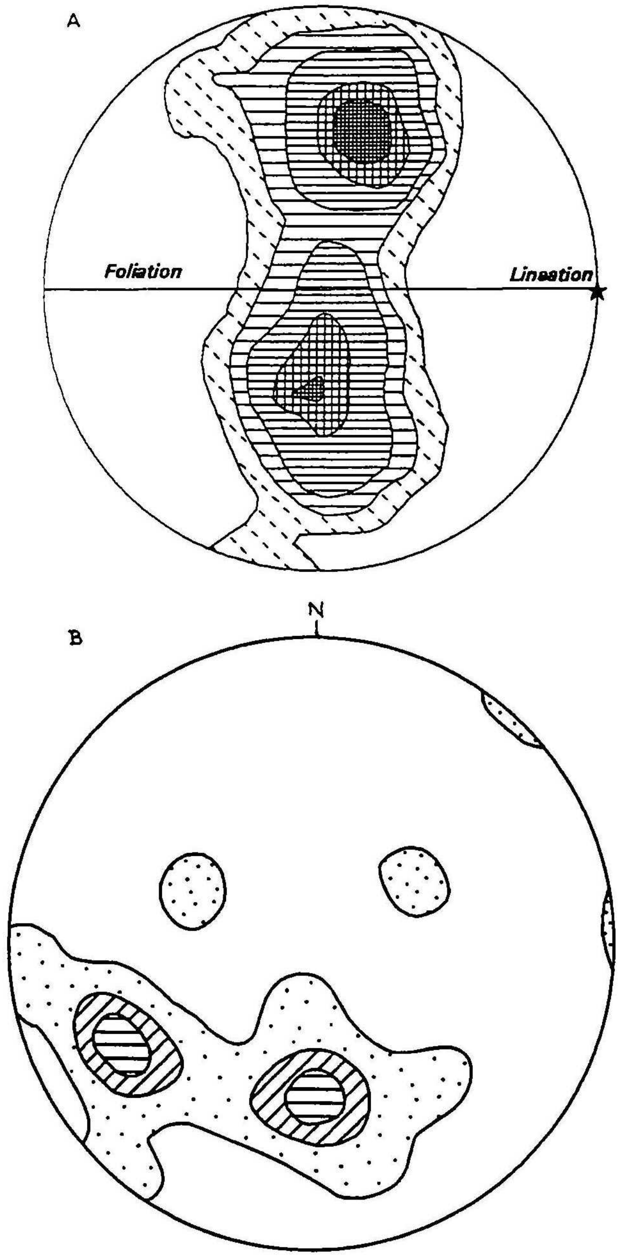


Figure 22. A. Orientation of 250 quartz-grain optic axes on the northern margin of the Hick Well Pluton, Raeside Batholith, Mount Ross area. B. Orientation of foliation planes on the northern margin of the Hick Well Pluton, defining the orientation of the regional folding which affected the pluton.

Other intrusions

A stock of medium-grained equigranular alkali-feldspar granite approximately 1 km across is exposed between Metzke Well and Boiler Well at GR158001, within the Hick Well Pluton. The rocks have a very low susceptibility (0-2 x 10^{-5} SIU), and are composed of abundant equant pink K-feldspar and white plagioclase grains 3-4 mm across with interstitial quartz. The stock is undeformed and contains no xenoliths, pegmatite, or microgranite/aplite veins. The intrusion is inferred to post-date deformation of the Raeside Batholith. A number of syenite veins have been mapped on the southeastern side of the stock, and there is a small body of quartzolite cropping out as an erosional remnant near the northeastern margin. The close association of these different magma types suggests that they may have formed at a high level due to magma immiscibility. Another quartzolite has been observed to the south of this intrusion at GR205962.

Fresh, undeformed medium-grained equigranular biotite-muscovite monzogranite crops out 3 km southeast of Boiler Well in a zone trending south from GR205959. The rock has a moderate magnetic susceptibility (20×10^{-4} SIU) but a low percentage of mafic and accessory minerals. Pink K-feldspar, white plagioclase, and quartz are approximately equally abundant. Plagioclase occurs as small phenocrysts in a few places. This body is cut by quartz veins, but is free of enclaves and veins. The monzogranite is coincident with the zone of higher magnetisation separating the Hick Well Pluton from the Auckland Pluton. The lack of both deformation and internal intrusions implies that this body also post-dates the emplacement of the Raeside Batholith.

Geochemistry

The Hick Well and Auckland Plutons are chemically very similar, both showing a high Na/K ratio characteristic of Archaean trondhjemite. In plots of normative Ab-An-Or and Na_2O-CaO-K_2O (Fig. 17A and B), almost all rocks from these plutons plot in the trondhjemite field. The low Y values together with the high Na/K ratio suggest that these plutons are related to the migmatite and banded gneiss suite of Yilgarn granitoids (Wyborn 1992; Fig. 17E). They show some similarity with rocks described by Witt & Swager (1989) from south of LEONORA as group 2 granodiorites. In that area, group 2 intrusions are also trondhjemite, and predate the main phase of regional folding.

Syenite (Ags, sy)

Syenite dykes form an intrusive stockwork (Ags) around GR 477135 in the Pig Well area northeast of Leonora. At GR 160000, southeast of Metzke Bore, an undeformed granite intrusion is cut by a number of garnetiferous syenite dykes which are 1-3 m wide and strike 070°.

Syenogranite to alkali-feldspar granite (Agy)

East of Old Woolshed Well (eg., GR235140), several intrusions of undeformed equigranular leucogranite have been identified (Agy). The rock contains only minor biotite. Leucogranite dykes identical to the larger bodies of Agy cross-cut the mylonitic fabric in the surrounding foliated gneissic granite of the Auckland Pluton. A dyke composed of medium- grained equigranular to quartz-phyric granite with up to 10% chloritised biotite trends northeast across the zone of outcrop. It cuts both granite units in the area, but cannot be traced into the adjacent supracrustal rocks of the Auckland area.

Minor intrusions

Porphyry (po), granite (g), pegmatite (p), and aplite (a)

Abundant porphyry and granite intrusions have been mapped east of Balkan Well around GR 095375. There are two types of porphyry present. Most of the intrusions are fine-grained feldspar-phyric porphyry in dykes up to 10 m wide. A small number of quartz-phyric dykes contain angular to rounded quartz phenocrysts up to 5 mm in diameter, small feldspar phenocrysts, and small rounded quartz grains. Biotite is present as fine-grained aggregates. There are also equigranular aplitic intrusions with laminar flow-banding parallel to the dyke walls. Dyke orientation is variable.

The gneissic and foliated granite of the Raeside Batholith is characterised by the presence of numerous minor intrusions. The majority of dykes in the Batholith are microgranite, pegmatite, and rare aplite.

Dolerite (d) and gabbro (gb)

A number of minor dolerite dykes have been mapped east of Leonora around GR 390050, where they intrude a felsic volcanic sequence (Afv). These dykes are only weakly deformed, but are nevertheless metamorphosed, containing abundant metamorphic epidote. They are therefore thought to be Archaean. These dykes are very similar to dolerite sills northwest of Mount Davis.

Lamprophyre (l)

Two lamprophye dykes have been identified. At the Auckland Mine (GR284173) a minette occurs in the mine dumps, but has not been observed in outcrop. A thin minette dyke (0.3 m wide) has also been observed in the Robbies Well pluton in the west. The Auckland minette was analysed for Au, Pt, and Pd by Rock et al. (1988). High Au values are considered to be the result of post-intrusion mineralisation, rather than a primary feature of the minette (Jaques 1990).

A number of small intrusions of generally feldspar-phyric mafic-intermediate dykes are present in the Victory mining area in the northwest. These fall into the 'semi-lamprophyre' group of Rock et al. (1988), and are classed as calc-alkaline minor intrusions by Currie & Williams (1993).

Structure

The regional pattern of deformation in LEONORA is the result of four main and two minor episodes of deformation (Table1) each of which produced distinctive structures and regional features.

Table 1. Regional correlation of deformation events in LEONORA

	Swager & Griffin 1990 *Southern and central regions*	**Williams et al. 1989** *Northern region, around Leonora*	**Hammond & Nisbet 1992** *Northern region*	**This report** *Leonora*
D_e	Not recognised	Low-angle shears along granite-greenstone margins	Shear zones on gneiss/granite-greenstone margins	Low-angle shears along granite-greenstone margins
D_1	Thrust faults and sequence repeats	E-W overturning, and reclined folds. Low-angle thrusts	NNW-directed thrusts, sequence repeats	Thrust faults and sequence repeats
D_2	ENE-WSW shortening. Upright folds, NNW steep cleavage	ENE-WSW shortening. Upright folds, regional cleavage	ENE-WSW shortening, detachment	ENE-WSW shortening, Upright folds, cleavage, re-activation of earlier shears
D_3	Sinistral wrench fault during regional shortening, later faults	NW-NNW sinistral faults and shears NE faults	NS dextral faults and shears, related to D_2	NS dextral shears, NNW sinistral reactivation
D_4	NE striking faults.	Not noted	Not noted	NE striking faults, small displacement.
D_5				Gently dipping spaced crenulation cleavage

The earliest episode (De) produced gently dipping mylonite, orthogneiss, and schist in discrete zones of deformation which parallel bedding. These zones are easterly- striking in areas not affected by later deformation events, and movement directions are usually north-directed. Sedimentary basins such as the Pig Well Domain and the felsic sequences in the Malcolm and Glenorn Domains are bounded by regional faults which show evidence of early movement. These may have been faults which controlled the location and development of the sedimentary basins during the early (D_e) deformation event. The second event (D_1) was also largely bedding-parallel, and resulted in structural inversion of the previously deformed rocks. The event is correlated with regional north-south thrusting known throughout the Eastern Goldfields Province. The third episode (D_2) resulted in a widespread north to northwest-striking crenulation of the early schistosity and long-wavelength open upright regional folds. These folds affect the early orthogneiss. Regional northwest-striking strike-slip faults, dominated by the sinistral Kilkenny and Malcolm Faults, with an attendant cleavage and subhorizontal stretching lineation, were reactivated as sinistral faults during the third (D_2) and fourth (D_3) deformation events. East-northeast-striking (D_4) faults cross-cut all the earlier structures. In several localities a southeasterly- striking widely-spaced crenulation, commonly gently-dipping, is evidence of a sixth episode (D_5). Recent studies by Passchier (1990, 1992) in the Leonora area have helped clarify the structural relationships, and Passchier (1992) argues that the development of upright folding and steeply-dipping shear zones is synchronous (D_3 and D_4). Skwarnecki (1987) presented a detailed structural study of the areas surrounding the Sons of Gwalia and Harbour Lights gold mines. He concluded that the major shear zones hosting the larger mineral deposits in the area formed during diapiric granite intrusion, and synchronously with regional wrench fault deformation. Evidence presented by Williams et al. (1989) is inconsistent with this interpretation.

The structural evolution of the Leonora region is similar to that proposed in other areas of the Eastern Goldfields (eg., Menzies - Martyn 1987; Kalgoorlie and Kambalda - Archibald et al. 1978, Swager 1989; and Laverton and Wiluna - Hammond & Nisbet 1992). The well-exposed gently-dipping extensional faults preserved in LEONORA are evidence of an extensional structural event which exerted regionally important structural controls on the development of the stratigraphy and architecture of the greenstone belts in the Eastern Goldfields. Other evidence of this deformation event has not been recognised everywhere (but note Hammond & Nisbet 1992, Swager & Griffin 1990).

Three major shear zones are identified in LEONORA (Fig. 2). These shears represent major structures juxtaposing rock sequences with differing structural, lithological, or metamorphic character, and are interpreted as the major structures controlling the tectonic development in the region, and probably beyond. Within this framework, the area has been subdivided into a number of distinct structural domains (Fig. 2). These domains are fault-bounded regions, with internally simple structural patterns.

Major faults and domain boundaries

Sons of Gwalia Domain

Williams et al. (1989) discussed the regional deformation pattern in the Leonora area, and established that the Sons of Gwalia Shear Zone was a distinctive arcuate high-grade shear which broadly follows the boundary of the Raeside Batholith (Fig. 2). Deformation in the shear zone was shown to be earlier than the upright folding, which is in turn earlier than north-northwest-striking strike-slip faults. Rocks within the shear zone are mainly chlorite schist and talc-chlorite schist, with several lenses of undeformed basalt (with ocelli and acicular amphibole), gabbro, and amphibolite in the Sons of Gwalia area, and amphibolite and granite-gneiss in the western part of the domain. Carbonate alteration is common, and numerous concordant lenses and dykes of granitoid and porphyry are present. The orientation of the shear zone changes from dipping moderately east at Sons of Gwalia and Harbour Lights Mines to dipping gently to the north at Puzzle mine (GR223233) and flat at Tarmoola mine (Fig. 2). The zone dips about 30° north-northwest in the Mount Ross (GR085218) area.

In the Sons of Gwalia area, an intense east-dipping foliation, generally parallel to lithological contacts, is developed in most rock types, in particular within a zone incorporating the Sons of Gwalia mineralisation. Weakly foliated and unfoliated zones are confined to the granitic rocks, and to lenses of coarse to medium-grained actinolitic amphibolite (eg., immediately west of Sons of Gwalia mine). A strong lineation, defined by mineral elongation or streaking and by stretched vein segments, is usually present in the foliation. The lineation is interpreted as the finite extension direction in the rock because of its parallelism with stretched veins and the elongation of elliptical markers (originally amygdales?) in the same direction. Rare isoclinal folds with axial surfaces parallel to this foliation plunge parallel to the lineation. At Harbour Lights, the foliation, defined by mica-rich bands up to a few mm thick separated by quartz-carbonate microlithons, dips at about 50° towards 070° with a very strong stretching lineation plunging 50° towards 090°. The microlithons commonly contain an asymmetrical internal cleavage typical of S-C fabrics. A feature of the structure at Harbour Lights is the presence of boudins in the foliation ranging in size from microscopic to at least 30 m in length. The boudins are composed of quartz veins, quartz-carbonate bodies, and felsic alteration assemblages, commonly micaceous. They form tabular bodies, with the long axis of the tablets pitching gently north or south and their short axes perpendicular to the foliation. The tablets are thinned substantially on their up-dip and down-dip margins and either completely separated from adjacent up- and down-dip boudins or connected by narrow quartz-carbonate veins.

