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Contents

Abstract

The Mount Keith 1:100 000 Sheet area in the north of the Eastern Goldfields Province of the Archaean Yilgarn Craton, Western Australia, covers parts of the Mount Keith-Perseverance, Yakabindie, and Yandal greenstone belts. The greenstones comprise (in decreasing order of abundance): tholeiitic basalt, felsic volcanic and volcaniclastic rocks, ultramafic lavas, high-magnesium basalt, banded iron formation and chert, and siliciclastic rocks, intruded by small bodies of dolerite and gabbro. Gabbro, pyroxenite, and anorthosite form a layered mafic intrusion in the Yakabindie belt. Conglomerate and arkose (Jones Creek Conglomerate) make up the youngest Archaean unit recognised in the Mount Keith-Perseverance belt, and are unconformable on an early (syn-greenstone) granite intrusion. The greenstones are metamorphosed to greenschist facies. Voluminous poorly exposed granite occupies the regions between, and intrudes or is faulted against them. Most is Low-Calcium monzogranite, but High-Calcium and high-field-strength-element-enriched granites are also abundant; two small mafic internal granites intrude greenstone in the southeast. The major structural elements in the area trend north-northwest, and include: the steeply dipping layering of the greenstones, which is the result of major northerly-trending folding D2; steeply dipping foliation S2 (with an element of sinistral shear in the Mount Keith mine area); stretching lineation L2 plunging gently north or south; and major steeply dipping faults across the entire Sheet area. Small-scale structures are steeply plunging F3 folds, crenulations, and kink bands, with dextral sense of shear in some places, sinistral in others. An early south-dipping cleavage S1 has been previously reported in the Mount Keith mine area. Conjugate sets of D4 fractures striking northeast and southeast or east-southeast cut the greenstones and granites; the east-southeast-striking set was injected by Proterozoic mafic dykes in the north. Major mineral deposits include the Mount Keith nickel mine in the west, and the Bronzewing and Mount McClure gold mines in the southeast. The Mount Keith nickel deposit is a large-tonnage low-grade disseminated nickel sulphide deposit hosted by olivine cumulate in ultramafic volcanic rocks; resources at March 1997 were 588 Mt at 0.60% Ni (AGSO OZMIN database, May 1998). Bronzewing and the two northern deposits of the Mount McClure group occur in sequences of basalt, dolerite, ultramafic rocks, clastic sediments, and, at Mount McClure, felsic volcanic rocks. Hydrothermal fluid altered the rocks along major shear zones and precipitated gold, Fe-sulphide, and carbonate. Favourable structure was particularly important at Mount McClure, and ore occurs in both Fe-poor and Fe-rich rocks. Resources at Bronzewing (March 1997) were 38.1 Mt at 2.9 g/t Au, and at Mount McClure (all deposits) 12.7 Mt at 2 g/t Au (AGSO OZMIN database, May 1998).

Introduction

The MOUNT KEITH 1:100 000 sheet area (3043) occupies the north-central portion of the Sir Samuel 1:250 000 sheet area, and lies between latitudes 27° 00'S and 27° 30'S and longitudes 120° 30'E and 121° 00'E. It is located in the northeast of the Eastern Goldfields Province of the Yilgarn Craton, and covers parts of the Mount Keith-Perseverance (shortened to Mount Keith in this report), Yakabindie (named by Liu et al. in press), and Yandal greenstone belts. These are sequences of Archaean volcanic and sedimentary rocks, which have been intensively explored for gold and nickel. Significant deposits include the Bronzewing and Mount McClure gold mines in the southeast, and the Mount Keith nickel mine in the west. Granitic rocks occupy the central part of MOUNT KEITH between the greenstone belts.

Field mapping used 1:25 000-scale colour aerial photographs taken in March 1994 (Department of Lands Administration, Western Australia), and was carried out between May and October 1994. Further work was done in the southernmost part of the Mount Keith greenstone belt in 1997 (March). Traverses were closely spaced in the greenstone belts, whereas the granitic rocks were visited at spot localities. Cainozoic rocks were interpreted from the colour aerial photographs and Landsat Thematic Mapper imagery.

Field notes for each locality and measurements of magnetic susceptibility are available from AGSO's OZROX database, major and trace element analyses of major rock types from the ROCKCHEM database, and resource and geological information on major mineral deposits from the OZMIN database.

Access

MOUNT KEITH is about 400 km north of Kalgoorlie. The sealed Kalgoorlie-Wiluna Highway passes through the west of the Sheet area, and an unsealed road links the goldmines in the southeast to Leinster, 45 km south of the area. Station and exploration tracks give generally good access. An airstrip at Mount Keith village services the Mount Keith nickel mine, and other strips are located near the Bronzewing and Mount McClure gold mines.

Albion Downs (which includes Mount Keith), Barwidgee, Lake Way, Yakabindie, and Yandal sheep stations and Wanjarri nature reserve occupy parts of MOUNT KEITH. Barwidgee homestead is located in the northeast, and the abandoned Mount Keith homestead in the west.

Previous investigations

The first edition of the Sir Samuel 1:250 000 geological map was published in 1977. The explanatory notes for this map give details of earlier regional studies (Bunting & Williams 1979), together with notes on climate, physiography, and vegetation. Durney (1972) and Marston & Travis (1976) mapped and described in detail the unconformity in the Jones Creek (Six Mile Well) area of the Mount Keith greenstone belt. Naldrett & Turner (1977) produced a solid-geology map and documented the results of geochemical investigations of the nickel deposits in the Six Mile-Sheba portion of the same belt. Eisenlohr (1989, 1992) made a detailed structural study and synthesis of the Six Mile-Agnew area. Dowling & Hill (1990) and Hill et al. (1990, 1993) described the physical features of komatiite flows at Mount Keith, and Dowling & Hill (1993) documented the Mount Keith deposit. Bongers (1994) made a detailed structural study of the Mount Keith mine area, including surface and core studies. Hopf & Head (1998) describe the Mount Keith deposit, Dugdale (1997) and Phillips et al. (1998) the Bronzewing gold deposit and its complex vein system, and Harris (1998) the Mount McClure gold deposits.

Acknowledgments

WMC Resources Ltd (Western Mining Corporation) provided accommodation at Leinster Camp 2 in 1994, and allowed access to their 1:10 000 scale map of the Mount Keith greenstone belt and to Elizabeth Bongers' B.Sc. (Hons) thesis on the Mount Keith mine area. Great Central Mines N.L. supplied samples of drillcore from Bronzewing mine, and Australian Resources Ltd supplied samples of drillcore from Mount McClure. D.Townsend (GSWA) provided statistics of gold production from MOUNT KEITH. D.M.Hoatson reviewed the report. L.Murray drew Figures 1, 9, 10, 12, 13, and 15, G.Bladon assisted with production.

Archaean geology

Regional setting

MOUNT KEITH includes parts of the Mount Keith and adjoining Yakabindie greenstone belts in the west, and parts of the Yandal greenstone belt in the northeast and southeast (Fig. 1). The Yakabindie belt is faulted against the Jones Creek Conglomerate of the Mount Keith belt to the east. Much of the eastern margin of the Mount Keith belt is the Perseverance Fault (interpreted from aeromagnetic data), but 8 km north of the Mount Keith mine, the belt is intruded by granite (which comprises tonalite, granodiorite, monzogranite, and syenogranite; Myers, 1997), as demonstrated by rafts of banded iron formation, quartzite, and amphibolite in the granite near the contact with the greenstone belt. Similar rafts of amphibolite and banded iron formation in granite indicate that the western margin of the Yandal belt in the southeast is also an intrusive contact.

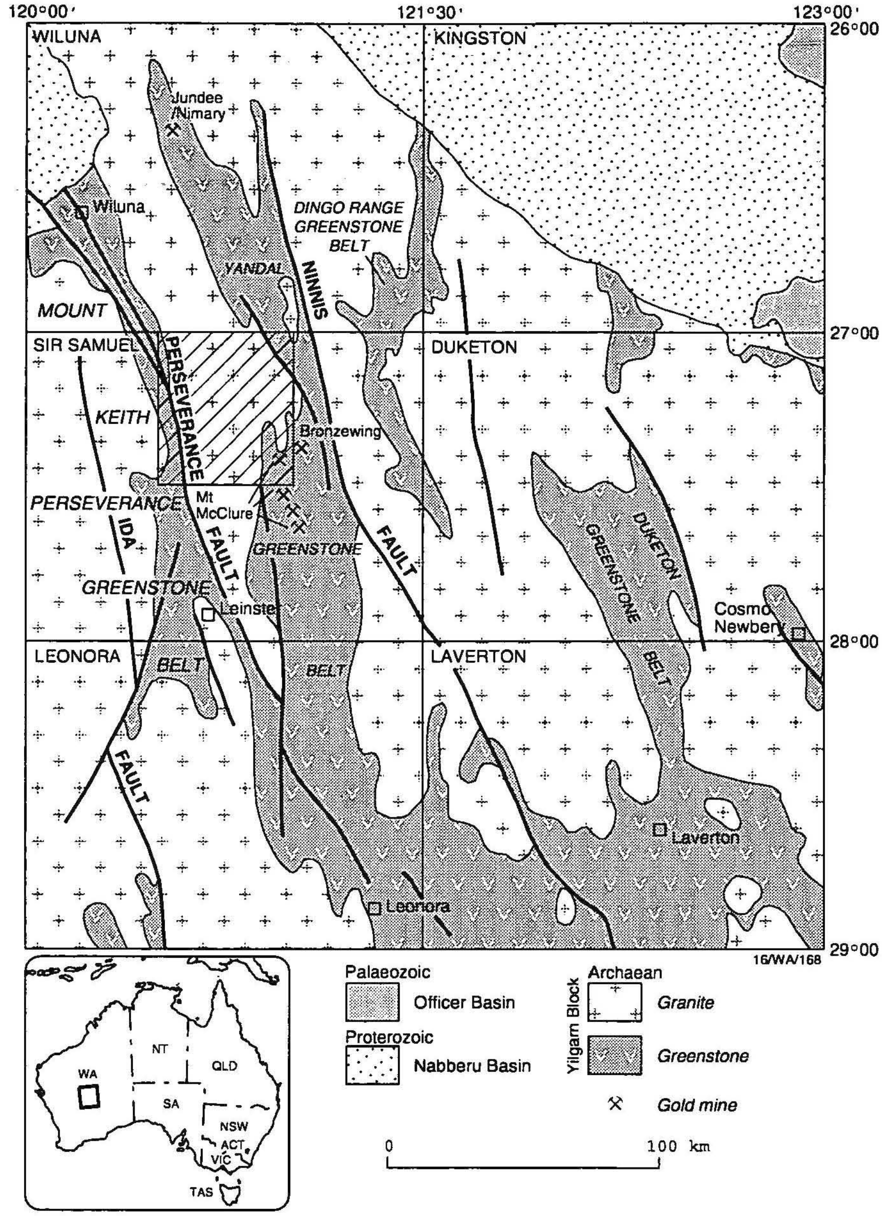

Figure 1. Regional geology of the northern part of the Eastern Goldfields Province (after Myers & Hocking 1988). The Mount Keith 1:100 000 Sheet area is hachured.