In the Trump mine area, the Sons of Gwalia shear zone extends from 100-200 m west of the granite contact to about 200 m west of Golden Blocks mine (GR333092). In the granitic rocks, horizontal to moderately-dipping foliation is developed in discrete zones up to 30 m thick within which the granite is altered to a quartz-sericite schist with abundant quartz veins parallel to foliation. In the most strongly sheared granites, the rock is converted to a platy sericite schist with relatively undeformed relict quartz grains. A horizontal stretching lineation is common in the sheared granite, generally defined by rodded quartz grains and elongate sericite clumps. Foliation in strongly deformed amphibolite just east of the granite contact is defined by alignment of trains of opaque mineral grains and a strong dimensional preferred orientation of newly crystallised hornblende and plagioclase (An>10%). This fabric indicates that the amphibolite facies metamorphism was synchronous with the Sons of Gwalia Shear Zone deformation. There is no evidence of a retrograde metamorphic overprint in this area.

In the Auckland mine area, three BIF intervals close to the granite-greenstone boundary are folded into a megascopic open asymmetric F_2 antiform, and most of the area is in the hinge of this fold. The BIFs are locally parallel to a strong foliation in surrounding rocks, and numerous isoclinal folds in layering have axial surfaces parallel to foliation. The most southerly zone, which extends over a 3 km strike-length, is composed of hematite-magnetite-grunerite(?)-quartz. The folds in this zone generally plunge at moderate angles to the northeast, approximately parallel to a strong stretching lineation which pitches down dip.

In contrast, the central zone (to the north) is dominantly a foliated and lineated quartzite composed of metamorphic quartz grains with stylolitic grain boundaries tending towards triple-junctions. Layering is defined by thin hematite bands parallel to the foliation. The zone, which is enveloped in ultramafic schist with relict spinifex texture on the southern side, extends for 3.5 km in length on the main range of hills, and converges towards the more southerly unit to the southeast. Isoclinal fold hinges are statistically parallel to the stretching lineation, which plunges at a moderate angle to the north-northeast. Most folds are S-shaped (looking down-plunge), ie., west-verging, although opposite vergences also occur. Parallelism of fold axes with the strong stretching lineation, and the metamorphic fabric of the quartzite, together with the mesoscopic structural features, suggest that this horizon is in a high-strain mylonitic zone within the Sons of Gwalia shear, with movement direction parallel to stretching lineations.

The granite immediately south of the Auckland Hills (GR270167) area is strongly deformed, with the cleavage defined by the elongation of quartz grains. Slices of granite have been incorporated into the greenstones, indicating that the deformation post-dates the emplacement of granite in this area. Observation of the granite-greenstone boundary shows leucocratic dykes cross-cutting both the granite and the early mylonitic foliation in greenstone. However, several of these dykes are folded such that the axial surface of dykes (injected at a high angle to the foliation) is parallel to the mylonitic foliation. This relationship indicates that the dykes were injected late in the deformation event, and further supports the view that the main granite body was emplaced during deformation and underwent low-grade metamorphism and cataclasis during progressive deformation.

The Horse Paddock Well area (GR235220) area is dominated by ultramafic schist with pods of serpentinised ultramafic rocks up to 500 m long. The foliation in this area dips gently to moderately north-northeast. At some localities, two early foliations are recognisable, both very similar morphologically. Commonly an overprinting relationship is apparent, but no consistent orientation or overprinting 'sense' between the two could be discerned, suggesting that they may be coeval, or represent foliations developed during progressive shearing in the Sons of Gwalia Shear Zone. A strong stretching lineation plunging north or northeast is common in the early foliation.

Throughout the Sons of Gwalia Domain, the early foliation is overprinted by later folds and crenulations with steeply-dipping north-striking axial surfaces and gently plunging to horizontal axes. The later folds are generally small crenulations on the early foliation plane, although regional upright folds with gently plunging hinges were identified at Sons of Gwalia, Trump (GR341078), and Tarmoola mines. Open asymmetric folds in BIF units, and early foliation at the old King of the Hills open pit (now filled with waste from Tarmoola mine) exemplify these structures. In the Auckland mine area, foliation in quartz mylonite is folded into open north-plunging folds of this generation, and a megascopic S-shaped early fold in the southern BIF unit is refolded by one of these late folds. At Harbour Lights mine, both large and small open gently plunging asymmetric folds verge to the west, which is opposite to the vergence of the gently east-dipping small crenulations. They have a steeply east-dipping axial surface and overprint the east-verging kink folds. Folds of this generation are correlated with the second regional deformation event of Skwarnecki (1987), and with upright folds and crenulations in the other areas.

West of Sullivans Creek in the Mount Ross area, the boundary between amphibolite and gneiss is strongly sheared (GR120230). A well-developed planar structure parallel to the boundary is present within both the amphibolite and gneiss. In the amphibolite, the intensity of the foliation decreases away from the boundary, from a penetrative foliation within 200 m of the contact to a decreasing number of anastomosing shears up to 700 m from the gneiss margin. At the gneiss margin, tectonic slices of amphibolite and ultramafic rocks between 0.5 m and 5 m thick and several metres long are interleaved with the gneiss. The foliation contains a strong mineral elongation lineation, especially near the contact. In amphibolite, the lineation is defined by amphibole laths; in gneiss, by the alignment of quartz grains and pressure shadows around feldspar phenocrysts. In the gneiss, numerous examples of S-C fabric and asymmetric pressure shadows are present around feldspar porphyroclasts, and some feldspar porphyroclasts show extensional rotational fractures. Both textures are definitive of normal movement on the shear surfaces. Quartz optic axes within the gneiss adjacent to the boundary define a single asymmetrical girdle indicating normal (top-side north) movement (Fig. 22) and a moderately high metamorphic grade during deformation (cf. Law 1987). Within the amphibolite, discontinuous faults with a strong down-dip linear fabric and distinctive siliceous fault fill (silicified ultramafic rock?) are offset by dextral strike-slip segments. Also within the amphibolite, rare irregular leucocratic feldspar-rich patches have been observed. These have a granophyric texture, and form thin veins often surrounding patches of deformed amphibolite. The patches and veins are interpreted as the product of local melting of the amphibolite after the main deformation, and indicate that the amphibolite margin also reached a high metamorphic grade. The zone of melting is in close proximity to the small granite pluton, which may have caused a sharp local temperature rise after the cessation of deformation.

Foliation in the gneissic granite is folded about a north-northeasterly-plunging axis (Fig. 22), at a high angle to the stretching lineation, confirming that the mylonitic foliation within the western exposures of the Sons of Gwalia Shear Zone pre-dates upright regional east-northeast shortening. The timing relationship is the same as that around Leonora. Schistosity in the amphibolite is also deformed on a mesoscopic scale by folds which post-date the shear fabric. East of Mount Ross, in the Auckland area, S-C fabric developed in chlorite schist clearly indicates top-side-north sense of movement.

Abundant porphyry dykes in the Auckland area form *en echelon* tension veins within a talc-chlorite schist, and are largely undeformed. Dykes on the margin of the ultramafic unit exhibit a weak foliation. Close to the margin of the Raeside Batholith in the Auckland area, the porphyry dykes are foliated, in some instances mylonitic with a mineral elongation lineation parallel to that in adjacent amphibolite. The foliation is marked by C-surfaces composed of very fine-grained siliceous gouge material separating quartz-rich domains dominated by small equant quartz subgrains.

Neither at Auckland nor at Mount Ross do the porphyry dykes extend into the structurally underlying granite or gneiss. At Mount Ross, a discordant dyke has been truncated by the major granite-greenstone boundary fault, but is essentially undeformed, even at the fault. These relationships suggest that porphyry emplacement took place throughout the development of the Sons of Gwalia Shear Zone. Large quartz blows along the trace of the gneiss-amphibolite boundary also indicate that late brittle movement took place, and that the brittle fault was located at the lithological boundary.

The microstructure of amphibolites in both areas is consistent with overprinting of high- grade ductile fabrics with brittle structures. The amphibolite is characterised by hornblende laths defining a strong planar fabric which is in places overgrown by randomly oriented amphibole laths with similar optical characteristics to the earlier syn-deformation amphibole. The rocks are cut by late clinozoisite veins, but show no other signs of retrogression. At Mount Ross, the metamorphic grade drops rapidly to the north, where the rocks are weakly deformed to massive greenschist-facies pillow basalts cut by thin feldspar (± quartz) porphyry dykes. The rocks in both amphibolite and greenschist facies rocks dip approximately 30° north, subparallel to the normal faults. North of Auckland Hills, retrogression in the lower-grade upper plate is evidenced by thin undeformed prehnite veins cutting the metabasalt.

A detailed evaluation of both the structural and metamorphic features of the Sons of Gwalia Shear Zone south of Leonora, and of the rocks structurally above it, was reported by Williams & Currie (1993) based on examination of diamond drill core from the area (GWDD-4).

Mount George Lineament (Mount Davis Domain)

The linear chert ridges extending in a north-northwesterly direction between Mount George in the south and Mount Newman in the north define a major regional topographic and geological lineament across LEONORA. The nature of the lineament remains enigmatic, despite the current and recent mapping programs. Rocks to the west of the lineament are dominantly basalt, amphibolite, and ultramafic rocks with thin chert, BIF, and interbedded sedimentary lenses. East of the lineament the sequence comprises abundant felsic volcanic rocks, dolerite intrusions, sedimentary sequences, and basalt flows. The Mount George Lineament contains an assemblage of chlorite schist, graphitic phyllite, quartz-sericite phyllite, minor quartzite, and quartz mylonite, and forms the western margin of the Keith-Kilkenny High-strain Zone. This zone includes several mylonite zones as well as steep faults not associated with mylonite (Hallberg 1985). However a ubiquitous strong slaty cleavage, in many places overprinted by a strong crenulation cleavage, characterises deformation in the Keith-Kilkenny Zone. Evidence from the Mount Newman area, discussed above, suggests that chert intervals to the west of the Mount George Lineament have been rotated into the lineament and have been cut by minor faults with observed sinistral and dextral movement, and that the faults were oriented parallel to the lineament. Abundant evidence of brecciation of the chert intervals and tectonic mixing of the chert with adjacent felsic volcanic and sedimentary rocks indicates that there may have been substantial movement distributed across 10-50 m-wide fault zones. However, the regional continuity of the chert intervals and the changes in stratigraphy suggest that the Mount George Lineament is the site of a major tectonic break, which may represent a reactivated original tectonic basin margin separating sequences to the west and east.

Keith-Kilkenny High-strain Zone

East of the Mount George Lineament, the geology changes markedly from dominantly greenstones to the west to a mixture of felsic and mafic igneous rocks with abundant intercalated sandstone, shale and conglomerate, as well as several lenses of siliceous and ferruginous BIF, to the east. Southwest of Mount Malcolm in the Malcolm Domain, a thin unit of quartz mylonite, formed from an original siltstone or shale horizon, forms a distinctive ridge extending from the railway line southeast of Leonora around the hinge of a regional fold, and continues northwesterly to the east of Mount Malcolm. A similar silicified layer is present on the western flank of Mount Malcolm, in a structurally higher position. The layer forms an isoclinal fold, whose core is marked by ironstone capping the original silicified shale. A very strong gently-dipping cleavage with a well developed stretching lineation is present in the core of the fold. A discordant asymmetric fabric on the limbs of the fold, where cleavage and lithological layering are parallel, may be an S-surface preserved between dominant C-surfaces. The fold is developed in a strongly altered andesitic volcanic complex, and bedding cannot be established in most places (Hallberg & Giles 1986; Hallberg 1985). The felsic rocks contain andalusite porphyroblasts, which formed before the crenulation cleavage related to the D_2 folds. The textures indicate that peak temperature was attained before D_2, probably late in the early (D_1) deformation event. East of the Keith-Kilkenny Zone in MINERIE, metamorphosed and silicified black slate contains euhedral andalusite porphyroblasts which overgrow the foliations in the slate (Hallberg 1985). The variations in timing of mineral growth with respect to deformation across the district indicate that either heating or deformation were diachronous.

The pattern of deformation established in the Mount Malcolm area is present across the whole of the Keith-Kilkenny Zone in LEONORA. Examination of old pits at Rabbit Warren (GR419108), Pride of Leonora (GR402099), and Pig Well mine (GR504179) shows similar features, although no regionally extensive shear zones have been established. In the Pig Well area, Williams et al. (1989) demonstrated the dominance of gently dipping cleavage surfaces which were rotated with bedding around a gently plunging hinge line trending northwest. Several polymict conglomerate horizons are strongly deformed to a northwest-trending linear fabric defined by pebbles. In most outcrops where the cleavage is gently dipping and bedding can be determined, bedding dips more steeply than cleavage, suggesting that steeply dipping beds in the Pig Well Domain are on the overturned limb of a west-verging fold. No direct facing evidence has yet been discovered. The Pig Well foliation is disrupted by normal faults which parallel the boundary faults of the Pig Well Domain, and clearly post-date the main foliation. Their orientation suggests that they may be related to the faults marking the boundary of the Keith-Kilkenny High-strain Zone. The amount of lateral movement on these faults is not known.

A schematic cross section of the Keith-Kilkenny Zone east of Leonora is shown in Figure 23. The cross section is drawn to indicate the likely structural style associated with the D_2 folding and faulting.

The upright folding of the early mylonitic foliation has produced a steeply dipping crenulation cleavage over much of the area, and has rotated early (presumably gently dipping) shear zones into steeply dipping dextral zones. Substantial lateral movement on late steep faults is probable, because of indications of the overall dextral movement across the zone. Reactivation of early shear zones in the limbs of upright folds is likely during this later event, but because both movements are dextral in upright limbs, no overprinting relationships have been established.

Structure of the domains

The domains shown in Figure 2 represent fault-bounded regions with internally consistent stratigraphy and structural patterns. They are defined with reference to the geological map. The description of structural orientation in this section is divided into a description of domains west of and including the Mount Davis Domain, and those domains east of the Mount Davis Domain.

Western domains

Bedding and foliation orientations in the western domains are shown in Figures 24 and 25. The predominance of east-striking bedding is evident (Fig. 24A-E). The spread of data points around a north-plunging great circle represents the regional F_2 fold hinge. By comparison, the stereograms of foliation clearly demonstrate the presence of two fabrics in the western domains. Figure 25A (Victory Domain) shows a foliation with a steep dip (~ 70° to 80°) and striking at ~ 340°. A second maximum indicates a strike of ~110° and a dip of about 55°-60° to the north. Comparison with the bedding trends (Fig. 24A) shows that this foliation maximum coincides with the bedding maximum, providing good evidence that this 110°-striking foliation is a result of a bedding-parallel deformation. The 340°-striking cleavage characterises two other western domains (Cork Tree Well, Fig. 25C; Mount Davis, Fig. 25D), where the maxima are strong and not dispersed. By contrast, foliations in the Sons of Gwalia Domain (Fig. 25E), the Raeside Batholith (Fig. 25F), and the Mount Stirling Domain are dispersed along a great circle, the pole of which lies within the statistical plane of the 340° foliation. This geometric relationship provides evidence that the easterly-striking foliation was folded during the same event (D_2) which produced the upright 340° foliation, and the east-striking foliation was therefore formed earlier than the 340°cleavage, probably during both D_e and D_1.

Eastern domains

The orientation of the upright foliation in the eastern domains is similar to that in the western domains, but may strike more westerly (330°, Fig. 26). The early foliation identified in the western domains is also present in the Mount Malcolm Domain and Pig Well Domains (Fig. 26A). Outcrop is poor in the other domains, and there are indications that a folded foliation is also present in those areas (Glenorn, Fig. 26C; Linger and Die, Fig. 26E). In both the Malcolm

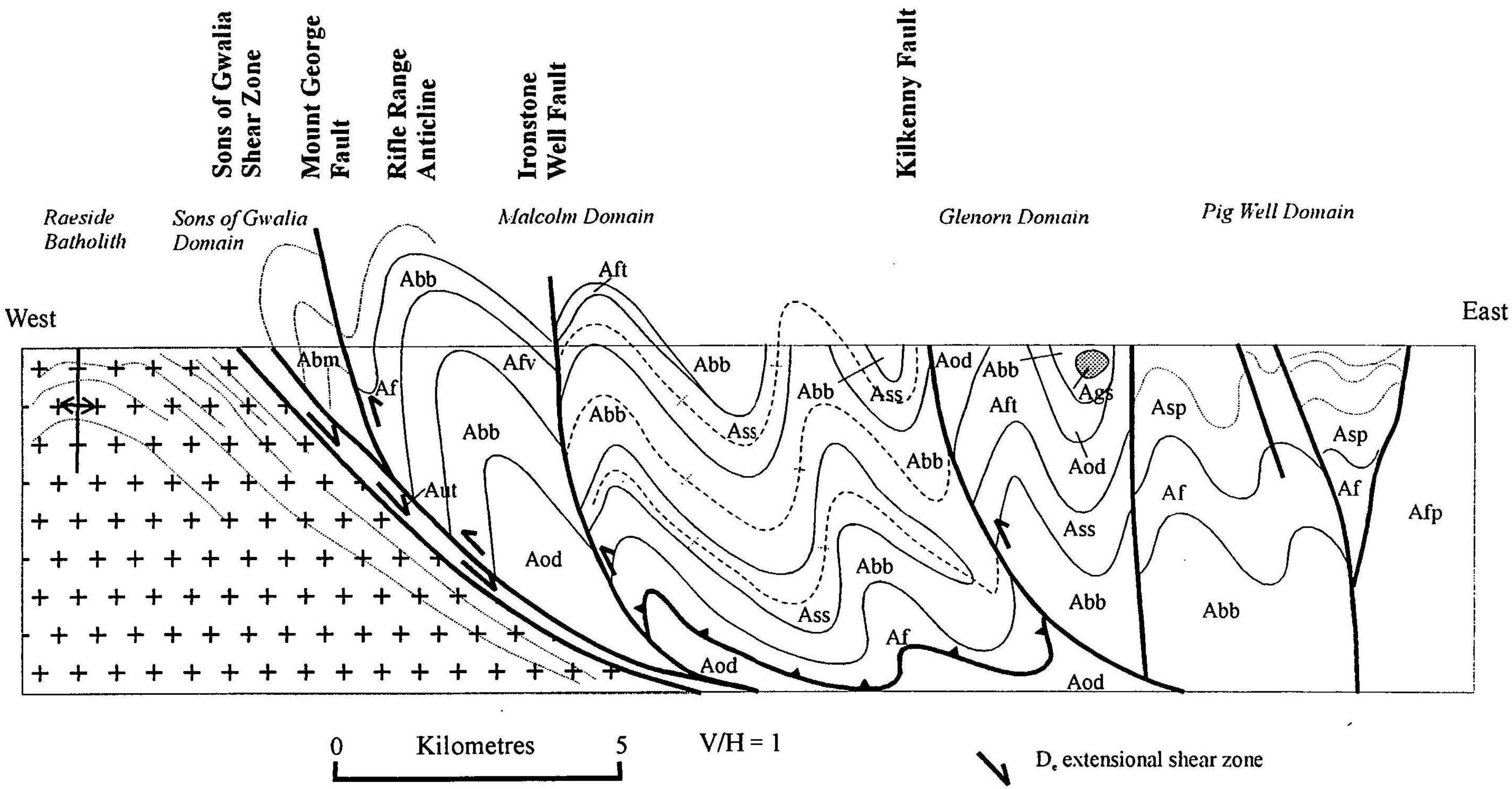
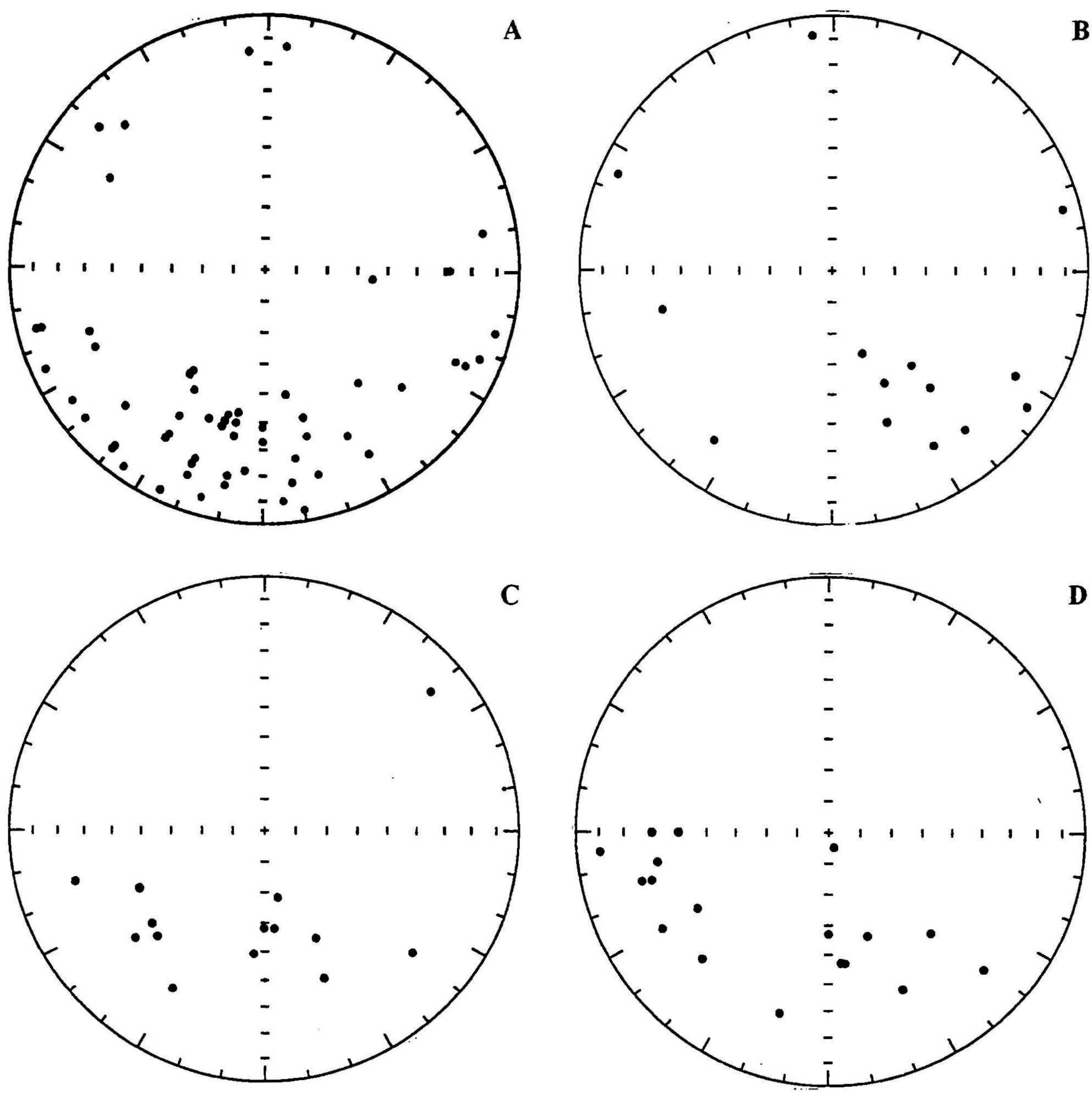


Figure 23: Schematic cross-section illustrating inferred relationships between domains. Note the repetition of units on D_1 structures in the Malcolm Domain inferred from map pattern in the Malcolm domain. This pattern is consistent with the pattern for D_1 in Figure 31A. For unit abbreviations see map or report contents.



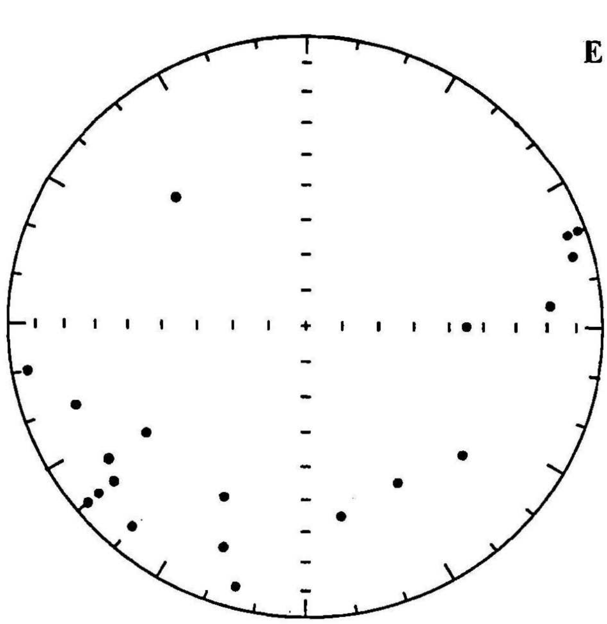
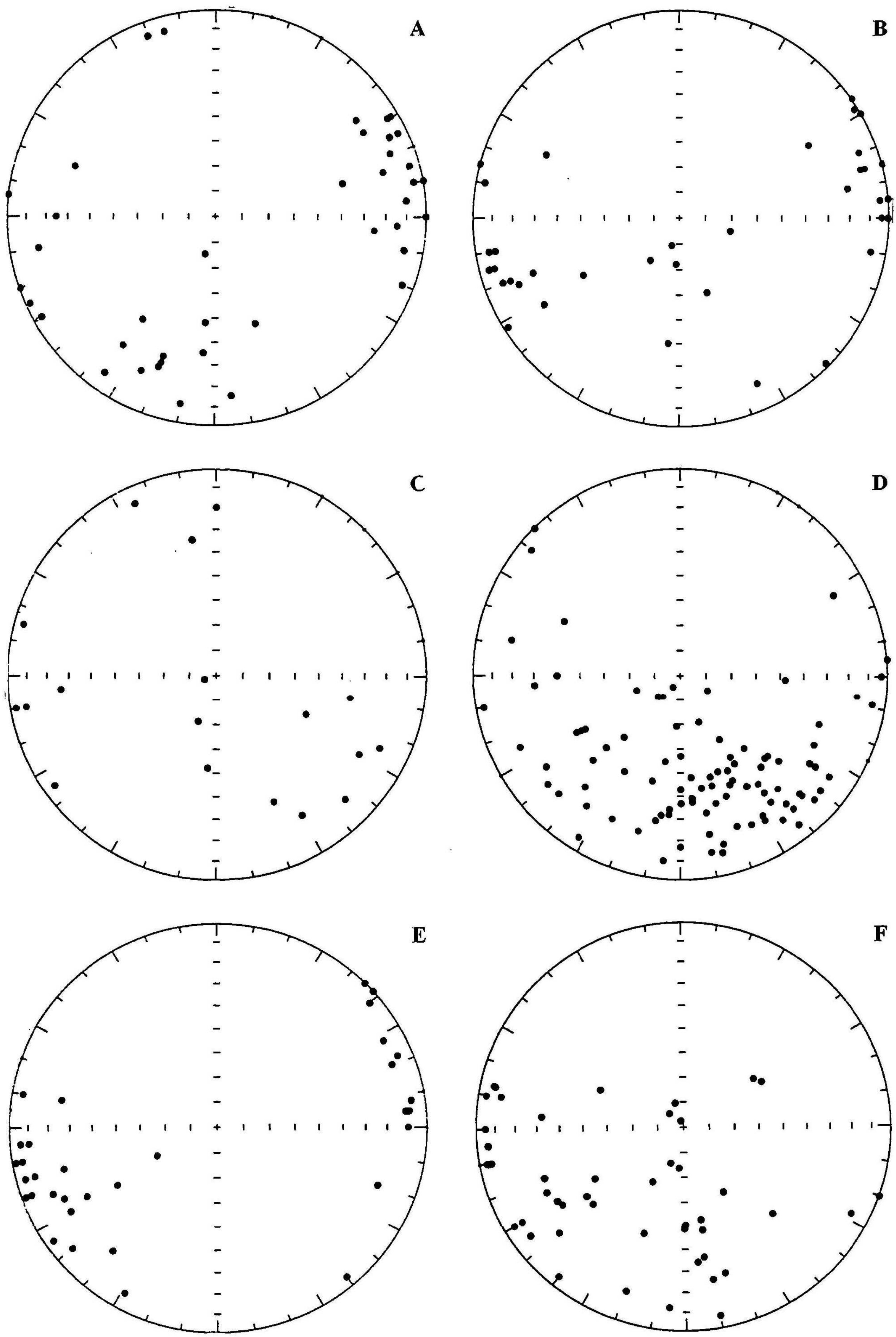


Figure 24: Bedding orientations, Western domains

Figure 25: Foliation and cleavage orientation, Western domains.