Metamorphosed ultramafic rocks

Ultramafic rocks are common in the Mount Keith greenstone belt, but rare in the Yandal belt. They crop out in a narrow zone intermittently from Mount Keith to the Perseverance nickel mine. In MOUNT KEITH, they are best exposed south of the Six Mile deposit, where a large hill of cumulate-textured peridotite (Aup) dominates the surrounding landscape (AMG 611592). The ultramafics are generally highly magnetic. The rocks are generally serpentinised, silicified, and/or schistose, but original igneous textures (cumulate textures and spinifex textures) are preserved. Silcrete derived from and overlying ultramafic rock is mapped as *Czu*.

Ultramafic rocks, unassigned (Au) and talc-carbonate rock (Auc)

Ultramafic rocks, unassigned, crop out in the vicinity of the Sheba prospect, in the south of the Mount Keith greenstone belt. Talc-carbonate rock forms two small outcrops at AMG 598630 and 598626, in the same area.

Komatiite (Auk)

Komatiite crops out at AMG 591707 north of Six Mile, and at AMG 598610 south of Six Mile, where it is associated with cumulate-textured peridotite. The komatiite is serpentinised, and displays relict spinifex textures formed of platy olivine crystals. The olivine is replaced by tremolite and serpentine. Interstitial material is fine-grained, and consists of serpentine, tremolite, chlorite, and magnetite. The spinifex-textures formed by rapid crystallisation in the upper part of a komatiite flow, whereas cumulate-textured peridotites represent the slower-cooled base of ponded flows.

Komatiite also forms small exposures in 'Spinifex Park' 2 km southwest of the Mount Keith mine, in RAB holes at AMG 548840, 570780, 580841, 580842, and 590705, and at AMG 917760 in the Yandal belt. The rock is dark green to black, fine to very coarse-grained, and cumulate or spinifex-textured. The cumulate-textured type (94968751) consists of serpentine (58%) pseudomorphous after equant euhedral olivine grains, very fine-grained interstitial chlorite (20), coarse-grained interstitial clinopyroxene (12), and opaque grains (10). The spinifex-textured type consists of serpentine (44%) in thin bands alternating with clinopyroxene, and as pseudomorphs after olivine euhedra, clinopyroxene (44) as plumose tufts of prisms between, and as inclusions in, olivine euhedra, opaque grains (10), and patches of blue-green amphibole? in the cores of some interstitial clinopyroxene aggregates.

Chlorite schist (Aul)

Chlorite schist occurs as small ankle-height exposures 7 km north of the Mount Keith mine, and in RAB holes around AMG 540900, 570785, 595693; also at 015740 in the Yandal belt. The rock is grey to green or less commonly brown or yellow, fine to medium-grained, and consists largely of chlorite with minor talc or quartz.

Peridotite (Aup)

Serpentinised peridotite crops out at the Six Mile deposit, in a line of exposures to the south forming a prominent silicified hill at AMG 611592 , where spinifex textures are associated with relict olivine cumulate textures, and at AMG 010580 in the Yandal belt. Relict cumulate olivine grains average 0.5 mm (up to 2 mm) across, and are pseudomorphed by radiating serpentine. Magnetite fills cracks in the olivine grains. Serpentine, talc, actinolite, and calcite make up the intercumulus material. Silica veinlets penetrate the rock. Originally considered to be large concordant sills (Bunting & Williams 1979), these cumulate-textured peridotites are now largely accepted as part of thick komatiite lava flows (Hill et al., 1990). Cumulate textures are considered to have formed where the flows ponded and formed slow-cooling lava lakes.

Tremolite-chlorite schist (Aur)

Tremolite-chlorite schist is commonly green, acicular or fibrous, and composed of fine tremolite needles (<1mm, but up to 8 mm) and varying amounts of chlorite, magnetite, talc, and calcite. Like talc-schist, it represents zones of high strain through the greenstones, and is highly schistose, with the foliation overprinted by crenulations and later folds. Vergence in these D_2 kinks indicates dextral shear. At AMG 607595, there is a classic example of heterogeneous strain partitioning in the greenstones, where the highly deformed ultramafic schists contrast greatly to the surrounding more competent, undeformed metagabbros. In the Yandal belt, talc-chlorite-tremolite schist (in drillhole rock chips and outcrop) is associated with a large area of siliceous caprock (Czu) above a small granite stock (AMG 985596).

Serpentinite (Aus)

Serpentinite after dunite is present almost exclusively in RAB holes 1-6 km north-northwest of Mount Keith mine, but boulders are exposed in a ditch at AMG 546862. The rock is generally green, yellowish green, or olive, but ranges to grey or black, fine to coarse-grained, equigranular, and consists of aggregates of serpentine minerals (60-90%) pseudomorphing cumulate olivine, magnetite (1-10) concentrated around serpentine aggregates, and talc (<1). Calcite as interstitial grains and veinlets forms up to 20% of some samples. Rare minerals include veinlets of chalcedony, opaline silica, strings of small quartz euhedra, and amphibole as tiny fibres.

Two samples with the assemblages

- Talc (70) - serpentine (27) - chlorite (2) - chalcedony (1) - opaque grains
- Serpentine (60) - talc (20) - chlorite (15) - opaque grains (5)

may be metamorphosed orthopyroxene-bearing peridotites or pyroxenites.

Talc schist (Aut)

Talc schist is exposed in several costeans at AMG 614610 and in a scrape 1 km farther south at AMG 614600, along the western margin of a long ridge of silica caprock. The schist is buff-brown, bleached white, or green, and contains chlorite porphyroblasts in places. Schistosity is strong, and is overprinted by an open-spaced crenulation cleavage and tight folds.

Talc-chlorite schist and chlorite-talc schist crop out in the Mount Keith belt at AMG 590670, 593660, 596649, 550830, and 576775. In the Yandal belt, talc schist is exposed at AMG 948755, and forms a raft in granite at AMG 844763. The rock is commonly yellowish green, pale green, or white, but in places grey, buff, or brown, fine-grained, and composed largely of talc with lesser chlorite. The only thin-sectioned sample (AMG 844763) is from the raft in granite, and consists of talc (50%) as a very fine-grained felted aggregate, chlorite (30), tremolite (15), and magnetite (5); the rock has been thermally metamorphosed to upper greenschist facies. In the greenstone belts, the schist consists largely of talc with small amounts of chlorite and magnetite. Kinks and small folds are common.

Low-grade metamorphic rocks

Amphibolite (Ala)

Amphibolite is fine, medium, or coarse-grained, grey or speckled black and white, equigranular, saccharoidal, and massive to lineated and/or foliated. There are two mineralogical types:

- Quartz-poor (0-3% quartz), probably meta-igneous;
- Quartz-rich (10-40% quartz), possibly a metasedimentary mixture of mafic tuff and silicic sediment.

In the Mount Keith greenstone belt, the quartz-poor variety is known only in one RAB hole (AMG 550884), and consists of yellow-green amphibole (65%), plagioclase (26) substantially altered to clinozoisite, quartz (3) as isolated grains, chlorite (3), and leucoxene (3). A raft of amphibolite (AMG 584927) is quartz-rich, and consists of pale green diopside (50%) as equant poikiloblasts containing numerous inclusions of amphibole and plagioclase, andesine (24) much altered to clinozoisite, blue-green amphibole (15), quartz (10) as numerous small polygonal grains, and hematite (1).

In the Yandal greenstone belt, quartz-rich amphibolite forms three outcrops northwest and north of Beale Well. The rock at AMG 915745 consists of dark laminae rich in amphibole (35%) and light laminae composed of quartz (35) as fine-grained polygonal mosaic, plagioclase (18) as tiny grains intermingled with the mosaic quartz, clinopyroxene (10) as coarse-grained lenses, opaque rods (2), and coarse titanite (<1). The outcrop at AMG 914764 is similar, and consists of pale green amphibole (41%) concentrated in laminae, quartz (40) as elongate mosaic aggregates of polygonal grains, clinopyroxene (10) as coarse grains concentrated in laminae, very fine-grained clinozoisite (5) as lenticular clusters after plagioclase, titanite (3) and opaque euhedra (1). The adjoining outcrop at AMG 915769 is meta-igneous, homogeneous, and consists of amphibole (50%) as large prisms and small stellate clusters, sodic labradorite (50) incipiently recrystallised, and opaque grains encrusted with titanite (<1).

Amphibolite also forms numerous rafts 150 m – 1 km long in granite 2-7 km west and southwest of Beale Well and 3-4 km northeast of Alf Well. All bar one of the rafts are meta-igneous, and are composed of blue-green amphibole (45-60%), remnant skeletal clinopyroxene (0-20) inside amphibole, sodic labradorite (18-38) much altered to fine muscovite ± epidote, quartz (1-2) as small isolated polygons, and microcline (2) in two samples as unaltered to cloudy brown large interstitial grains. These rocks are probably gabbro or dolerite intrusions in a greenstone sequence subsequently engulfed and metamorphosed by granite. A quartz-rich amphibolite raft at AMG 905730 consists of poikiloblastic amphibole (30%), plagioclase (30) pseudomorphed by muscovite + clinozoisite-epidote, quartz (30), microcline (6) as large strained grains, idioblasts of epidote (2,) and titanite (2; 94968402).

Schistose clay rock (Alb)

Schistose clay rock crops out near MacFarlane's Find, and 4 km northwest, 7 km north and 8.5 km north of the Mount Keith mine in the Mount Keith greenstone belt, and at three localities near Beale Well in the Yandal greenstone belt. The rock is cream to yellow, and fine to very fine-grained.