	Figure 24	Figure 25
A: Victory	n=58;	n=40
B: Corktree Well	n=15;	n=35
C: Mount Stirling	n=16;	n=22
D: Sons of Gwalia	n=18;	n=103
E: Mount Davis	n=21;	n=36
F: Raeside Batholith		n=46


A
B
C
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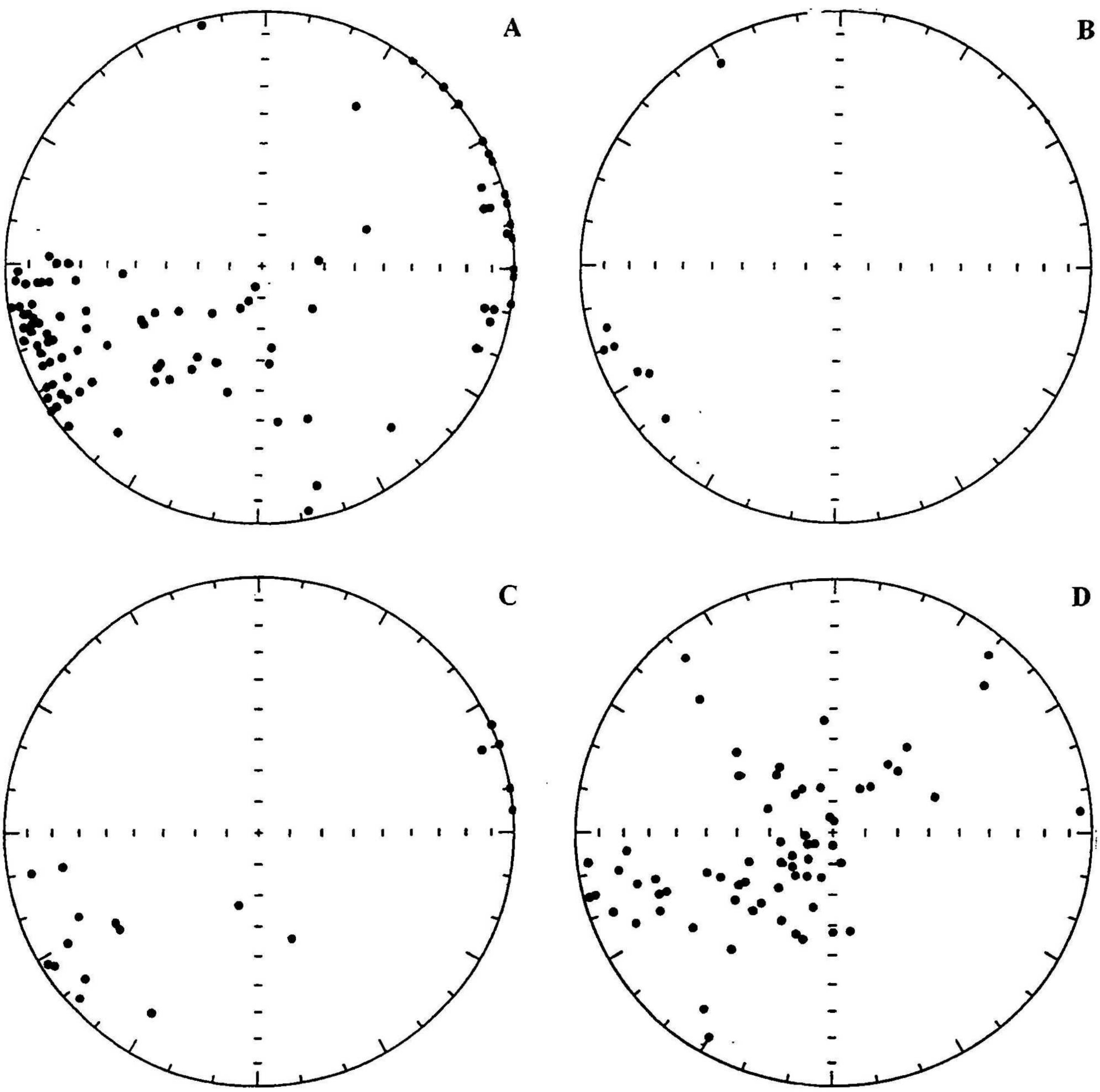
E
F



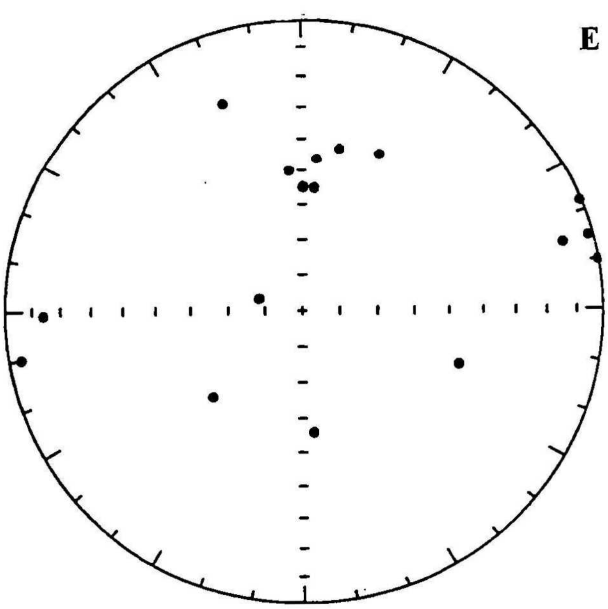


Figure 26: Foliation and cleavage orientations, Eastern domains

A: Malcolm	n=99
B: Possie Well	n=8
C: Glenorn	n=17
D: Pig Well	n=65
E: Linger and Die	n=17

Domain and Pig Well Domain, the gently dipping foliations are dispersed on a great circle indicating a statistical F_2 fold axis plunging gently to 330-340°. Bedding in the Pig Well Domain dips to the southwest (Fig. 27), and observations in the pits in the area show that bedding is commonly cut by a more gently dipping cleavage. This relationship suggests that bedding is locally overturned, and the fold style suggests control of the structure by northeast-verging low-angle thrusts. These structures are overprinted by the upright folds and regional upright foliation. Similar geometric relationships have been observed in pit outcrops in the Glenorn and Linger and Die Domains. The geometric pattern in the Malcolm Domain is very similar to that in the Pig Well Domain, with slightly different orientations for the early foliation. The geometric data support the field observation of macroscopic overprinting relations in the Malcolm Domain.

The geometric similarity between structural elements of the western and eastern domains suggests that both regions have been affected by the same deformation events, albeit to differing degrees of intensity. There appears to be a partitioning of strain into regional shear zones in the eastern domains (cf. Fig. 2), whereas the western domains have been less affected by shear, possibly due to the presence of the Raeside Batholith acting to create a large strain shadow during the regional upright folding and faulting event. However, the presence of the upright foliation throughout the western domains shows that the region north of the Raeside Batholith underwent flattening during the upright event. Therefore, the Raeside Batholith, which must have existed prior to folding to have created the strain shadow, must also have been flattened during the upright folding event, probably enhancing an original domal shape to the intrusion. The presence of folds in the foliation within the Batholith supports this interpretation.

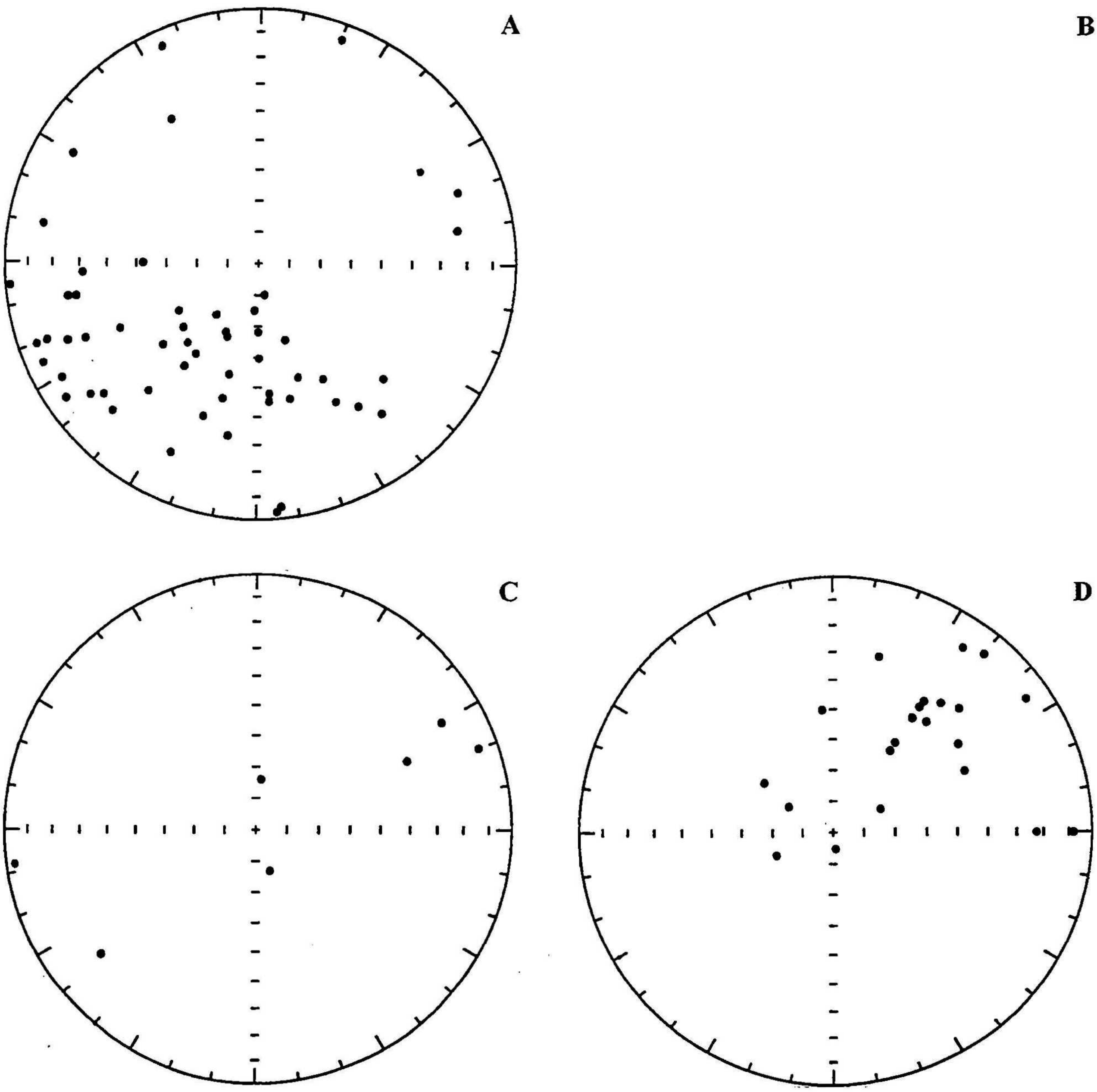
Movement directions on major shear zones

Movement directions have been determined on three of the major shear zones in LEONORA, with various degrees of certainty.

Sons of Gwalia Shear Zone

Several indicators at Harbour Lights confirm an east-side-down movement (Skwarnecki 1987), including extensional carbonate vein fibres, and at Sons of Gwalia a similar movement pattern is well established from S-C fabrics and asymmetric deformed veins (Williams & Currie 1993). At Trump mine, deformed granite developed an excellent S-C fabric pattern at both macroscopic and microscopic scales (Williams et al. 1989) and an unequivocal east-side-down to the southeast movement on a gently dipping shear surface is defined. Despite the mesoscopic and microscopic indicators of extensional movement on the Sons of Gwalia shear, there is good evidence (below) that the extensional normal movement is overprinted by a significant thrust movement (east-side-up) during later deformation

Within the sedimentary-felsic volcanic sequence examined in drill core from GWDD4, Williams & Currie (1993) reported small-scale reclined folds with wavelengths of a few centimetres and axial surfaces parallel to the prominent cleavage, dipping about 45° east, with the enveloping surface defined by swarms of fold closures dipping steeply east, subparallel to the drill core. They presented an interpreted fold profile from logging the vergence of minor folds, and interpreted a number of third-order fold closures with wavelengths between 20 m and 40 m and second-order folds with wavelengths between 140 m and 180 m. Fold axial surfaces are parallel to a strong cleavage. Lack of large-scale repetition suggests folding was accompanied by major faulting parallel to the axial surface. The inferred first-order folds are isoclinal with half-wavelength of about 660 m, bounded at the top by a major shear zone against ultramafic rocks, and at the base by a 200 m-thick shear zone within the basaltic rocks. The overall fold geometry suggests vergence to the west, and this, together with the thrust sense-of-shear indicators in the upper ultramafic units, imply that these are best interpreted as a series of west-directed thrust faults and associated folds.



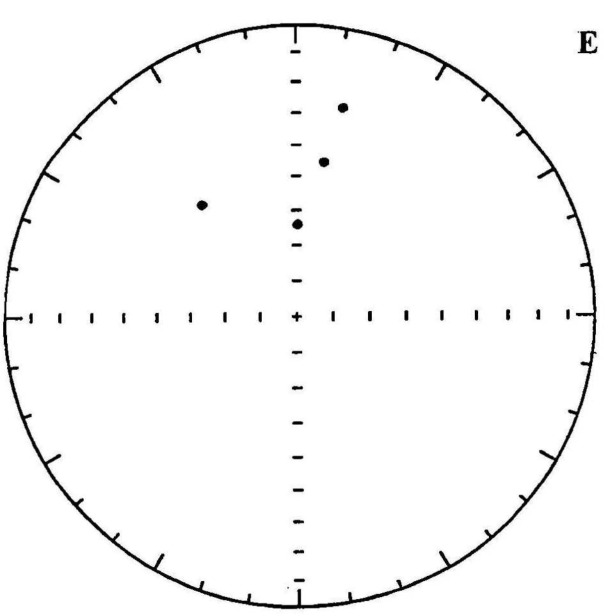


Figure 27: Bedding orientations, Eastern domains

A: Malcolm	n = 64
B: Possie Well	n = 0
C: Glenorn	n = 7
D: Pig Well	n = 23
E: Linger and Die	n = 4

Movement indicators show that the thrust movement was restricted to discrete shear zones and does not 'reset' the extensional shear indicators normally observed in the margin of the Raeside Batholith. The fold profile supports the view that a post-extensional west-directed overthrust event recorded in the Sons of Gwalia shear zone was a major regional tectonic event in the area (D_2).

King of the Hills

Foliation in the King of the Hills area dips gently to moderately north. Sense-of-shear determinations made in the field and from thin sections gave contradictory results. Those determined from thin sections are probably more reliable and indicate a top-side-south to southwest sense, but this result is considered tentative. Early workings at the Arboyne open pit (reworked as the Tarmoola mine), exposed shear zones with well developed S-C fabrics in pillowed metabasalt and associated south-dipping *en echelon* quartz veins. These features demonstrate consistent top-side-south movement after the development of the regional foliation. Extensional quartz veins in the Horse Paddock Well area also indicate top-side-south thrust movement (J. Martyn, personal communication).

Auckland Hills

Fabrics from silica-rich 'chert-hematite BIF' mylonitic horizons at Auckland Hills are shown in Figures 12 and 13. All specimens from Auckland Hills show a similar asymmetric crossed-girdle fabric pattern typical of simple shear deformation (Lister & Williams 1979). The sense of asymmetry is sinistral, which in the present geographical orientation represents north (hangingwall)-side-down, or extensional normal movement. Previous north-side-up fabrics reported by Williams et al. (1989) are now re-interpreted as due to the effects of either later deformation or poor sample orientation control. Passchier (1993 unpublished manuscript report to AGSO) reported a comprehensive fabric analysis which also supports the extensional movement on the Sons of Gwalia Shear Zone at Auckland Hills. The north-side-down movement is consistent across the northern part of the Raeside Batholith. This movement is also consistent with sinistral movement recorded in the Robbies Well Pluton (Passchier 1994).

Mount George Lineament

The fabric patterns shown in Figure 11 are from layered quartzite composed of alternating fine-grained (cherty) and coarse-grained layers, located at the reservoir east of Leonora. The main element of the fabric is an asymmetric girdle (trending about 340° in Fig. 11) which indicates sinistral shear. Williams et al. (1989) discussed the evolution of the fabrics, and inferred a lower-strain environment and possibly a lower metamorphic grade for the deformation in the chert units at Leonora compared to that at Auckland Hills. The quartz-grain texture, consisting of straight grain boundaries meeting in triple junctions, is also different from the Auckland Hills quartzite, where grain boundaries are stylolitic.

Williams et al. (1989) were equivocal about the movement direction on the Mount George Lineament based on the quartz fabrics, and suggested that they may result from two periods of recrystallisation. The best evidence for the sense of movement on the Mount George Lineament is the regional structural pattern of deformation in the area. The tight north-trending faults and folds in the Keith-Kilkenny High-Strain Zone are late folds, and merge with the Mount George Lineament. Their orientation is consistent with regional sinistral movement along the lineament. The cleavage within the Mount George Lineament is also oriented in a more northerly direction than the trend of the lineament, consistent with sinistral shear. Within the chert units in the Mount George Lineament, pull-apart structures formed under a sinistral couple. However, dextral S-C fabrics and secondary shear zones within the Lineament have also been observed, which may indicate reactivation and dextral movement during the development of the shear zone.

Mount Malcolm Shear Zone

The Mount Malcolm Shear Zone was defined by Williams et al. (1989) as a foliated zone of slate and felsic rocks trending east-west in the Malcolm Domain, and swinging north into the Kilkenny Fault (Fig. 2). Mylonite in the zone is characterised by extreme extension parallel to a stretching lineation defined by elongate quartz fibres around small opaque grains. The fibres join, and define a lithological layering parallel to the strong shear foliation. Indications from quartz-layer boudinage show a subhorizontal stretching direction in the north-striking limb of the folded shear, parallel to a well defined surface stretching lineation and axes of isoclinal folds. Asymmetric pressure shadows and fibre growth directions indicate dextral movement parallel to the stretching lineation. This is consistent with a folded shear surface of regional extent, initially gently north-dipping and with a hanging wall-to-the-north movement direction.

Interpreted structures from aeromagnetics and cross-section reconstruction

Interpretation of the fault pattern from the 400 m line-spacing aeromagnetic data acquired by AGSO is shown in Figure 2. The aeromagnetic data show that major changes in trend and structural style take place across the Mount George Lineament. The fault identified on the interpretation (Fig. 2) is almost parallel to but not coincident with the prominent chert units in the area. The chert units are interpreted as stratigraphic units, which therefore define the regional bedding trends on the eastern limb of a regional antiform with axial trace west of the Mount George Lineament. Schematic interpreted cross sections derived from both the mapping and aeromagnetic interpretation are shown in Figure 23.

The pattern of deformation and the cross-sectional geometry of LEONORA changes across the Mount George Lineament. West of the lineament, the geometry has been controlled by the development of the Raeside Batholith as a core complex (Williams & Currie 1993; Williams & Whitaker 1993) emplaced in the solid state beneath the thick amphibolite-facies Sons of Gwalia Shear Zone of proto-mylonite, and by later south-directed overthrust movement and associated faulting. The location of the Sons of Gwalia Shear Zone parallel to the Raeside Batholith boundary, the parallel nature of metamorphic isograds and deformation within the gneiss and amphibolite, and the continued operation of the shear from high grade to low grade, provide strong evidence that the Raeside Batholith was emplaced into the greenstone sequence on the Sons of Gwalia Shear Zone, and that the granite was emplaced in the solid state. The tectonic environment in which this occurred is inferred to be extensional (D_e), with the top plate moving relatively northwards with respect to the underlying granite.

Fold axes trend easterly in northern LEONORA, and the regional geology suggests that the stratigraphy is repeated from north to south. The inferred folding and faulting associated with this repetiton is shown in Figure 28. This south-directed thrust faulting is correlated with the D_1 regional thrusting event. The fabrics formed during extension and emplacement of the Raeside Batholith were cut by dextral faults linked to the thrust event. Thrust faulting is well established at the Tarmoola mine, and has been shown to post-date the earlier extensional fabric (Fairclough & Brown 1997).

Regional structures developed during both D_e and D_1 were folded into upright regional north-northwest-trending folds, and overprinted by a steeply dipping cleavage axial planar to these folds during regional approximately east-west shortening (D_2).

East of the Mount George Lineament, the structural pattern mapped from the aeromagnetic images is dominated by north-northwesterly-striking faults, and by folds with axial traces parallel to the faults. Both axial surfaces and faults dip moderately to steeply east. The parallelism of the structures suggests that the faults originated as east-dipping high-angle reverse faults, and are related to the regional folds (formed as hangingwall anticlines and footwall synclines) in a fold-

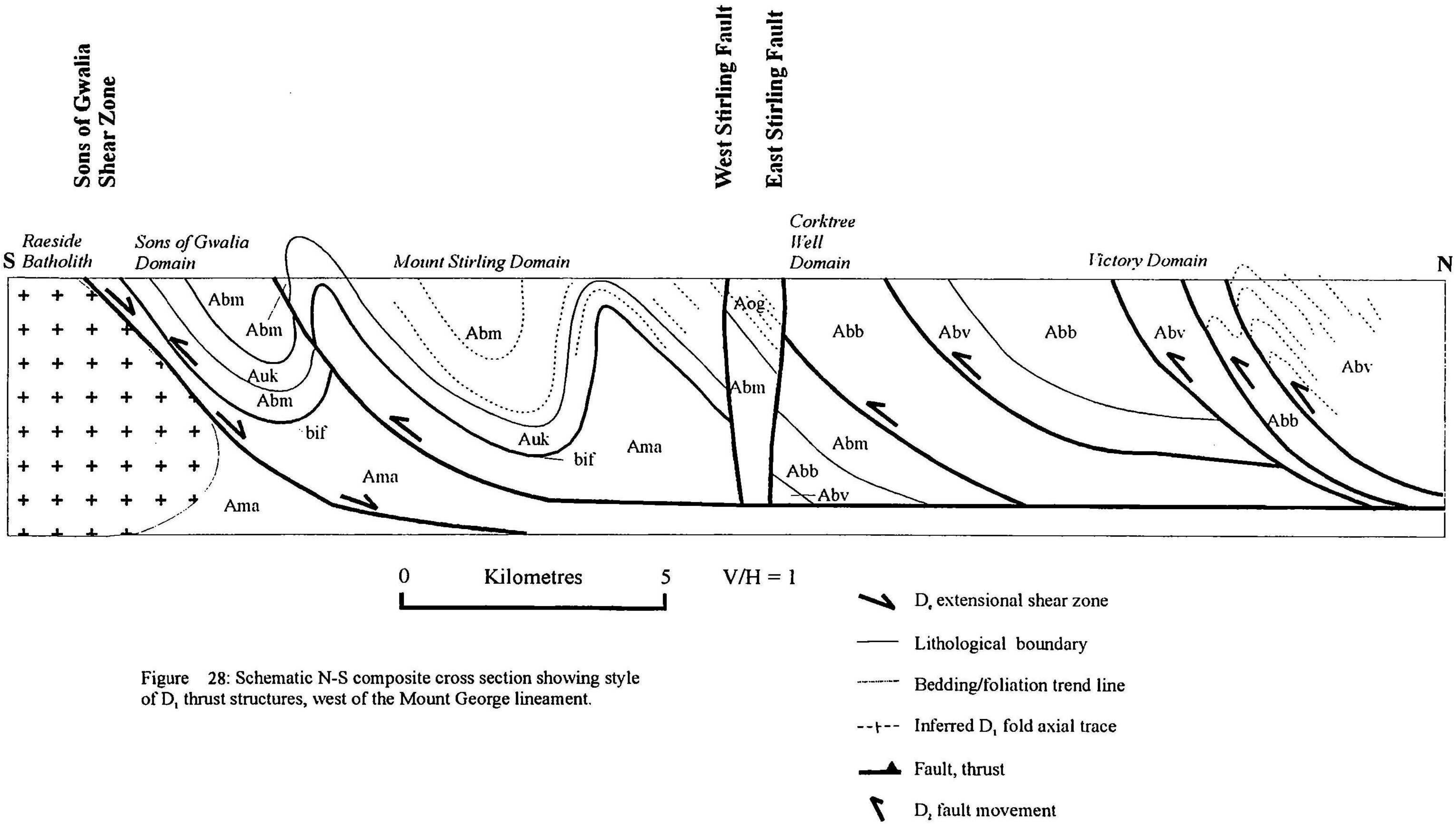


Figure 28: Schematic N-S composite cross section showing style of D_1 thrust structures, west of the Mount George lineament.

thrust belt. The map pattern indicates that the faults cut early D_2 fold hinges. A pervasive mylonitic shear fabric is preserved in some of the D_2 hinge areas, and these fabrics are overprinted by faults and foliations formed during the upright fold-thrust event. The subhorizontal lineation and associated dextral shear indicators in many of the felsic schists east of the Mount George Lineament may be the result of slip in discrete shear zones formed during D_2, or may have formed during an earlier event. The deformation style associated with the D_2 event is shown in schematic cross section in Figure 23. The easterly-dipping primary extensional fault (Sons of Gwalia Shear Zone) was reactivated during D_2 to place ultramafic rocks high in the sequence east of Sons of Gwalia mine. There is no evidence in the eastern domains for large-scale stratigraphic repetitions or overturning during the D_1 thrusting event. Therefore, the interpretation implies that the rocks become progressively older to the east. This is supported by a zircon age of 2692 Ma on felsic volcanics near Leonora (Pidgeon 1986), whereas a U-Pb age on zircon from the Mount Germatong area is older (2735 ± 10 Ma; Pidgeon & Wilde 1990). The geometric reconstruction also implies that the conglomerate in the Pig Well Domain was deposited on units stratigraphically beneath the felsic volcanic rocks, and was therefore unconformable on, and localised within, a basin developed adjacent to the Kilkenny Fault.

Hallberg (1985) earlier concluded that the deformation pattern east of the Mount George Lineament indicated a cross-sectional geometry dominated by a fold-fault pattern formed by east-west compression. The interpretation presented in this report is broadly in agreement with his conclusions.

Discussion

The regional pattern of structures and overprinting relationships in the Leonora area allow a subdivision of the structural history into four main events. On both sides of the Mount George Lineament, the earliest cleavage is inferred to be gently dipping prior to the upright folding event, because in both regions extensive gently dipping to subhorizontal cleavage is present which is not consistent with refolding of an earlier upright or steeply dipping surface. Thus, sense-of-shear indicators, early non-coaxial deformation, and discrete gently dipping mylonite zones indicate an early regional low-angle north-directed ductile normal faulting event. Granodiorite and monzogranite intrusions at the western margin of the greenstone sequence were strongly deformed during this event, and in places were converted into orthogneiss and proto-mylonite at their margins.

The Sons of Gwalia Shear Zone has been mapped from the Mount Ross area to Auckland mine area, and south to the Sons of Gwalia mine. The shear has similar structural and metamorphic features throughout its mapped extent. The observational and textural evidence from Mount Ross in the central west of LEONORA suggests that the shear zone was active during emplacement of the Raeside Batholith. The low-temperature deformation of the granite, and the absence of melting textures and cross-cutting relationships at the granite margins, strongly suggest that the preserved boundary of the granite is a faulted margin, not an intrusive one.

The D_e mylonitic structures associated with the extensional deformation are overprinted by thrust fabrics on the margin of the Raeside Batholith, and also at the Tarmoola mine (Fairclough & Brown, 1997). The thrust event may be the cause of discordant movement indicators, and slivers of granite which form part of the layer-parallel shear zones within the greenstone sequence may have been emplaced during this event. The movement direction during this thrusting was to the south. Movement on the Mount Malcolm Shear Zone was also to the south, and it may also be a D_1 structure. In this report, the south-directed thrust stacking is inferred to be the result of D_1 events, because similar structures in MELITA have an east-west axial trend, typical of D_1 structures in other areas, but perpendicular to the D_2 regional pattern. However, rotation of D_1

fold hinges may have occurred as a result of the local heterogeneity in the strain field caused by the presence of the Raeside Batholith.