Quartz-feldspar schist (Alf)

Quartz-feldspar schist crops out around AMG 600700 and at several places 4-10 km north of Mount Keith mine, and at AMG 900816, 903808, and 922720 in the Yandal greenstone belt. In outcrop, the schist is almost everywhere heavily weathered to a yellow, fine to very fine-grained quartz-clay rock with relict schistosity. Fresh rock in a RAB hole at AMG 578782 consists of small phenocrysts of saussuritised plagioclase and broken and partly recrystallised quartz in a very fine-grained groundmass of chlorite, quartz, plagioclase, epidote, and muscovite (94968787). The rock is a deformed and metamorphosed dacitic or tonalitic porphyry; the considerable extent of the exposures suggests that the precursor was a felsic volcanic.

Schistose clay rock with quartz eyes (Alfq)

This rock is essentially identical to heavily weathered quartz-feldspar schist (Alf), with the addition of clear quartz eyes 1 cm or so apart. These are interpreted as relict quartz phenocrysts, consistent with a felsic volcanic origin. The rock crops out over small areas at AMG 595698 and 540935 (where it is closely associated with quartz-feldspar schist) in the Mount Keith greenstone belt, and at AMG 922720 and 917780 in the Yandal greenstone belt.

Muscovite schist (Alm)

Muscovite schist crops out at and around AMG 605685 (MacFarlane's Find), 602708, and 546867 in the Mount Keith greenstone belt. The rock is almost everywhere heavily weathered to a pale brown, fawn, cream, yellow, or white fine to very fine-grained schistose muscovite-clay rock. Around MacFarlane's Find, relict layering is visible, with kinks and folds. Possible precursors include felsic volcanic rocks and pelitic sediments.

Quartz-biotite schist ± feldspar (Alqb)

Quartz-biotite schist ± feldspar occurs at a single outcrop at AMG 593922 in the Mount Keith belt, where it forms several rafts over a length of about 250 m in granite. It is coarse-grained, lineated, and consists of abundant biotite, quartz, and feldspar.

Quartz-muscovite schist ± feldspar (Alqm)

Quartz-muscovite schist ± feldspar crops out around AMG 560910 and 540855 in the Mount Keith greenstone belt, and around AMG 918760 and 924715 in the Yandal greenstone belt. The rock is usually fresh in outcrop, silvery white to grey (with maroon mottles in places), and consists of quartz (50-60%) as elongate polygonal grains or as augen of large strained single grains, strongly oriented muscovite (32-35), and hematite (5-8). Possible pre-metamorphic parents include pelitic sediments and felsic volcanic rocks.

Mafic extrusive rocks

Fine-grained mafic igneous rocks, undivided (Ab)

Fine-grained mafic igneous rocks, undivided, crop out near the Goliath and Sheba prospects in the Mount Keith greenstone belt, and in the Fred Bore – Beale Well area of the Yandal belt.

Amphibolitic metabasalt (Aba)

Amphibolitic metabasalt is characterised by destruction of primary igneous textures and by a strong penetrative foliation (and commonly lineation). The foliation is commonly weakly crenulated or wavy at granite margins. It is most common at greenstone margins and in mafic inclusions in the adjacent granite rocks. The amphibolite is recrystallised, and slightly coarser-grained and darker than the metabasalt (Abb). The foliation and lineation are defined by the alignment of hornblende and plagioclase (substantially altered to clinozoisite) grains, and the amphibolite sometimes has a black and white banded pattern, defined by narrow bands (0.2 - 0.5 mm) containing differing proportions of hornblende and finer-grained mosaics of plagioclase and minor quartz. The rocks also contain minor epidote, biotite, titanite, and iron oxides. The amphibolites close to granite contacts are commonly intruded by felsic porphyry dykes, usually strongly foliated, and quartz veined.

Metabasalt (Abb)

Metabasalt crops out over substantial areas of the Mount Keith and Yandal greenstone belts, forming low rounded hills covered by scattered low outcrop and scree. The rock is grey to grey-green, fine-grained to aphyric and massive, and grades into medium-grained dolerite, considered to represent the slower cooling centres of thick basalt flows. The fine-grained rock is generally weakly foliated, with heterogeneous zones of stronger foliation in areas of shearing such as at contacts with more competent rocks (granite, gabbro, conglomerate) and fault zones. The basalt is mainly tholeiitic in composition, metamorphosed to greenschist facies, and generally consists of randomly oriented plagioclase laths (20%) interlocking with secondary blue-green amphiboles (70%). Original labradorite commonly forms cores inside recrystallised margins, but in some rocks is pseudomorphed by clinozoisite. Primary clinopyroxene is rare to absent in some rocks, but forms up to 45% of others, with correspondingly less amphibole. Other minerals present are titanite, opaque grains, and leucoxene. Chlorite, epidote, and carbonate alteration are common. Veinlets of quartz, epidote, clinozoisite, and carbonate less than 1 mm wide cut the rock.

Mafic schist (Abf)

Mafic schist crops out in the south of the Mount Keith greenstone belt at AMG 602576 and 614607. In a RAB hole at AMG 920758 in the Yandal belt, green schist consists of quartz (50%) as small oriented elongate polygons, oriented prisms of amphibole (40) concentrated in laminae, muscovite (9) after plagioclase, opaque grains (1), and titanite (<1). The precursor to the schist is unknown; altered basalt and tuff-arenite mix are possibilities.

Intercalated greenstone and granite (Abg)

In the southeast, a 1 km-wide band containing well exposed interlayered greenstone and granite crops out within foliated granite at the western margin of the Yandal belt. The individual granite and greenstone layers range from 1 to 50 m wide, and form north-northwest-trending low narrow ridges. The unit as a whole has a characteristic banded appearance on photographs and satellite and aeromagnetic images. The greenstones are moderately to steeply foliated metamorphosed mafic rocks, such as fine-grained amphibolite and lesser amounts of coarse-grained porphyritic basalt (informally known as 'cat rock' because of its spotted appearance; Figure 2), and felsic rocks. The felsic rocks are fine-grained, white to pink, and where fresh, are composed of feldspar, quartz, and biotite. They may be derived from either granite rock or felsic volcanic/volcaniclastic rocks in the greenstone sequence.

Figure 2. Foliated porphyritic metabasalt ('cat rock') interlayer in intercalated greenstone and granite unit (Abg). AMG 904632. Hammer 32 cm long.

All rocks are deformed to various degrees, particularly the felsic rocks, which exhibit a strong foliation or are mylonitised. The best preserved example of mylonite is at AMG 933595, where a prominent thin ridge of fresh fine-grained mylonitised granite occurs within coarser-grained less deformed granite (Fig. 3a, b). At this location the sheared granite clearly exhibits porphyroclastic feldspar grains, stretched quartz rods, and biotite ribbons. Dark bands smeared through the mylonite zone represent finely crushed rock powder. All rock types in *Abg*, especially the granites, exhibit a strong subhorizontal mineral lineation trending 160° with a 5° plunge to the southeast. In granite, it is defined by stretched rod-shaped quartz augen and aggregates of recrystallised biotite.

Rocks in the interleaved granite-greenstone zone have attained amphibolite facies, in contrast to those in the adjacent greenschist facies greenstone sequence to the east. The amphibolite is fine-grained and displays a strong foliation defined by the alignment of elongate quartz, plagioclase, and hornblende grains. They locally display thin gneissic banding formed by segregation of mafic and felsic minerals (eg. at AMG 910614 and 904632). Despite the high metamorphic grade, the greenstones in the interleaved zone retain primary textures in places.

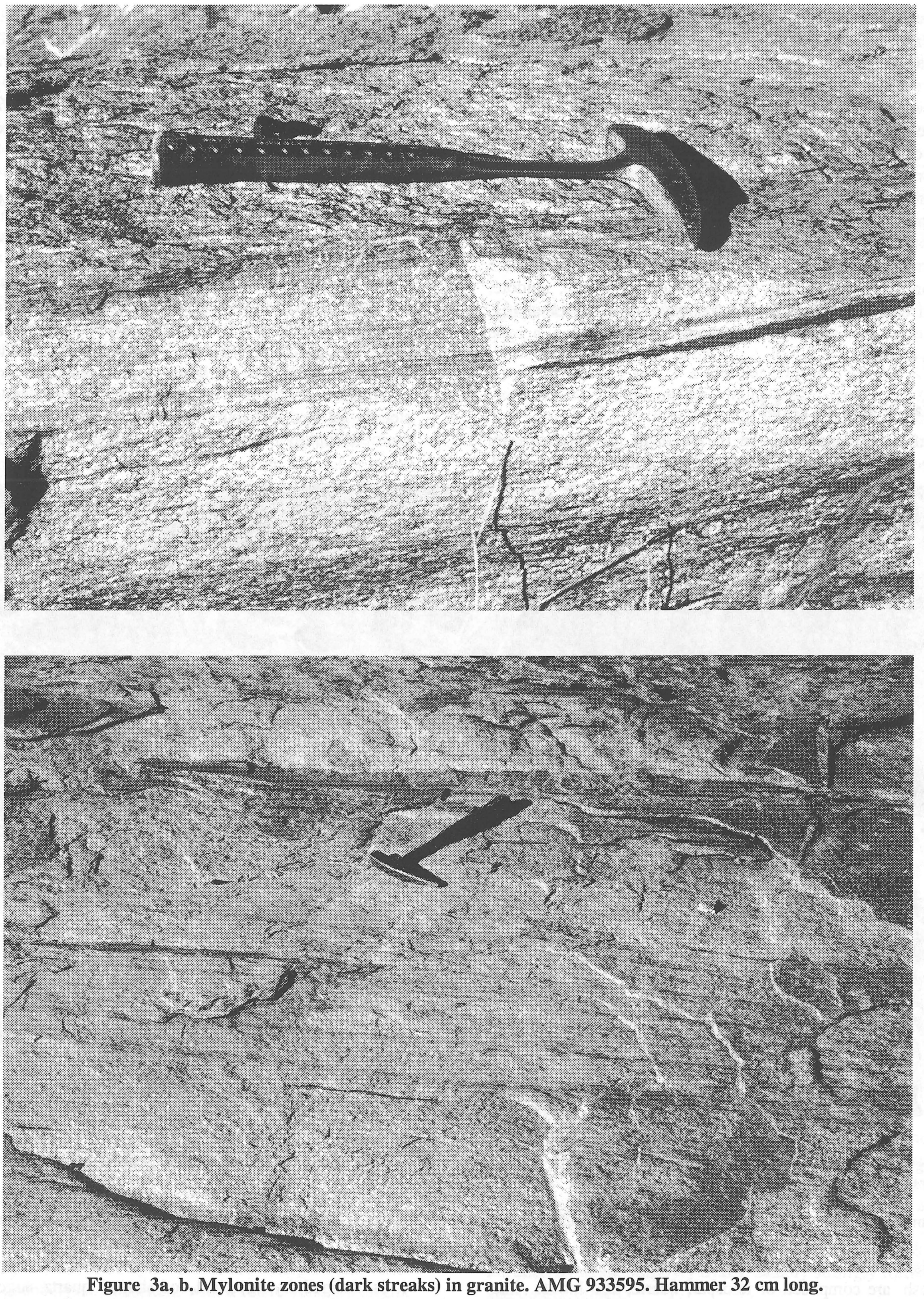

Figure 3a, b. Mylonite zones (dark streaks) in granite. AMG 933595. Hammer 32 cm long.