The thrust faults and folds east of both the Sons of Gwalia mine and Mount Davis Domain are typified by fault-emplaced ultramafic intervals within the upper felsic rocks east of the mine. The major folds identified in the Gwalia Deeps drill hole have axial surfaces parallel to earlier folded foliation, and folds are verging west on the largest identified scale. Shear zones bounding fold limbs have top-side-west (thrust) movement indicators. The consistent easterly dip of structures across the Keith-Kilkenny High-strain Zone suggests that this thrust event may have significant total movement. The age of this thrust faulting is uncertain, as discussed above, but the orientation of the structures, and the overprinting relationships suggest a correlation with regional D_2 rather than D_1.

Mylonites, shear zones, and the gneissic granite foliation of the extensional event (D_e) are folded around a subhorizontal northwest-trending hinge with steeply dipping axial surface (D_2). Structures of this third event are truncated by faults and shear zones of regional extent striking to the northwest, including the Mount George Lineament (fourth event D_3). The Mount George Lineament forms the western edge of the Keith-Kilkenny High-strain Zone. The eastern bounding structure is not well defined on LEONORA, but may be the Kilkenny Fault. The zone shows a regional pattern of sinistral shear across its entire width. The folds and faults in the zone clearly rotate or truncate the early mylonites, and the major bounding faults are themselves unrotated. The zone is therefore later than the folded mylonites, and by implication at least the sinistral component of the Mount George Lineament is later than the Mount Malcolm Shear Zone and associated structures. Late faults, minor folds, and dykes postdate these events (Thom & Barnes 1977; Skwarnecki 1987; Hallberg 1985), but are not discussed further in this report.

Metamorphism

Metamorphic assemblages vary across LEONORA from quite high-grade in the west adjacent to the Raeside Batholith to much lower-grade in the east, in the Pig Well Domain. Details of the metamorphic assemblages in drill core east of Sons of Gwalia mine (GWDD4) have been presented by Williams & Currie (1993). In the drill core, two contrasting metamorphic assemblages are juxtaposed relatively abruptly across a ductile shear zone, correlated with the Sons of Gwalia Shear Zone. The upper part of the core contains greenschist-facies assemblages, whereas the lower part of the core, within the Sons of Gwalia Shear Zone, contains amphibolite-facies assemblages. Microprobe studies of mineral compositions and application of thermodynamic calculation methods to the results are shown in Table 2.

In the greenschist-facies assemblages, the metamorphic minerals have been strongly overprinted by deformation. Tremolite porphyroblasts lie in the S-C fabric, are commonly augen-shaped, and are strung out in the foliation. Phyllosilicates are wrapped around phenoclasts and shredded. In the amphibolite-facies assemblages, unoriented amphibole idioblasts cut the gneissic fabric, which is defined by granoblastic plagioclase and biotite, and shows little post-crystallisation deformation.

Kyanite-andalusite schist at the water reservoir on the west flank of Mount Leonora is a unique assemblage in LEONORA. The kyanite texturally overgrows the andalusite, suggesting that the high-temperature metamorphism associated with the Sons of Gwalia shear zone was overprinted by a higher-pressure event resulting in the growth of kyanite in rocks of the appropriate composition. There is a weak steep lineation defined by the kyanite porphyroblasts, which suggest formation in an overthrusting environment, unrelated to the extensional structures in the adjacent Sons of Gwalia Domain. Andalusite porphyroblasts which pre-date the D_2 deformation are also common in the Malcolm Domain. No kyanite has been observed in these rocks.

In felsic volcanics east of the Sons of Gwalia Shear, in the Melita Domain, there is a relatively common development of chloritoid, also reported by Witt (1994) from MELITA to the south.

Table 2. Summary of results of thermodynamic calculations applied to mineral chemistry data (Williams & Currie 1993)

	Low-grade rocks (greenschist facies)	***High-grade rocks (amphibolite facies)***
Rock composition	Felsic, ultramafic	Mafic
Assemblages	chlorite-muscovite-biotite (-albite-calcite-magnetite+/-kutnahorite)	oligoclase-tschermakitic amphibole-biotite (+/-magnetite-sphene)
	chlorite-tremolite-calcite (-epidote-sphene+/-biotite)	ilmenite-sphene-calcite-biotite-kspar-quartz
Temperature	370 ± 25°C	600°C (magnetite-ilmenite)
		620°C (amphibole)
Pressure	210 ± 50 MPa	560 MPa
Fluid composition	fluid dominated by water	CO_2/H_2O between 3 and 6.
Fluid pressure	fluid pressure = total pressure	
Oxygen fugacity		$10^{-18.6}$ bars
Inferred T gradient	60°C/km	35°C/km
Structural relationship	minerals earlier than fabric	minerals within or overprinted by fabric

The metamorphic and structural history of LEONORA is summarised in Figure 29. The evidence supports a tectonic evolution from an earliest extensional deformation producing high-temperature/low-to-moderate-pressure metamorphism, overprinted by regional thrust faulting and folding which increased pressure and allowed kyanite growth in appropriate rock types. The deformation overprint in the low-grade rocks reported by Williams & Currie (1993) may have occurred during continued development of the D_2 thrust faults. The only rocks to record the high-pressure event are those of appropriate composition within the metamorphic halo associated with the extensional deformation. The distribution of metamorphic assemblages indicates that the overthrust rocks originated outside the extensional shear zones. The overthrust (upper plate) units do not record the later pressure increase. This relationship is shown in Figure 30 as a schematic P-T-t path for the rocks within the upper and lower plates during the early deformation. Note that the metamorphic data in LEONORA are not constrained by absolute ages on either rocks or mineral phases to allow a definitive P-T-t path to be established.

Proterozoic geology

Mafic to ultramafic dykes (Pdy)

Linear east-northeast-striking dykes have been identified in several localities in LEONORA. These dykes cut all the major structures, and are unmetamorphosed. They are therefore considered to be Proterozoic in age, based on the age of similar parallel dykes in the Norseman area (Fletcher et al. 1987) Distinctive magnetic lineaments are closely coincident with mapped dykes. In addition, several magnetic lineaments cross LEONORA with similar trends to the

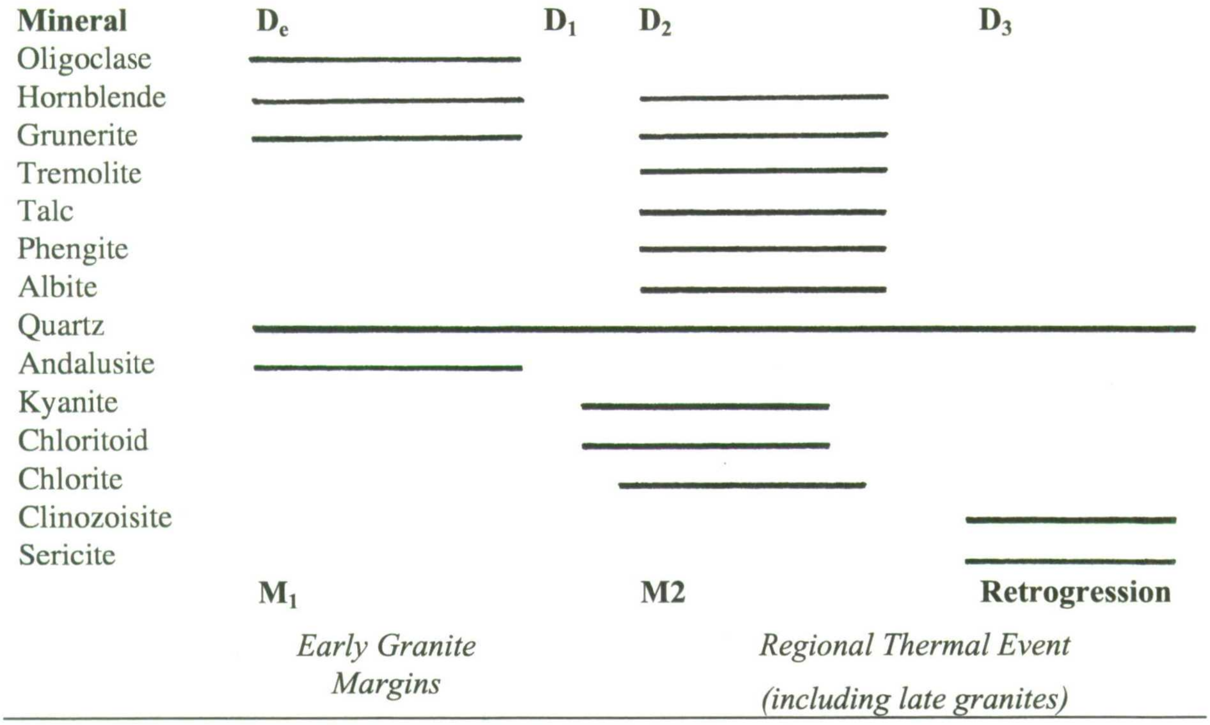


Fig. 29. Timing of metamorphic mineral growth relative to structural events.

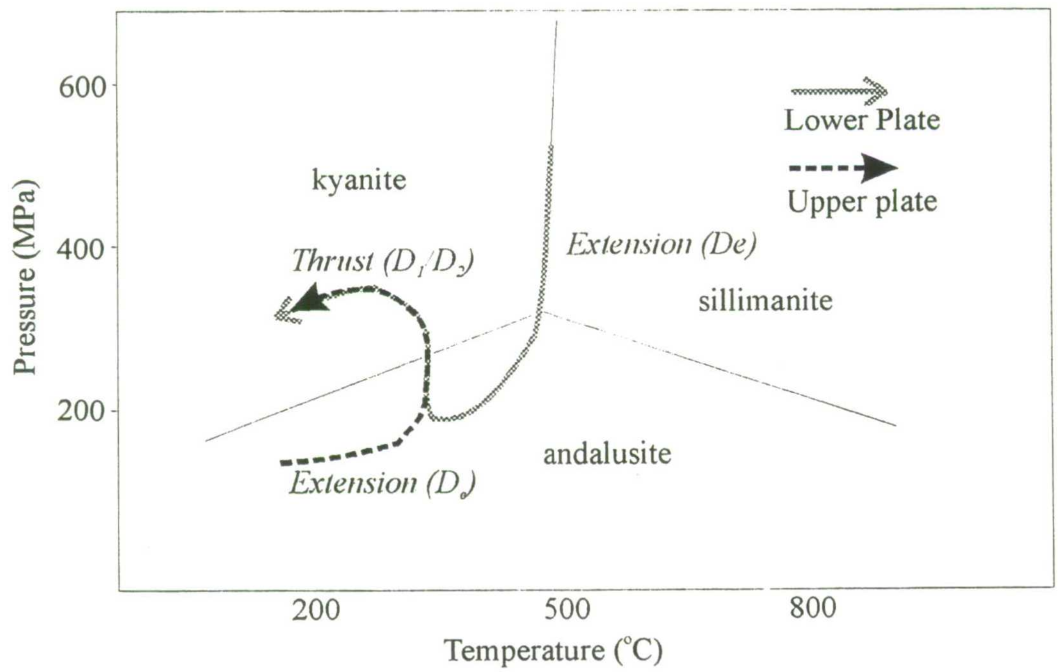


Figure 30. P-T-t path inferred at the boundary of Raeside Granite dome during emplacement and subsequent $D_{1/2}$ thrust faulting. Texturally late growth of kyanite parallel to the D_2 lineation indicates formation after extension.

known dykes; these lineaments are interpreted to mark the position of unexposed dykes of the same suite (Fig. 2).

The King of the Hills Dyke (Thom & Barnes 1977; Hallberg 1985) forms a prominent ridge extending from near Robbies Well (GR050265) to south of West Terrace (GR470340). North of Robbies Well, the dyke is granophyric with abundant pegmatitic and graphic granite clasts, particularly near its margins. There are also patches of vein quartz which have an irregular shardparticularly near its margins. There are also patches of vein quartz which have an irregular shard-like shape, suggesting their derivation from fracturing of the wall rock and incorporation into the dyke during emplacement (Fig. 31). Near Cocoa Bore, the dyke is mafic, but has granite pegmatite xenoliths concentrated near its centre. Feldspar crystals in the pegmatite are 30-40 mm across. In this region, there are also basalt and diorite clasts which are restricted to the margins of the dyke, suggesting derivation from the local greenstone sequence. There is a xenolith-free zone with a chilled margin which extends about 6 m from the edge of the dyke. The central region of the dyke north of Cocoa Bore is marked by a zone of sericitic, probably deuteric, alteration. The dyke is irregular in thickness, ranging from a few metres wide in the east to up to 1.5 km wide north of Kent Bore (GR28032). It has been emplaced as two major strands. The northern strand continues from the east of the map to the fault separating the Corktree Well and Mount Stirling Domains. The western strand crosses this fault to the south of the eastern strand, with no apparent displacement, but does not continue east of Cocoa Bore. This observation suggests that the Mount Stirling Fault Zone acted as a mechanical heterogeneity during the emplacement of the dyke, and prevented fracture propagation.

Figure 31. Quartz inclusions in the King of the Hills Proterozoic dyke.

The dyke north of Braemore Station (GR386082) is more typical of the post-metamorphic dykes in LEONORA. It is an unmetamorphosed dolerite with minor deuteric alteration.

Cainozoic geology

No detailed investigation of the Cainozoic geology was undertaken during the current investigation. Division of the area into regolith terrain units is being reported separately (Craig & Churchward 1997). The regional pattern of regolith landforms has been described by Chan et al. (1992). LEONORA includes parts of seven regolith landform provinces. Lake Raeside is the topographically lowest area, and is fed from the north by the major drainage systems of Sullivans Creek, Station Creek, and Dodger Creek. The lake separates dominantly depositional plains (regolith terrain 'Se'; Chan et al. 1992) to the south from large alluvial fan and weathered bedrock terrains to the north ('Sf', 'Bh' and 'Dr' units). Cainozoic unit boundaries on the geological map were derived from aerial photograph interpretation. Boundaries between units are commonly gradational.

Colluvium and derived material (Cza, Czc, Czg)

These deposits include colluvial and alluvial sheetwash sand, and pebble to cobble gravel and breccia, generally in large areas of low relief. In the east, around Boys Well (GR467230), the deposits form inactive alluvial fans heavily dissected by the current dendritic drainage pattern.

Sand plain (Czs)

Characteristic brown quartz sand forms flat gently north-sloping plains vegetated with spinifex and mallee eucalypts on the Bundarra Granite in the northeast. The area is bounded by low cliffs (breakaways), which generally comprise a layer of silcrete above a thick pallid zone of remnant quartz grains in kaolin. The silcrete gives way to and underlies sand plains within a short distance of the breakaways.

Playa lake deposits (Czp, Czd)

Lake Raeside is the only salt lake in LEONORA, and contains halite and gypsum interbedded with grey sticky malodorous clay and sand (Czp). In some winter seasons these deposits are covered with water, but otherwise the unit is characterised by a surface coating of halite.

The lake is flanked by a variety of saline plains and aeolian deposits (Czd) dominated by sand dunes. The dunes are covered with salt-tolerant vegetation, and groundwater derived from the dune areas is invariably highly saline. The boundary between these deposits and the surrounding sheetwash deposits (Czc) is gradational, but there is a sharp boundary visible on Landsat TM images which represents the change of vegetation type to less salt-tolerant varieties, including mulga, away from the influence of the lake.

Laterite and lateritic deposits (Czl, Czf)

Laterite (Czl) is restricted to small remnants capping mesas (eg., GR364113), and is invariably flanked by aprons of talus comprising laterite pisoliths (Czf). Deposits of laterite pisoliths alone are far more widespread than the laterite. Good examples occur around the Malcolm Dam area (GR480090) and in the northwest (GR130380).

In-situ cap-rock and derived products (Czu)

Small areas of buff-coloured silicic rocks are interpreted as Cainozoic silicification products of Archaean ultramafic rocks. The rocks are in narrow bands concordant with the layering of enclosing rocks. They usually occur in layer-parallel fault zones, and retain the structure (and in places the fabric) of the primary rocks. Examples occur at Mount Ross (GR100228), east of Tarmoola (GR220226), and north of Auckland (GR260183 and 260187). In the Mount Ross area, they form distinctive ridges. The rocks are composed of undeformed chalcedonic silica. Similar silicic cap rocks over ultramafic horizons have been reported from north of LEONORA (Hill et al.1990), where the cap rocks preserve the cumulate textures of the original peridotite. Around GR250310, a north-northwest-trending ridge with rare exposures of peridotite is covered by lag deposits of chalcedony and minor magnesite. These are interpreted to be the result of *in situ* serpentinisation of the underlying peridotite. Ridges of similar chalcedonic silica in the northeast (eg GR080440) may be of similar origin.

Alluvium (Qa)

Areas of unconsolidated river sands and gravels containing present-day streams and their associated flood plains are included in this unit.

Economic geology

Gold

Gold production from mining centres on or overlapping LEONORA is shown in Table 3. Table 4 lists resources in LEONORA 1:100 000 Sheet area, and also includes production figures from old workings. Significant gold-producing centres are described below.

Table 3. Reported gold production, LEONORA and environs. Data supplied by Geological Survey of Western Australia

Mining Centre	Ore treated (t)	Grade (g/t)	Gold therefrom (kg)	Total gold (kg)
Cardinia	7710.77	20.00	154	209
Diorite	78629.88	17.67	1390	1436
Dodger's Well	2858.7	30.91	88	91
Lake Darlot	104092.71	18.32	1907	2092
Leonora	8866272.37	10.15	89967	90145
Mertondale	94872.45	20.77	1970	1991
Mt Clifford	15650.41	40.09	627	742
Mt Malcolm	68889.19	22.71	1565	1572
Pig Well	16782.49	29.49	495	496
Randwick	13750.36	25.02	344	359
Webster's Find	24917.18	19.86	495	520
Teutonic Bore			10	10
Wilson's Creek	659.92	20.24	13	14
Wilson's Patch	31412.55	14.44	454	463
Mt Malcolm District Sundry Production	3244.91	369.90	1200	1354

West of the Mount George Lineament

Sons of Gwalia mine

Mineralisation at Sons of Gwalia mine occurs in highly foliated chlorite-sericite-quartz (± pyrite) schist in a zone up to 150 m wide and extending for 400-500 m along strike. The mineralised zone is pipe-like, plunging down the dip of the foliation for about 1700 m. Average dip of the lode system and foliation is 45° towards 106°, average pitch of the orebody within the foliation is 70° to the south (Finucane 1965; Kalnejais 1990). Underground mining was conducted on a number of high-grade shoots and lodes in the mineralised zone, all elongated parallel to the foliation with a pitch in the same direction as the pervasive mineral lineation (70° south). A feature of the Sons of Gwalia mineralisation is the change in strike of the lithological boundaries in the vicinity of mineralisation. The early foliation remains parallel to the lithological boundaries. The lode horizons are interpreted as zones of more intense shearing and fluid flow

Table 4. A. Resources, and B. Production figures from old workings, LEONORA 1:100 000 Sheet area. Data supplied by Department of Minerals and Energy, Perth, Western Australia

SITE	Cat	Type (res)	Geology	Tonnage (M	Grade (g/t)	Mineral	Cont Metal (t)	Date	Ref	Type	Stage	Latitude	Longitude	Easting	Northing
BLACKIES	INF	I/S	Shear	0.04	1.8	Au	0.072	29/06/94	Mdex	DO		28.9314	121.4072	344749	6798562
FORGOTTEN FOUR	IND	I/S	Shear	0.186	2.1	Au	0.391	30/09/95	Mdex	MO	S	28.9283	121.4117	345179	6798905
FORGOTTEN FOUR	INF	I/S	Shear	0.032	2.1	Au	0.067	30/09/95	Mdex			28.9283	121.4117	345179	6798905
GWALIA NORTH	INF	I/S		0.556	2.1	Au	1.168	30/06/91	Mdex	DO		28.7969	121.2936	333460	6813304
GWALIA NORTH	IND	I/S		0.068	2.3	Au	0.156	30/06/91	Mdex			28.7969	121.2936	333460	6813304
GWALIA NORTH GROUP									Mdex	DO		28.8464	121.3047	334623	6807841
HARBOUR LIGHTS GROUP	MES	MIN		0.014	42.4	Au	0.594	31/12/93	Mdex	MO	S	28.8750	121.3205	336213	6804693
HARBOUR LIGHTS OPEN CUT									Mdex	MO	S	28.8750	121.3206	336213	6804693
HARBOUR LIGHTS UNDERGROUND	INF	I/S	Shear	0.507	7.3	Au	3.701	20/08/93	Mdex	DU		28.8750	121.3206	336213	6804693
HARLECH	IND	MIN	Shear						Mdex	DO		28.7380	121.2111	325308	6819713
IRON KING									Mdex	DO		28.5319	121.0858	312707	6842364
JASPER - AUCKLANDS	IND	MIN	Shear	0.75	2.6	Au	1.95	31/03/93	Mdex	DO		28.7603	121.2425	328411	6817296
JASPER HILL / DOMINION									Mdex	MO	S	28.7583	121.2222	326428	6817482
KRANG	IND	I/S	Shear	0.424	1.9	Au	0.806	30/09/95	Mdex	DO		28.9258	121.4030	344340	6799180
KRANG	INF	I/S	Shear	0.33	1.9	Au	0.627	30/09/95	Mdex			28.9258	121.4030	344340	6799180
LADY SMITH									Mdex	DO		28.8169	121.3722	341164	6811197
LEONARDO	IND	I/S	Shear	0.55	1	Au	0.55	30/09/95	Mdex	DO		28.9350	121.4150	345510	6798170
LEONARDO	INF	I/S	Shear	0.55	1	Au	0.55	30/09/95	Mdex			28.9350	121.4150	345510	6798170
LEONORA GROUP	IND	MIN		1.23	2.5	Au	3.075	30/06/95	Mdex	DO		28.7603	121.2425	328411	6817296
LEONORA GROUP	INF	I/S		1.44	1.9	Au	2.736	30/06/95	Mdex			28.7603	121.2425	328411	6817296
LEONORA GROUP	IND	I/S		0.12	1.8	Au	0.216	30/06/95	Mdex			28.7603	121.2425	328411	6817296
LINGER AND DIE / DECADE									Mdex	MO	S	28.6297	121.3175	335531	6831869
MICHAELANGELO - FORGOTTEN FOU	IND	I/S	Shear	1.609	2	Au	3.218	30/09/95	Mdex	DO		28.9361	121.4178	345785	6798051
MICHAELANGELO - FORGOTTEN FOU	INF	I/S	Shear	0.499	1.9	Au	0.948	30/09/95	Mdex			28.9361	121.4178	345785	6798051
MT DAVIS	INF	I/S		0.2	1.8	Au	0.36	30/09/94	Mdex	DO		28.7058	121.2358	327673	6823323
POKER	IND	I/S	Shear	0.09	2.6	Au	0.234	31/03/93	Mdex	DO		28.8464	121.3047	334623	6807841
POKER	INF	I/S	Shear	0.04	3.2	Au	0.128	31/03/93	Mdex			28.8464	121.3047	334623	6807841
PROSPERO	INF	I/S		1.6	1.2	Au	1.92	10/04/95	Mdex	DO		28.8675	121.4136	345284	6805657
PROSPERO	INF	I/S		0.6	1.9	Au	1.14	10/04/95	Mdex			28.8675	121.4136	345284	6805657
PUMPING STATION	IND	MIN		0.18	2	Au	0.36	30/09/94	Mdex	DO		28.7939	121.2936	333452	6813639
RAESIDE GROUP	IND	I/S	Shear	2.797	1.8	Au	5.035	30/09/95	Mdex	MO	S	28.9283	121.4117	345179	6798905
RAESIDE GROUP	INF	I/S	Shear	1.451	1.6	Au	2.322	30/09/95	Mdex			28.9283	121.4117	345179	6798905
RAESIDE GROUP	DEM	MIN	Shear	1.1	2.4	Au	2.64	28/06/96	Mdex			28.9283	121.4117	345179	6798905
SAVANNAH									Mdex	DO		28.8705	121.3255	336692	6805193
SEVERN	IND	MIN	Shear						Mdex	DO		28.6975	121.1983	323993	6824189
SEVERN WEST	IND	I/S	Shear	0.03	2.9	Au	0.087	30/09/94	Mdex	DO		28.6978	121.1944	323613	6824151
SONS OF GWALIA OPEN CUT	MES	MIN	Shear	4.6	3.5	Au	16.1	30/06/95	Mdex	MO	O	28.9183	121.3314	337337	6799905
SONS OF GWALIA OPEN CUT	IND	MIN	Shear	1.4	3.6	Au	5.04	30/06/95	Mdex			28.9183	121.3314	337337	6799905
SONS OF GWALIA TAILINGS									Mdex	MT	S	28.9267	121.3283	337053	6798978
SONS OF GWALIA UNDERGROUND	INF	I/S	Shear	4	3.5	Au	14	30/06/94	Mdex	DU		28.9183	121.3314	337337	6799906
SPLINTER	IND	I/S		0.028	3.9	Au	0.109	30/09/95	Mdex	DO		28.9333	121.4155	345560	6798370
SULLIVAN CREEK - LEONORA	DEM	MIN	Margin	0.1	100%	SAND	100 000	1/09/92	Mdex	MO	O	28.7533	121.1669	321021	6817955

TARMOOLA - KING OF THE HILLS	DEM	MIN	Margin	14.341	2.47	Au	35.422	31/03/96	Mdex	MO	O	28.6728	121.1617	320368	6826873
TARMOOLA - KING OF THE HILLS	DEM	I/S	Margin	17.079	1.97	Au	33.646	31/03/96	Mdex			28.6728	121.1617	320368	6826873
TARMOOLA - KING OF THE HILLS	DEM	I/S	Margin	5.658	0.61	Au	3.451	31/03/96	Mdex			28.6728	121.1617	320368	6826873
TARMOOLA DEEPS	INF	I/S	Margin	0.5	4.58	Au	2.29	22/08/95	Mdex	DU		28.6728	121.1616	320367	6826873
TARMOOLA LATERITES	DEM	MIN	Laterite	0.235	1.38	Au	0.324	30/09/95	Mdex	MO	O	28.6703	121.1561	319821	6827142
TARMOOLA NORTHEAST EXTENSION			Margin						Mdex	X		28.6681	121.1636	320550	6827399
TOWER HILL OPEN CUT			Margin						Mdex	MO	C	28.8989	121.3214	336332	6802046
TOWER HILL UNDERGROUND	INF	I/S	Shear	0.25	2.91	Au	0.727	30/06/92	Mdex	DU		28.9003	121.3217	336361	6801892
TOWER HILL UNDERGROUND	DEM	I/S	Shear	0.2	2.91	Au	0.582	30/06/92	Mdex			28.9003	121.3217	336361	6801892
VICTOR WELL									Mdex	DO		28.8130	121.2714	331317	6811489
VICTORY / HEALD									Mdex	DO		28.5114	121.0464	308809	6844580
MOUNT STIRLING			Granite	0.033	54	Au	0.157	1954	List	MU	O			311120	6834050
DIORITE KING			Shear	0.001	79	Au	0.078	1954	List	MU	C			310250	6825000
BLUE SPEC			Shear		59	Au	0.002	1954	List	MU	C			308600	6844500
VICTORY			Shear	0.037	100	Au	0.325	1954	List	MU	C			309100	6844220
IRON KING			Shear		23	Au	0.002	1954	List	MU	C			312700	6842364
GAMBIER LASS			Shear		29	Au	0.225	1954	List	MU	C			351000	6819200
HARRISTON			Shear		58	Au	0.095	1954	List	MU	C			351850	6813550

Key to abbreviations

Cat - category: INF - inferred resource; IND - indicated resource; MES - measured resource; DEM - demonstrated resource

Type (res) - type of resource: I/S - in situ; MIN - mineable

Geology: Margin - granite/greenstone margin, mineralisation in granite; Shear - mineralisation in faults in greenstones

Type - type of deposit: DO - deposit, open pit; DU - deposit, underground; MO - mine, open pit; MU - mine, underground; MT - mine, tailings; X - another resource reference applies

Ref - reference: Mdex - MINEDEX database, Geological Survey of Western Australia; List - List of cancelled gold mining leases which have produced gold. Western Australia Department of Mines, 1954 (reprinted 1980), Perth within the system; the high-grade shoots may have nucleated at irregularities in the shear zone and propagated parallel to the movement direction. The presence of weakly deformed mafic rock to the immediate west of the mineralised zone is considered to be significant, and the Sons of Gwalia mineralisation may have formed adjacent to this competent mass during deformation in the Sons of Gwalia Shear Zone, because of concentration of fluid flow in high-strain volumes.