Mount Goode Basalt (AbMG)

A small area of metamorphosed tholeiitic basalt of the Mount Goode Basalt extends into MOUNT KEITH from SIR SAMUEL at AMG 587558.

High-Mg basalt (Abm)

High-Mg basalt with preserved coarse pyroxene spinifex texture is associated with the outcropping ultramafics south of the Six Mile deposit. It is generally fine-grained and resembles tholeiitic basalt (Abb), but can be distinguished by its higher magnetic susceptibility. It is composed of Mg-rich metamorphic minerals such as tremolite, with chlorite, minor plagioclase, carbonate, magnetite, and quartz. The spinifex texture arises from random tremolite-actinolite needles up to 2 cm long, which replace original pyroxene grains.

Porphyritic metabasalt (Abp)

Porphyritic metabasalt crops out at AMG 005090 in the north of the Yandal belt, and bears sparkling phenocrysts of pyroxene up to 3 mm long.

Mafic volcanic rocks ± sedimentary rocks (Abv)

Mafic volcanic rocks ± sedimentary rocks crop out at AMG 987567. Another outcrop labelled on the map at AMG 590558 is incorrect, and should be labelled Abb metabasalt.

Mafic intrusive rocks

Metadolerite (Aod)

Medium-grained mafic intrusive rocks with an equigranular, locally preserved ophitic to sub-ophitic texture commonly occur as concordant layers in basalt. In the field, intrusive dolerite can be distinguished from extrusive dolerite (medium-grained interiors of basalt flows) by its slightly coarser grain, darker colour, and occurrence as resistant ridges. It is massive, and largely resistant to deformation. In areas of high strain, the surrounding finer-grained basalts tend to be highly foliated, whereas the dolerite is only weakly foliated. Where foliated, the dolerites weather to lozenge-shaped boulders.

The rock is grey or green, medium-grained with ophitic texture preserved in places, equigranular, massive to (rarely) weakly foliated and lineated, and consists of blue-green amphibole (45), sodic labradorite (45) as zoned laths, and titanite clusters (10). The dolerite at AMG 938749 is carbonated; plagioclase is altered to very fine-grained calcite and epidote (together 58%), and large skeletal remnant grains of colourless clinopyroxene (20) are partly replaced by amphibole (18).

Gabbro (Aog)

Coarse-grained metagabbro forms a folded sill about 4 km south of Six Mile Well, and small bodies at many other places. It is green, grey, or speckled green and white, massive, medium to coarse-grained, and equigranular with relict cumulate texture occasionally preserved. The gabbro consists of actinolite and minor hornblende (50-70%) and plagioclase (30-50%). Amphibole is subidioblastic, and commonly simply twinned with acicular borders. Relict clinopyroxene forms lamellar or skeletal cores within some amphibole grains. Primary subophitic to ophitic textures are commonly preserved as plagioclase inclusions in amphibole (after clinopyroxene). Plagioclase is commonly altered to epidote/clinozoisite or sericite. Where preserved, original plagioclase is oscillatorily zoned labradorite with andesine rims. Chlorite, opaque grains, titanite, leucoxene, apatite, secondary quartz, and carbonate are accessory. Quartz and epidote fill veinlets.

Kathleen Valley Gabbro

The Kathleen Valley Gabbro crops out as low hills in the southwest, and extends south on to SIR SAMUEL. It is a differentiated layered mafic intrusion comprising mainly gabbro, but ranging in composition to anorthosite and (amphibolitised) pyroxenite end members. The suite also includes tonalite and quartz gabbro. The rocks are metamorphosed to greenschist facies, with original clinopyroxene altered to blue-green acicular to fibrous amphibole, but original igneous textures and zoned plagioclase (labradorite) are preserved. The gabbro intrusion forms a fault-bounded block in the Yakabindie greenstone belt, and is faulted against metabasalt, and locally the Jones Creek Conglomerate, of the Mount Keith belt to the east. Primary layering trends 060° and dips steeply northwest. Differentiated layering indicates the intrusion youngs to the southeast, and is therefore overturned (Bunting & Williams 1979). Sinistral strike-slip movement along two large north-northwest-striking shear zones disrupted the intrusion, forming three fault blocks, which have been significantly displaced. Deformation within the intrusion is confined to these narrow shear zones. Smaller normal faults slightly offset compositional layering west of these larger shears. Undeformed late pegmatite dykes trending dominantly northwest (parallel to the shears and normal faults) intrude the gabbros and crosscut a north-trending foliation within them. The components of the intrusion are described below, from bottom to top.

Layered gabbro (AoKVl)

The lowest and northernmost unit of the Kathleen Valley Gabbro is a layered gabbro with 2 to 10 m compositional rhythmic layering clearly visible on air photos, and centimetre-scale layering in hand specimen (Fig. 4). The layering is due to varying proportions of amphibole and plagioclase, and some pure white anorthosite (100% plagioclase) and black pyroxenite layers are also present.

Anorthositic gabbro and anorthosite (AoKVa)

The layered gabbro is overlain to the south by coarse-grained anorthositic gabbro and anorthosite containing 60-70% plagioclase, but with 80-95% plagioclase in anorthosite (Fig. 5). Plagioclase occurs both as phenocrysts and in the groundmass. Phenocrysts are milky-white, rounded to euhedral (tabular), and are mainly 1-2 cm in size, but ranging from 5 mm to 10 cm. Most groundmass plagioclase is euhedral, and ranges from less than 0.5 mm to 6 mm in size. The original poikilitic texture of some anorthositic gabbros is preserved. Large oikocrysts (up to 15 cm) of fibrous amphibole after clinopyroxene enclose up to 90% euhedral plagioclase crystals in a net-like poikilitic texture, which is best observed etched out on weathered surfaces.

Gabbro, undivided (AoKV)

East of the large shear zones, the anorthositic gabbro has been displaced ~ 1.5 km to the north by sinistral strike-slip movement, and the layered gabbro is not exposed. Here the anorthosite is overlain by quartz gabbro and tonalite (see below) and then by a unit of dominantly black medium-grained metagabbro (AMG 583573) containing 60-70% metamorphic amphibole replacing primary igneous pyroxene. The amphiboles (2-5 mm) are typically euhedral and stand out in relief on weathered surfaces. The proportions of plagioclase and amphibole vary throughout the unit, and where the gabbro contains more plagioclase, the rocks consist of black amphibole crystals in a whiter

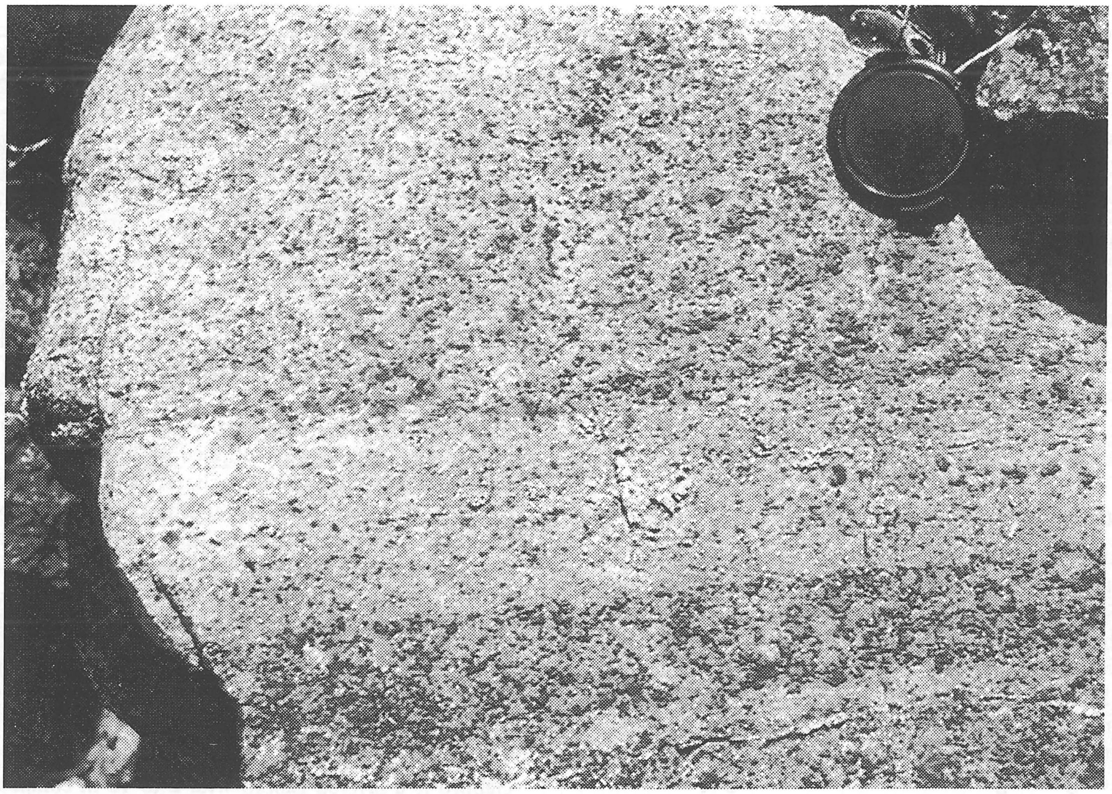

Figure 4. Compositional rhythmic layering at base of Kathleen Valley Gabbro (AoKVl). AMG 574571. Lens cap 5 cm across.