Harbour Lights mine

Mineralisation at the Harbour Lights mine lies within a zone of strong alteration and deformation, containing quartz-dolomite-biotite-chlorite-fuchsite schist and talc-chlorite-biotite-carbonate schist, with several lenticular felsic bodies and thin quartzite layers, the last probably being metamorphosed quartz veins. The geology and distribution of gold mineralisation within the zone and its geochemical characteristics have been described in detail by Skwarnecki (1987) and by Dudley et al. (1990). The main structural characteristic of the mineralisation is the presence of an unmineralised massive quartz-carbonate-mica alteration assemblage in small to large boudins. The larger boudins commonly have fuchsitic selvedges. Alteration and veining around the boudins, together with mineralisation in the fuchsitic selvedges, show that the boudins influenced the local flow of mineralising fluids. Fuchsitic selvedges adjacent to the quartz-carbonate megaboudins are among the most intensely mineralised zones of the mine. Mineralised zones tend to pinch out between boudins, imparting an apparent shallow southerly plunge to the orebodies, parallel to the boudin axes. While this may define the plunge on an ore lens scale, the ore zone as a whole has greater continuity in a direction parallel to the stretching lineation developed in the area, pitching approximately down-dip.

The association of ore lenses with specific features developed during the formation of shear zones, and contemporaneous alteration and shearing (Dudley et al. 1990), are strong arguments for synchronous deposition of the ore and bulk rock deformation at both Sons of Gwalia and Harbour Lights Mines. Folding of mineralisation by late upright folds (F_2) (Williams et al. 1989; Dudley et al. 1990) also demonstrate that mineralisation at Harbour Lights mine took place before regional F_2 folding.

Tower Hill mine

The orebody at Tower Hill mine lies between the Harbour Lights and Sons of Gwalia mines, and is located adjacent to the Raeside Batholith, which formed the footwall to the orebody. Strike length is 600 m, and the orebody extended across strike for about 150 m. Mineralisation was in a number of quartz lodes developed parallel to the structural fabric and lithological boundaries (Schiller & Hanna 1990). The host rock is chlorite-biotite-sericite-fuchsite-carbonate schist. Lodes at Tower Hill mine are folded with the schistosity (Schiller & Hanna 1990), indicating a timing of lode formation in relation to deformation structure that is similar to Sons of Gwalia and Harbour Lights mine.

The extension of the Sons of Gwalia Shear Zone to the north is also mineralised, with a large number of prospects following the trace of the shear zone (Poker GR346078, Trump GR341078, Ping Pong GR335083, Station Creek GR309124, Auckland GR284173, Jasper Hill GR272162, and Wonder GR107227). The Sons of Gwalia Shear Zone contains mines at Jasper Hills and King of the Hills.

Tarmoola mine

At Tarmoola mine (GR204268), mineralisation is located in and around a small granitoid intrusion, that was discovered after exploitation of King of the Hills and Arboyne Mines in the same area. The bulk of the currently exploited economic mineralisation is in quartz veins in the greenstones. Mineralisation appears to be controlled by the heterogeneities caused by the presence of the granitoid body within the shear zone, but detailed structural controls on the mineralisation have not been released to date.

Mount Stirling

Mineralisation also occurs at Mount Stirling, where a quartz-vein stockwork has been mined in a granite stock (GR111341). Production was more than 3300 t of ore for 5610 oz of gold at an average grade of 54 g/t.

Diorite King

Diorite King (GR102250) in the west comprises mineralised quartz veins in brittle metabasalt units. Fracturing appears to be associated with anastomosing shear zones in the basalt, which were probably formed during extensional movement on the Sons of Gwalia shear zone. Diorite King produced in excess of 2800 oz of gold from 1134 t of ore (average grade 79 g/t)

Other workings

In the north of LEONORA, a line of workings follows a cherty mylonitic horizon in basalt. Historical (pre-1954) production from Blue Spec (~GR4408; 322 oz @ 59 g/t), Victory (GR084436; 11 636 oz from 3726 tonnes @ 100 g/t), and Iron King (GR127423; 69 oz @ 23 g/t) demonstrate that the east-striking structure hosting these deposits was productive and hosts several small but rich deposits. There is no evidence of late cross-cutting structures in these areas, suggesting that the deposits may have formed at the same time as the mylonite. Mineral lineations in the host rocks of these workings plunge north approximately down-dip on the bedding/foliation surface, and appear to control the mineralisation.

Discussion

The Mount George Lineament and parallel bounding fault on the eastern side of the Keith-Kilkenny High-strain Zone are not mineralised, although splays off these or equivalent structures often contain mineralisation (eg., Mertondale mine, Nisbet & Williams 1990; Emu-Lawlers mine, Groves et al. 1989). Mineralisation is also present in faults striking east-northeast at Victor Well (Riviera) mine (GR312124), where the gold is dominantly in quartz veins. In contrast, the Tarmoola deposit lies on the northern margin of the Sons of Gwalia Shear Zone, in common with the other major deposits of the Leonora district.

Consequently, significant potential for discovery of large gold deposits in the Leonora area lies in the early (D_e or D_1) higher-strain shear zones of higher metamorphic grade, rather than in the more easily identified late vertical (D_2) structures of lower strain and metamorphic grade. The identification of these early zones may be aided by the observation that all of the siliceous or cherty bands examined to date contain a mylonitic fabric, and mark high-strain zones of the early (D_e or D_1) deformation. Silicification leading to the formation of these siliceous/cherty bands took place either before or during the early deformation, and hence their location can be used in field mapping to determine the position in the structural sequence of high-strain zones, and differentiate between early and late mylonites.

East of the Mount George Lineament

Mineralisation east of the Mount George Lineament is largely hosted in brittle fractures associated with quartz vein development. The veins are normally undeformed, and commonly in brittle host rocks adjacent to shear zones. The ore bodies at Pride of Leonora, Rabbit Warren, and Pig Well fall into this category.

Golden Crown

At the Golden Crown (GR489031) in the Malcolm Mining Centre, mineralisation is localised near a north-dipping shear zone at the boundary between a porphyry unit and andesitic volcanic rocks (Hallberg 1985), close to a distinctive foliated chert-hematite interval. Mineralisation is in massive quartz veins which cross-cut the foliation and are interpreted to have formed late in the movement history of the north-dipping shear zone. The map pattern shows that there was little, if any, offset of the chert-hematite unit by later faults. However, the early structures have been folded, and the timing of mineralisation at Malcolm and the vicinity is equivocal.

Gambier Lass

Gambier Lass (GR500192) has been a significant producer in the Pig Well Mining Centre near the eastern margin of LEONORA, producing 8075 oz at an average 29 g/t. Mineralisation is in quartz veins, which cut the early foliation and overturned folding in the conglomerate and sedimentary units forming the host rocks. Therefore the mineralisation is most likely related to late movement on the major faults bounding the Pig Well Domain, and hence may be of a different generation from the gold at Leonora.

Harriston

Harriston (GR519135) was the other major producer in the Pig Well Mining Centre (3406 oz @ 58 g/t), and appears to be related to quartz veins adjacent to a porphyry intrusion into the conglomeratic host rocks. Exposure is poor, and controls on the mineralisation are not well known.

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Appendix 1: List of thin sections and rock samples mentioned in text

Sample No.	Location	Grid Ref.	Description
87963410	Braemore	391068	Quartz-sericite schist
87963412	Braemore	390074	Dolerite
87963419	Braemore	387073	Quartz-sericite schist
87963519	Mount Malcolm	519001	Gabbro
87963420	Braemore	386071	Quartz-phengite schist
87963429	Braemore	388093	Felsic tuff
87963434	Braemore	394107	Felsic volcanic rock
87963440	Mount Ross	083211	Granite mylonite
87963449	Mount Ross	102245	Amphibolite
87963452	East of Mount Leonora	111237	Quartz mica schist
87963473a	Mount Ross	098224	Amphibolite
87963473b	Mount Ross	098224	Amphibolite
87963482	Auckland Hills	258158	Granodiorite
87963492	Victory area	137420	Gabbro
87963498	Mount Malcolm	462035	Andalusite schist
87963518	NE of Mount Malcolm	505056	Quartz-sericite schist
87963519	NE of Mount Malcolm	519061	Dolerite
87963532	Braemore	371085	Felsic tuff
87963541	Leonora	375040	Quartzite
87963570	Gambier Lass area	518185	Porphyry
87963610	Auckland Hills	272168	Quartzite
88963033	Iron King area	087452	Mylonitic shale
88963011	Victory area	043450	Chalcedony
88963033	Victory area	087452	Quartz-phengite schist
88963028	Victory area	074434	Chert
88963087	Mount Stirling	098368	Gabbro
88963180a	Mount Ross	068209	Granite mylonite
88963283	Hick Well	121192	Gneiss
1110-2	Sons of Gwalia	385000	Quartz-mica schist
AB140085	GWDD4	390987	Amphibolite
WMC 140090	GWDD4	390987	Amphibolite
HL3,173.5m	Harbour Lights	353055	Mafic schist
JH-1	Auckland Hills	270170	Quartzite

Appendix 2. List of chemically analysed samples (from AGSO's ROCKCHEM database)

Sample number	Area	Grid ref.	Rocktype	Rock unit or grouping
87963444	Mount Stirling	113339	Qz-phyric granite	Agm
88963025	Victory	090442	Hi-Mg basalt	Abm
88963036A	Victory	106434	Lamprophyre	lp
88963036B	Victory	106434	Lamprophyre	lp
88963036C	Victory	106434	Lamprophyre	lp
88963096	Mount Stirling	130343	Hi-Mg basalt	Abm
88963103	Balkan Well	115390	Vesicular basalt	Aby
88963104	Balkan Well	106379	Hi-Mg basalt	Abm
88963304	Auckland	271168	Lamprophyre	Dyke in Auckland Pluton
89963019	Robbies Well	096248	Porphyry	Porphyry dyke, Robbies Well Pl.
89963020	Robbies Well	096248	Syenogranite	Robbies Well Pluton
89963021	Diorite King	100250	Tonalite gneiss	Inclusions or sweats in Ala
89963022	Jasper Hill	260152	Tonalite gneiss	Auckland Pluton
89963379	Metzke Bore	152020	Granodiorite gneiss	Hick Well Pluton
89963380	Jasper Hill	250140	Granite	Auckland Pluton
89963381	Trump	336077	Granite	Auckland Pluton
89963382	Braemore	390088	Dolerite	Aod
89963383	Mount Ross	067206	Porphyry dyke	Hick Well Pluton
89963385	Mount Stirling	142351	Hi-Mg basalt	Abm
89963384	Mount Cutmore	093327	Porphyry	Porphyry dyke in basalt Abb
89963385	Mount Stirling	142351	Hi-Mg basalt	Abm
89963386	Balkan Well	116367	Hi-Mg basalt	Abm
89963387	Balkan Well	105386	Basalt	Abb
89963388	Iron King	136416	Granodiorite	Dyke in basalt Abb
89963389	Iron King	108419	Basalt	Abb
89963390	Victory	093442	Hi-Mg basalt	Abm
89963391	Grattan Well	271222	Hi-Mg basalt	Abm
89963505	Linger and Die	363305	Granodiorite	Agg (Linger and Die)
89963506	Stirling	117295	Basalt	Abb
89963507	Stirling	093327	Basalt	Abb
89963508	Tower Hill	363020	Tonalite	Auckland Pluton
89963509	Metzke Bore	152020	Microgranite	Hick Well dyke
89963510	Metzke Bore	152020	Tonalite gneiss	Hick Well Pluton
92969036	White City Well	157002	Granite	Raeside Batholith, other
92969037	Metzke Bore	158002	Syenite dyke	Raeside syenite
92969051	White City Well	205958	Granite	Raeside Batholith, other
92969083	Penzance	309353	Granite	Bundarra Batholith
92969084	Penzance	342358	Granite	Bundarra Batholith
92969085	Penzance	324412	Granite	Bundarra Batholith
94969599	Tarmoola mine	204273	Granodiorite	
94969712A	Tarmoola mine	204273	Amphibolite	
94969712B	Tarmoola mine	204273	Chloritic granite	
94969712C	Tarmoola mine	204273	Granite	
94969712D	Tarmoola mine	204273	Bleached granite	
94969712E	Tarmoola mine	204273	Mineralised breccia	
94969712F	Tarmoola mine	204273	Altered ultramafic	
94969712G	Tarmoola mine	204273	Fresh granite	
94969713A	Tarmoola mine	204273	Semi-bleached granite	
94969713B	Tarmoola mine	204273	Bleached granite	
94969713C	Tarmoola mine	204273	Granite	
94969714	Tarmoola mine	204273	Bleached granite	
94969715A	Tarmoola mine	204273	Bleached granite	
94969715B	Tarmoola mine	204273	K-feldspathised granite	
94969715C	Tarmoola mine	204273	Granodiorite	
94969715D	Tarmoola mine	204273	K-feldspathised granodiorite	

94969715E	Tarmoola mine	204273	Fresh granodiorite	
822	Tarmoola mine	204273	Dolerite	
1797	Tarmoola mine	204273	Hi-Mg basalt	
1798	Mount George	344098	Hi-Mg basalt	Abm
1799	Mount Ross	140268	Hi-Mg basalt	Abm
1800	Victory Cnr W.	124403	Basalt	Abb
1801	Balkan Well	108373	Hi-Mg basalt	Abm
1802	Balkan Well	108362	Hi-Mg basalt	Abm
1803	Balkan Well	081370	Basalt	Aby
1814	Sons of Gwalia	356002	Talc schist	
1890	Tower Hill	359021	Peridotite	
1891	Mount Leonora	375010	Clastic sediment	
1892	Mount Leonora	375010	Clastic sediment	
2425	Gambier Lass	532193	Dacite	Afp
2426	Gambier Lass	514211	Dacite	Afp
2427	Gambier Lass	516192	Dacite	Afp
2468	Gambier Lass	532193	Dacite	Afp
2471	Gambier Lass	516192	Dacite	Afp
2473	Pig Bore	464153	Syenite	Pig Well syenite
106657	Mount Stirling	113326	Plagiophyric granite	Porphyry dyke in basalt Abb