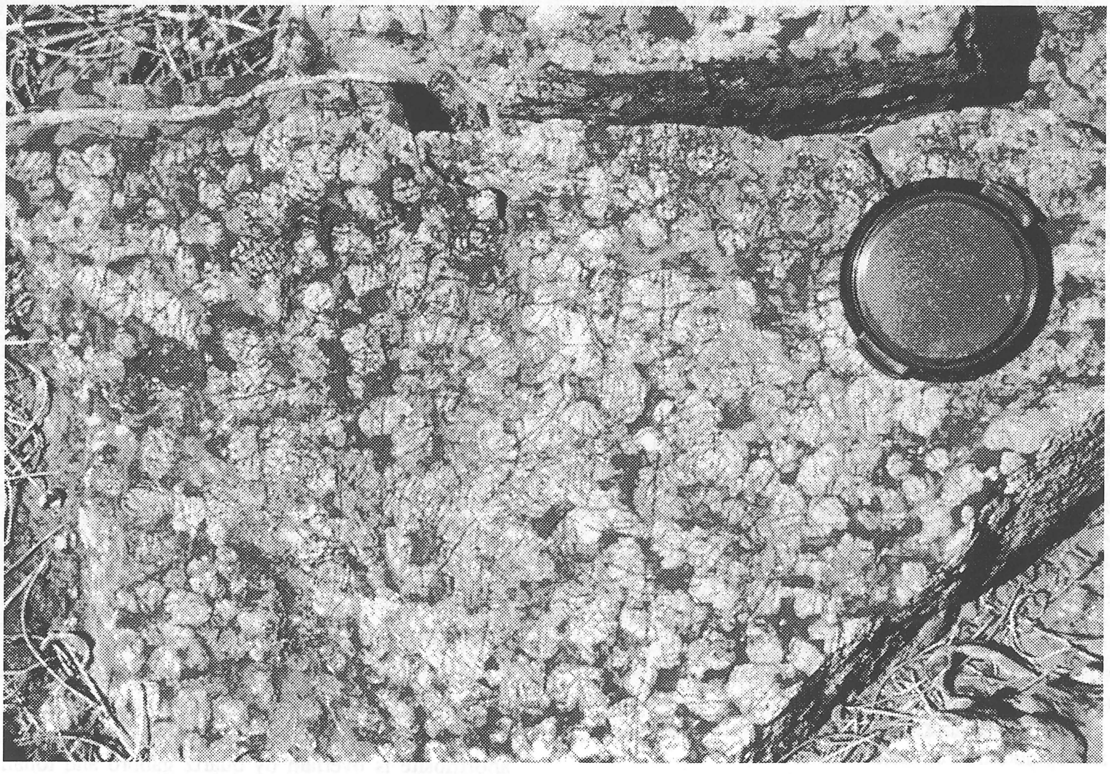

Figure 5. Anorthosite, Kathleen Valley Gabbro (AoKVa). AMG 574571. Lens cap 5 cm across.

plagioclase-rich groundmass, with plagioclase also forming euhedral phenocrysts. The unit also contains metamorphosed pyroxenitic gabbro containing more than 80% amphibole, 10% plagioclase, and less than 3% quartz. In thin section, the amphibole is blue-green and is probably actinolite. Two more intervals of undivided gabbro crop out at AMG 585562 and 587559.

Quartz gabbro and tonalite (AoKVg)

A sliver of tonalite occurs along the ridge top at AMG 582574. The tonalite is finer-grained than the surrounding gabbros, and has a distinctive smooth outcrop pattern on the aerial photographs. The tonalite consists of 30-40% quartz, 40-50% plagioclase, and 20% blue-green amphibole. Quartz is present as a granophyric groundmass, and occurs as small clear crystals (2 mm). Small pink garnets (xenocrysts? 2 mm) characterise the unit.

Quartz gabbro and dolerite (AoKVq)

Quartz gabbro and dolerite crop out in the hilly area between the two main shear zones (AMG 585560). In the larger fault block to the west and south, on SIR SAMUEL, quartz gabbro and tonalite constitute the uppermost units of the Kathleen Valley Gabbro. The gabbro contains 5% quartz as phenocrysts (up to 1 cm) and in the groundmass. Blue-green amphibole is also present. A primary flow foliation of aligned euhedral plagioclase laths is preserved in places.

Metamorphosed felsic volcanic and volcaniclastic rocks

Felsic rocks crop out in both the Mount Keith and Yandal greenstone belts. Most outcrops are strongly foliated to schistose and deeply weathered or altered, and the protolith is impossible to determine; these rocks are mapped as low-grade metamorphic rocks (see above). Where the rocks retain evidence of a felsic volcanic origin, such as a fine-grained siliceous matrix or quartz-feldspar mineral assemblage, they are described as either metamorphosed felsic extrusive rocks, (Af) or dacite, rhyolite, etc, where this is possible. Where the rocks are strongly deformed and recrystallised, they are labelled Afs, indicating felsic schist; the schistosity is defined by oriented white mica, feldspar, and quartz.

Felsic extrusive rocks (Af)

Felsic extrusive rocks crop out at AMG 523928 and 530918 in the Mount Keith greenstone belt, and at AMG 922736, 918728, 935720, and 910805 in the Yandal greenstone belt. The rocks are everywhere highly weathered, and yellow, pink, red, purple, white, or variegated in these colours. Porphyritic rocks are massive to foliated, and consist of medium size phenocrysts of clear quartz in a fine to very fine-grained groundmass of clay and muscovite. Aphyric rocks at AMG 910805 are autobrecciated, vesicular, flow-brecciated, flow-banded, and display open to isoclinal flow folds (Fig. 6).

The felsic rocks about 4 km east of Mount Phillipson in the southeast may be remnants of a distal facies to the Spring Well Volcanic Complex (Giles 1981), 50 km to the south.

Dacite (Afd) and rhyolite (Afr)

Dacite crops out as a single layer about 50 m thick in the Yandal greenstone belt at AMG 914662. The rock is almost fresh, greyish yellow, strongly foliated, and comprises medium size phenocrysts of magmatically embayed quartz, plagioclase much altered to muscovite ± calcite, and elongate aggregates of biotite in a fine to very fine-grained recrystallised groundmass of polygonal quartz and plagioclase, oriented biotite ± chlorite (94968365, -8439).

Rhyolite crops out at a single locality on the western edge of the area at AMG 524927, and extends into YEELIRRIE.

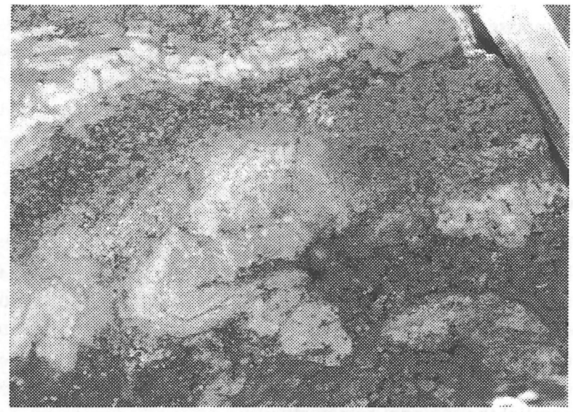

Figure 6. Fragmented isoclinal flow folds in felsic volcanic rock (Af). AMG 909806. Scale in millimetres.

Quartz-muscovite schist (Afs)

Quartz-muscovite schist derived from felsic volcanic rock crops out at AMG 602675, 609660, and 560908 in the Mount Keith greenstone belt, and at AMG 922747, 915755, 917770, 908810, and 939700 in the Yandal greenstone belt. The rock varies from grey (fresh) to yellow, white, cream or red (weathered), and consists of fine to medium size augen of quartz in a fine to very fine-grained groundmass of muscovite, feldspar or clay, and minor iron oxide.

Metasedimentary rocks

Metasedimentary rocks are common though not abundant in the Mount Keith greenstone belt, and virtually absent from the Yandal belt. They are poorly exposed, heavily weathered, and commonly foliated and silicified. Possible parent rocks include sandstone, siltstone, mudstone, and felsic volcaniclastic rocks.

Chert (Ac)

Chert crops out as discontinuous ridges up to 2 m wide and parallel to the north-northwest regional trend. The chert is banded black, white, brown, or green, recrystallised, and locally brecciated. Laminae range from less than 1 mm to greater than 1 cm thick. Complex folds are preserved in places. The chert may represent primary chemical sediments, silicified shale or siltstone, or very fine-grained quartzite.

Banded iron formation (Aci) and banded iron formation with iron silicate (Acis)

Banded iron formation is laminated to thin-bedded, very fine-grained, and composed of red jaspery quartz and black goethite. The large ridge in granite at AMG 590920 is heavily weathered.

Banded iron formation with iron silicate forms numerous elongate rafts in granite around AMG 600910 and 846750. The rock is laminated brown, black, yellow, and grey, recrystallised to medium grain, and composed of quartz (60%) as a strain-free granuloblastic mosaic, magnetite (28), grunerite (10), and hematite (2).

Metasedimentary rock, undivided (As)

An outcrop of metasedimentary rocks at AMG 545933 comprises an interbedded sequence of schistose clay rock with quartz eyes, chert, and laminated siltstone, medium-grained micaceous sandstone with angular to subangular grains, and fine-grained sandstone with flattened chert pebbles.

Oligomictic conglomerate (Asc)

Foliated oligomictic conglomerate associated with limonitic siltstone forms a long narrow ridge at AMG 607572. The conglomerate contains rounded flattened elongate pebbles of fine-grained vein quartz up to 10 cm (average size 2 cm) in length, in a brown siliceous (possibly secondary jasper) matrix. The flattened clasts parallel the regional schistosity.

Shale, slate, phyllite ± siltstone (Ash)

The most abundant metasedimentary rocks in the Kathleen Valley-Six Mile area are weathered, fine-grained, laminated to thin-bedded metamorphosed shale, slate, and siltstone, which occur as thin beds within metabasalt and ultramafic sequences. The fine-grained incompetent sediments are generally strongly foliated, and provide evidence of multiple deformation, with crenulated or tightly folded foliation, boudinage, and kink bands. They are locally schistose (defined by mica) or phyllitic with a micaceous sheen, and are altered to clay, ranging in colour from grey to white (kaolinised), or buff brown (limonitised). They are commonly silicified or locally ferruginous. The mineral assemblage is typically granoblastic quartz, muscovite, and clay. Altered andalusite and kyanite porphyroblasts occur in some of the more schistose rocks, giving them a knotted appearance.

Graphitic shale, slate, schist (Ashg)

Black graphitic shale is interbedded with limonitic shale at AMG 607572, and with chert and muscovite schist at AMG 552885.

Jones Creek Conglomerate

The Jones Creek Conglomerate, defined by Durney (1972), extends over a strike length of 90 km from Agnew to Mt Keith, in the Mount Keith greenstone belt. In MOUNT KEITH it consists of mainly oligomictic granite conglomerate with arkose interbeds. A 1000 m-thick cross section of the unit crops out west of Jones Creek. Here the conglomerate unconformably overlies monzogranite to the west. Apart from a weak foliation at a 30° angle to bedding (strike 175°) in the arkose, deformation is confined to narrow northwest-trending shear zones, and sheared contacts with adjacent rocks, and original sedimentary textures and structures are preserved. Durney (1972) and Marston & Travis (1976) give detailed descriptions of the conglomerates in this area. U-Pb dates on detrital zircons suggest that the sediments are younger than 2645 Ma (Nelson, in press).

Conglomerate; granite clasts and matrix (AsJC)

In general, the conglomerate is cream-coloured, thick-bedded, and well sorted. Towards the base, in three channel-like embayments in the monzogranite, the clasts are larger and less well sorted than those higher up, angular and tightly packed, with angular granite blocks 1.5-3 m in size, and subangular to well rounded granite boulders and cobbles that are lithologically identical to the underlying monzogranite. At the base of each embayment there is a transition zone of fractured monzogranite passing down into massive unbroken granite, which makes the exact location of the unconformity difficult to identify. Away from the granite contact, the conglomerate has a more open framework and is better sorted, with predominantly well-rounded 8-20 cm cobbles (although they range from 1 cm up to 1 m in some beds). The clasts consist mainly of massive medium to coarse-grained granite, with subordinate foliated granite, felsic porphyry, and mafic rocks. The matrix is medium to coarse-grained, and consists of well-sorted medium-grained quartz, plagioclase, microperthitic microcline, biotite, muscovite, and epidote. Original textures are recrystallised and there is a preferred orientation of quartz, feldspar, and secondary mica. However, original subangular to subrounded shapes of the detrital quartz and feldspar grains (0.2 -2 mm) can still be discerned. In the conglomerate, boundaries between clasts and matrix are generally sharp, but locally gradational due to partial recrystallisation.

Arkose (AsJCa)

Arkose is interbedded with, and is compositionally identical to the arkosic matrix of, the conglomerate. It grades into the conglomerate by the incorporation of scattered pebbles and isolated granite clasts (20-50 cm). The arkose is cream, white, buff or yellow, medium to coarse-grained, moderately to poorly sorted, and moderately to heavily weathered. Bedding is defined by grainsize variation, biotite laminations, pebble bands (including rare imbricated shale pebble bands), and low-angle cross-bedding. Graded beds, truncated cross-beds, and granite cobbles loading into the underlying sediment all indicate the sequence youngs to the east. Detrital grains are subangular to subrounded, and composed of quartz and weathered feldspar in some places, quartz and fine muscovite in others. Quartz grains are flattened and elongate, imparting foliation and lineation to the rock. At AMG 593652 (94968900), the arkose is very coarse-grained, conglomeratic, and contains well-rounded pebbles, cobbles and boulders of several granite types. Arkose at AMG 592641 is well bedded, and displays east-facing graded bedding (Fig. 7), and interbedded medium to very coarse-grained conglomeratic beds with low-angle cross-bedding (Fig. 8).

Conglomerate; mafic matrix (AsJCb)

The uppermost mafic conglomerate beds have loosely packed clasts in a para-amphibolite matrix. The conglomerate forms plains dotted with granite cobbles and boulders. In contrast to the undeformed felsic conglomerate, the matrix of the mafic conglomerate typically is strongly foliated parallel to the regional north-northwest trend. The mafic-matrix conglomerate becomes more dominant farther south, in SIR SAMUEL.

In the Kathleen Valley area, Durney divided the greenstones into the 'Western greenstone' and 'Eastern greenstone' sequences, separated by the Jones Creek Conglomerate. He suggested that the conglomerate unconformably overlies the monzogranite and 'Western greenstones' and in turn is overlain by the 'Eastern greenstone' sequence, thus dividing the greenstones into two major depositional and tectonic cycles. The western contact with the monzogranite is clearly unconformable, and Marston & Travis (1976) describe the contact farther

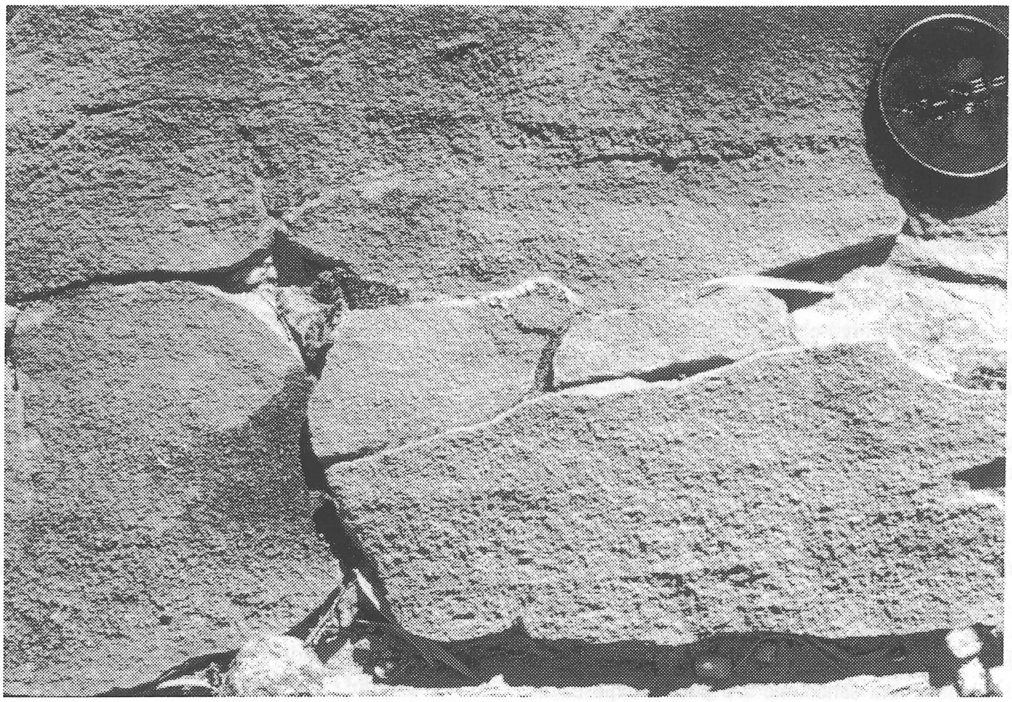

Figure 7. Upward-facing graded bedding in arkose of Jones Creek Conglomerate; coarse-grained base of bed at top of shadowed joint in lower right, fine-grained top at lower edge of lens cap. AMG 592641. Lens cap 5 cm across.

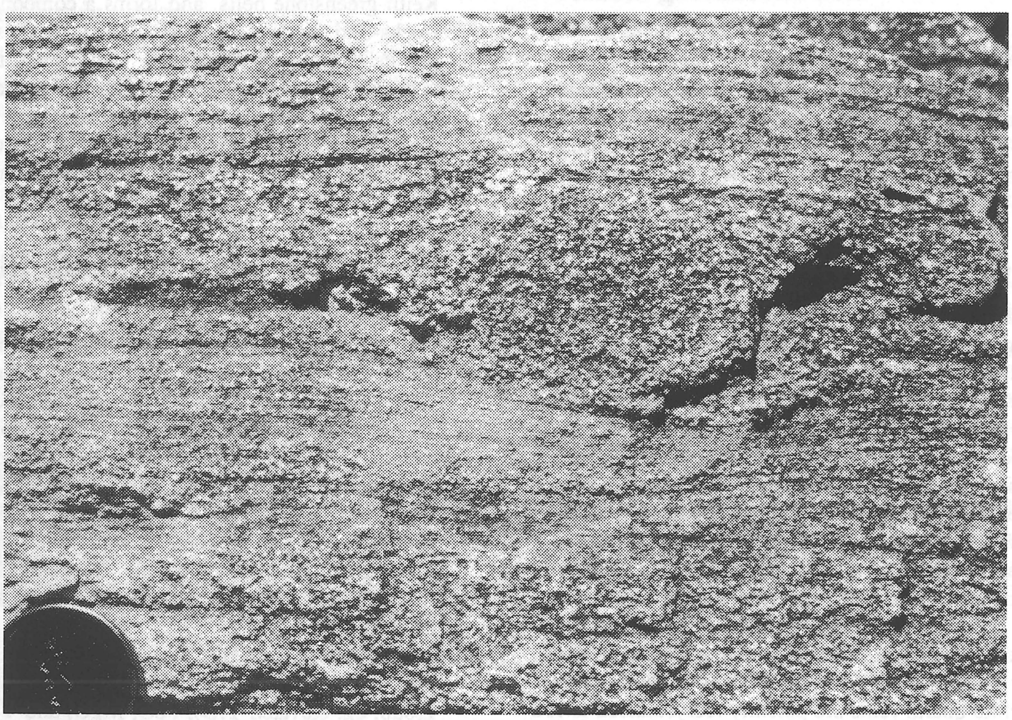

Figure 8. Low-angle cross-bedding in lens of sandstone in very coarse-grained arkose of Jones Creek Conglomerate. AMG 592641. Lens cap 5 cm across.

south with the 'Western greenstones' as a 'tectonically modified unconformity'. However, the eastern contact of the conglomerate is highly tectonised. The conglomerate is mylonitised and has a schistose matrix and adjacent metasediments, ultramafic rocks and para-amphibolites are schistose and highly deformed and contorted. Marston & Travis (1976) suggested the eastern contact is affected by a regional strike-slip fault system, and that lenses of the 'Eastern greenstones' within the Conglomerate are tectonic slices emplaced during strike-slip deformation. The inference is that the Jones Creek Conglomerate was deposited in a fault-bounded trough between the two greenstone sequences, and represents the youngest Archaean formation recognised in the area.

Marston & Travis (1976), and Bunting & Williams (1979) discuss the depositional environment of the Jones Creek Conglomerate. The poorly sorted angular boulders and clasts in the unconformity embayments may represent local talus deposits flanking an eroding upland area comprising the western monzogranite. Farther from the unconformity, the well-rounded closely packed clasts in the conglomerate indicate a high-energy environment. Bunting & Williams (1979) suggested the conglomerate was transported from eroding upland areas to a high-energy shoreline, where it accumulated as alluvial fans and talus in a rapidly subsiding fault-bounded elongate trough, with the more distal conglomerate representing beach or river gravel.

Sandstone and siltstone (Ass)

Grey clayey sandstone crops out at AMG 539906 in sequence with chert and quartz-muscovite schist, and is fine-grained, massive, poorly sorted and cleaved. Laminated siltstone and sandstone are poorly exposed at AMG 546930 in sequence with schistose clay rock with quartz eyes, chert, and quartzite; the sandstone is medium-grained, and composed of angular to subangular quartz in a fine-grained muscovite matrix.

Quartzite (Asq)

Quartzite crops out at AMG 582925 as a discontinuous ridge 2 km long, and at AMG 932718. The rock is blue or grey, fine-grained, recrystallised, foliated and lineated, and consists of granoblastic quartz (99%), muscovite after interstitial plagioclase, and hematite.

Granite

Granite occupies the country between the Mount Keith and Yandal greenstone belts, and is generally heavily weathered. Much of the granite is foliated and mylonitic. Quartz forms lenticular strained grains or recrystallised lenticular aggregates of small polygonal grains. Microcline is strained, broken, or brecciated to small fragments. Plagioclase is altered to muscovite ± epidote, and in places is recrystallised to polygonal mosaic patches; unaltered plagioclase is oligoclase. Biotite is weakly to strongly oriented and commonly altered to chlorite. Amphibole is blue-green. Iron oxide, allanite, zircon, titanite, and green spinel are accessory. Plagioclase-garnet-bearing pegmatite-aplite dykes and quartz veins are common in some areas, especially north and west of Alf Well. Some very coarse-grained white quartz veins are patchily recrystallised to red medium-grained quartzite.

Thin zones of subhorizontally lineated mylonite, now quartz-muscovite schist, cut the granite in some areas. Tabular zones of kaolin and epidote alteration several metres wide and striking east-northeast are common west of Beale Well and Alf Well.

Ninety-three samples of granite, gneiss, and a few dykes and xenoliths were collected from MOUNT KEITH. They are mostly surface samples, but include some drill core from Bronzewing mine supplied by Great Central Mines NL. Based on petrography and geochemistry, the samples have been classified into four of the five groupings of Champion & Sheraton (1997), and are delineated in Figure 13.

Low-Ca group

The most abundant type is Low-Ca granite, which occupies the central part of the Sheet area and is generally a massive porphyritic monzogranite or syenogranite with smaller regions of equigranular texture. It contains two rafts of felsic volcanic rock near its contact with the Yandal belt, and is faulted on its western side. These granites are chemically distinct from other groups, are easily recognised by their high K_2O, Rb, Rb/Sr, Th, U, Zr, and LREE, and are the youngest granites in the Eastern Goldfields Province.

High-Ca group

This group contains the bulk of the granites within the Eastern Goldfields Province (60%). Members of this group range from strongly deformed foliated granite interlayered with greenstone, eg. in the Cocks-Satisfaction Zone and in the northwest, to massive granite which is commonly well exposed, such as in the Barr-Smith Range. Chemically, these are trondhjemites and granodiorites characterised by high Na_2O and low to moderate K_2O, Rb, Th, and Zr, as is typical of the High-Ca group.

High-Ca granite is fine, medium, or coarse-grained in different places, and is well represented in MOUNT KEITH, where it crops out marginal to the Yandal and Mt Keith greenstone belts, and forms a component within the Cocks-Satisfaction Zone (Fig. 13). Bodies of High-Ca granite, intimately associated with Low-Ca granite, also occur in the Hannans Bore region of the central Low-Ca granite. The large body on the eastern side of the Mount Keith greenstone belt includes elongate rafts of banded iron formation, amphibolite, and quartzite along its western margin.

High-HFSE group, including High-Fe subgroup

Only a few members of this group have been recognised in MOUNT KEITH, where they occur mainly within the Cocks-Satisfaction Zone of strongly foliated and lineated granite (Agb) containing slices and rafts of amphibolite, banded iron formation, metadolerite, and talc schist. Elsewhere in the Yilgarn Craton, High-HFSE granites are commonly associated with volcanic rocks of similar chemistry. This, together with the structural and lithological complexity of the Cocks-Satisfaction Zone, makes it hard to decide whether these units are intrusive or extrusive.

A notable subgroup is high in Fe, but otherwise has many characteristics in common with the High-HFSE group, eg. elevated TiO_2, FeO, MgO, and Y, coupled with low Rb, Sr, and Th, although at lower silica levels (72-75%) than those observed elsewhere for the High-HFSE group. The High-Fe subgroup may represent either previously unrecognised mafic members of the High-HFSE group, or possibly volcanic rocks (related to High-HFSE volcanics) in the Cocks-Satisfaction Zone. If this is so, then the zone may contain significantly more greenstone than previously thought, suggesting it may have some potential for undiscovered Au mineralisation.

The overall embayed, ie. intruded, shape of the northern part of the Cocks-Satisfaction Zone, the 2738 ± 6 Ma age found on deformed and recrystallised granite in this zone 4 km south of the map sheet (sample no. 142813, Nelson 1998), and the intercalated amphibolite and banded iron formation, indicate that the zone is composed of rocks older than the adjoining granite. Regardless of their origins it would appear that these rocks represent a continuation of the High-HFSE volcanics and granites that crop out at Kookynie in MELITA to the south, and include the units around the old Teutonic Bore mine in WEEBO.

Mafic group

Tonalite and granodiorite of this group form small internal plutons (eg. the granodiorite south of the Anomaly 45 prospect in the southeast) and porphyry dykes within the greenstones. Members of this group are characterised by 55-68% SiO_2 and elevated Ni and Cr, relative to High-Ca granite. Within the Eastern Goldfields Province, members of this group appear to be the most favoured hosts for granite-hosted gold mineralisation, eg. at Granny Smith, Lawlers, and Liberty. So, the granodiorites south and south-southeast of Anomaly 45 may be potential hosts for gold.

Descriptions of greenstone belts

Mount Keith greenstone belt

Mount Keith mine area

The area north and south of the Mount Keith nickel mine is shown in Figure 9, which is a simplified solid geological map compiled from the present survey and from detailed mapping by Western Mining Corporation geologists. The area is part of the eastern succession of Eisenlohr (1992), and comprises mafic volcanics, felsic volcanics and sediments, ultramafic units, and granite in the east. Stratigraphic facing of the succession differs from place to place. Durney (1972) and Bunting & Williams (1977) recorded east-facing sedimentary structures in the Jones Creek Conglomerate in the Six Mile Well area. East-facing sedimentary structures observed during the present survey 2 km northwest of Six Mile Well included graded bedding (Fig. 7), low-angle trough cross-bedding (Fig. 8), and silt-filled scours in sandstone. WMC geologists have recorded east-facing komatiite flows at 'Spinifex Park', 2 km southwest of the mine, on the interpreted west limb of a fold. Naldrett & Turner (1977) found west-facing ultramafic flows 4 km south of Six Mile Well. The differences are resolved by inferring the existence of a fault, called the Erawalla Fault by Liu et al. (in press), between the Jones Creek Conglomerate and the volcanic-sedimentary sequence (Naldrett & Turner 1977).

Lithological contacts are not exposed in the area of Figure 9, but bedding in chert units in the greenstone succession is moderately to steeply east dipping. Contacts of mafic and ultramafic units encountered in drill core are steeply dipping, generally westward or vertical (Bongers 1994).

Six Mile Well area

The Mount Keith greenstone belt in the Kathleen Valley area south of Six Mile Well is made up of basalt, dolerite, gabbro, ultramafic rocks, felsic volcanics, silicic sedimentary rocks, and low-grade metamorphic rocks of uncertain parentage. It is characterised by an ultramafic unit that extends nearly continuously from Mount Keith to the Perseverance nickel mine. The ultramafics host disseminated Fe-Ni sulphides, with numerous subeconomic nickel deposits occurring in dunite pods along the belt (eg. Six Mile Well). Spinifex cooling textures in komatiite indicate that the sequence faces west (Naldrett & Turner 1977), and is in sheared contact with the eastward-facing Jones Creek Conglomerate, which is regarded as a late component of the greenstone succession (Marston & Travis 1976; Eisenlohr 1987). Within the greenstone sequence, the less competent rocks (metasediments and basalt) are strongly foliated. In contrast, more competent rocks (eg. gabbro, dolerite, and dunite) are weakly deformed, and retain primary textures and relationships. Most greenstones have been affected by lower to upper greenschist facies metamorphism. Amphibolite facies rocks are mostly restricted to the intercalated greenstone at the margins of the greenstone belts and to mafic inclusions in granite.

McFarlane's Find area

A solid-geology map of the area around McFarlane's Find is shown in Figure 10. The sequence begins with basalt in the east, overlain by schistose quartz-feldspar-muscovite rocks and their weathered equivalents, and ultramafic rocks (chiefly serpentinised dunite and talc schist). These rocks are faulted against arkose of the Jones Creek Conglomerate, which unconformably overlies granite to the west.

Yandal greenstone belt

The Yandal greenstone belt trends north-northwest for about 200 km from WEEBO in the south (Oversby 1995), to LAKE VIOLET in the north (Stewart & Bastrakova 1997; Stewart 1997). The belt contains a number of significant gold deposits, including Bronzewing, Jundee, Nimary, Mount McClure, and Darlot, as well as numerous smaller occurrences, such as the old Corboys mining centre. The belt is flanked by the Ninnis Fault (Westaway & Wyche, in press) to the east, and by the Barwidgee Lineament to the northwest in the Corboys Find area. The margins are fault-bounded, with the contacts characterised by strong deformation, relatively high-grade metamorphism, and interleaved granite and greenstone. The western margin of the Yandal greenstone belt occupies the eastern side of MOUNT KEITH and SIR SAMUEL. The greenstone sequence differs from the Mount Keith greenstone belt to the west in that the Yandal sequence appears to contain less mafic and ultramafic rock, and more felsic and sedimentary rock. Westaway & Wyche (in press) suggest that the sequence of sedimentary, mafic, and ultramafic rocks along the western side of the Yandal belt is similar to, and may correspond to the lower part of, the Leonora–Laverton greenstone sequence immediately to the south (Association 1 of Hallberg 1985).

Mount McClure area

West of the Mount McClure pits, the western margin of the Yandal greenstone belt is represented by a strongly deformed and metamorphosed zone, approximately 6 km wide, of complexly interleaved granite and mafic and felsic rocks (units Abg and Agb). The gamma-ray signature of this zone is characteristic of basalt rather than granite. The greenstones (mafic and felsic rocks) occur as 1-50 m thick bands, intercalated with granite. Rocks in the interleaved granite-greenstone zone have attained a higher metamorphic grade than those in the adjacent greenstone sequence. The mafic rocks commonly attain amphibolite

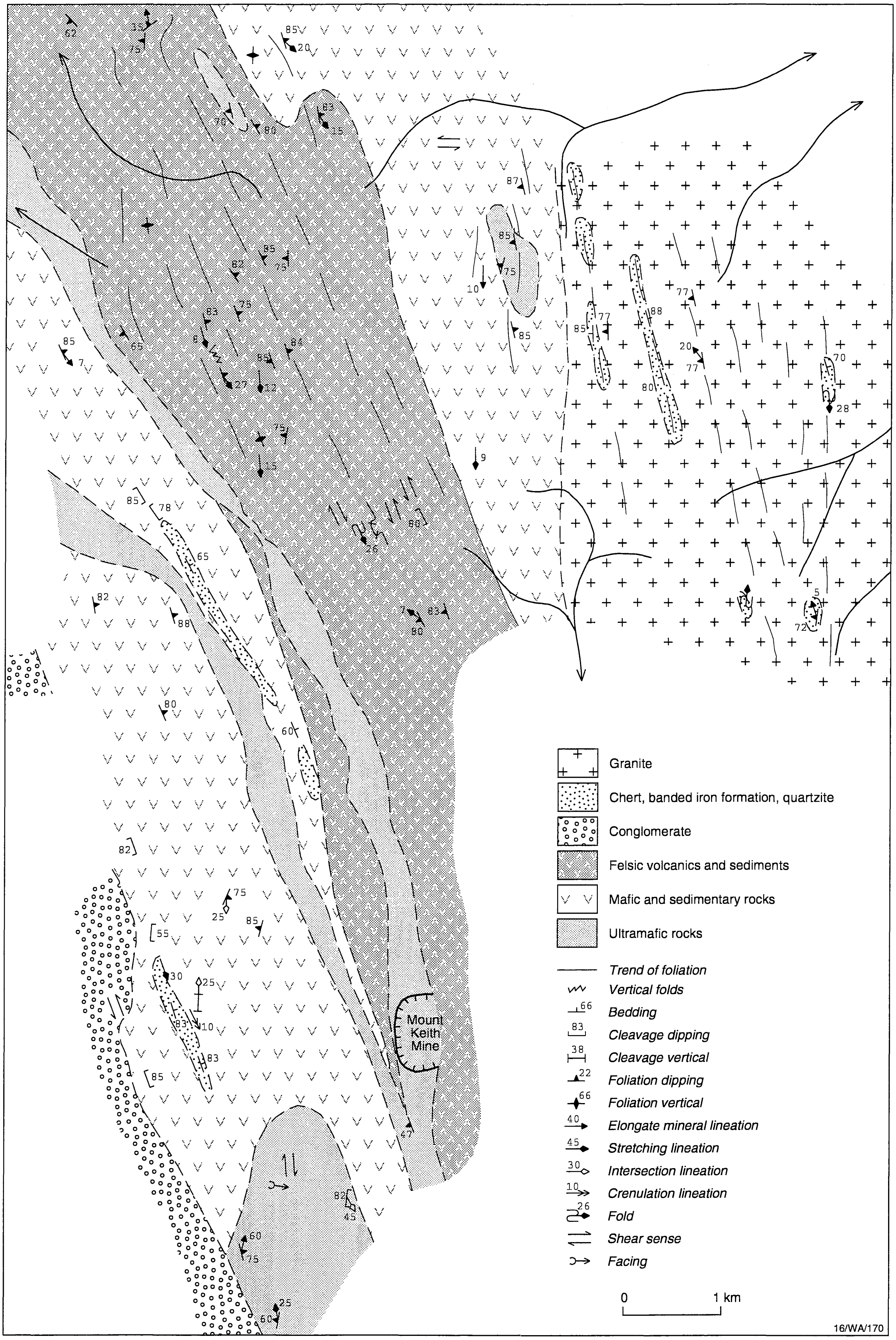

Figure 9. Solid-geology map of Mount Keith mine area compiled from Western Mining Corporation unpublished maps and AGSO geological mapping in 1994.

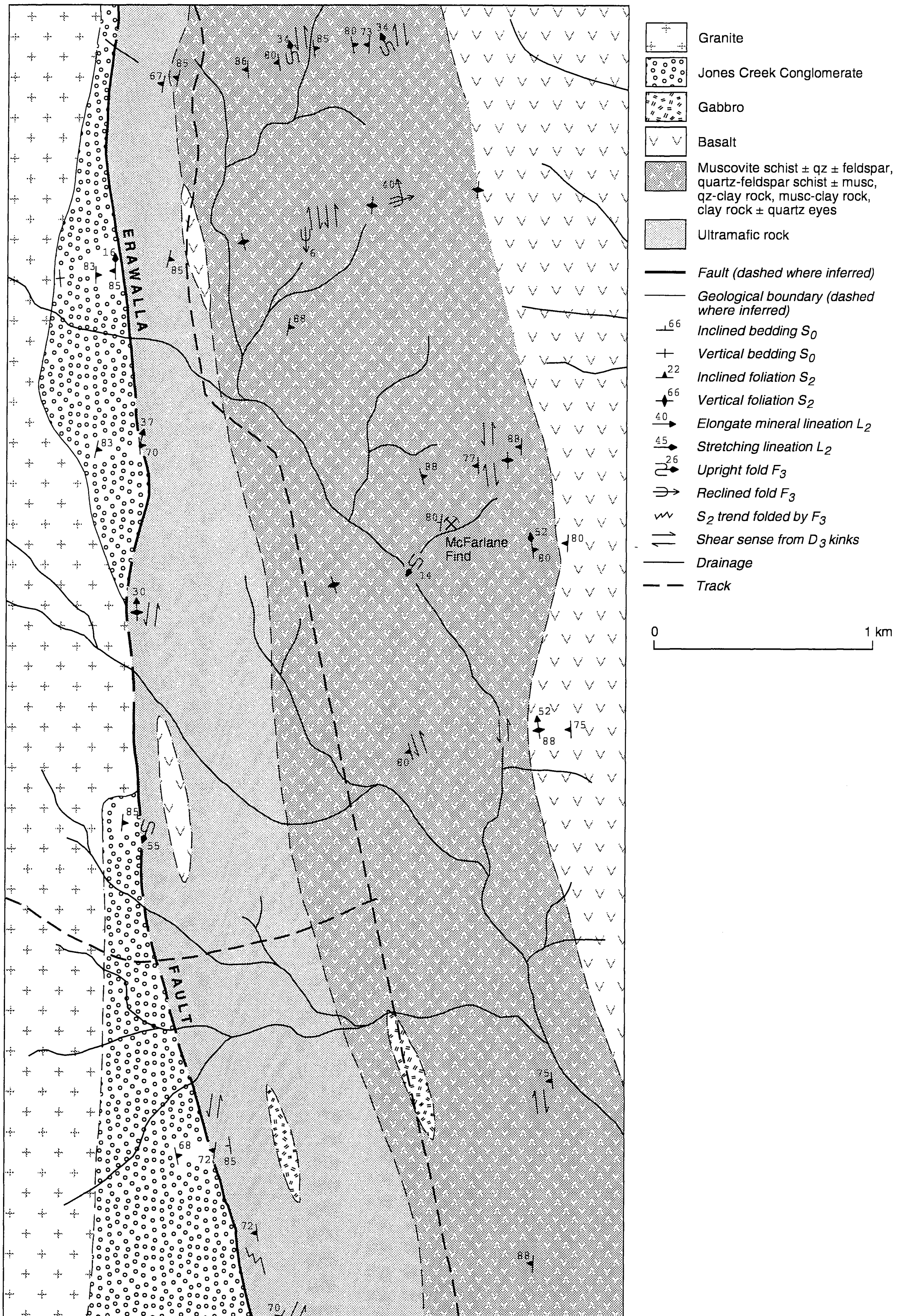

Figure 10. Solid-geology map of area around McFarlane's Find, Mount Keith greenstone belt. Compiled from AGSO geological mapping in 1994, RAB hole bottom sample identification by AGSO 1994, and aeromagnetic interpretation.

facies, whereas those within the greenstone sequence to the east are mainly greenschist facies. The amphibolite is fine-grained, strongly foliated, and locally has thin gneissic banding formed by segregation of mafic and felsic minerals. Despite the high metamorphic grade, the greenstones in the interleaved zone retain primary textures in places.

Both granite and greenstones range from weakly to strongly deformed. They exhibit moderate to steep east-dipping foliation (40-75°), and there is also a strong subhorizontal mineral lineation that has a shallow (5°) southward plunge. In granite, it is defined by stretched, rod-shaped quartz augen and aggregates of recrystallised biotite. Shearing is common in the granites, and is expressed as local thin high-strain mylonite zones, or by the alteration to quartz-mica schist. The best-preserved example of mylonite is at AMG 933595, where a prominent thin ridge of fresh, fine-grained mylonitised granite occurs within coarser grained less deformed granite. At this location, flattening of large mafic enclaves can be used as a measure of shear intensity. In the mylonite zone, the enclaves are stretched and flattened parallel to the strongly developed foliation and lineation. In the surrounding granite they are far less deformed. At AMG 936599, kink banding is developed in quartz-mica schist (Fig. 11).

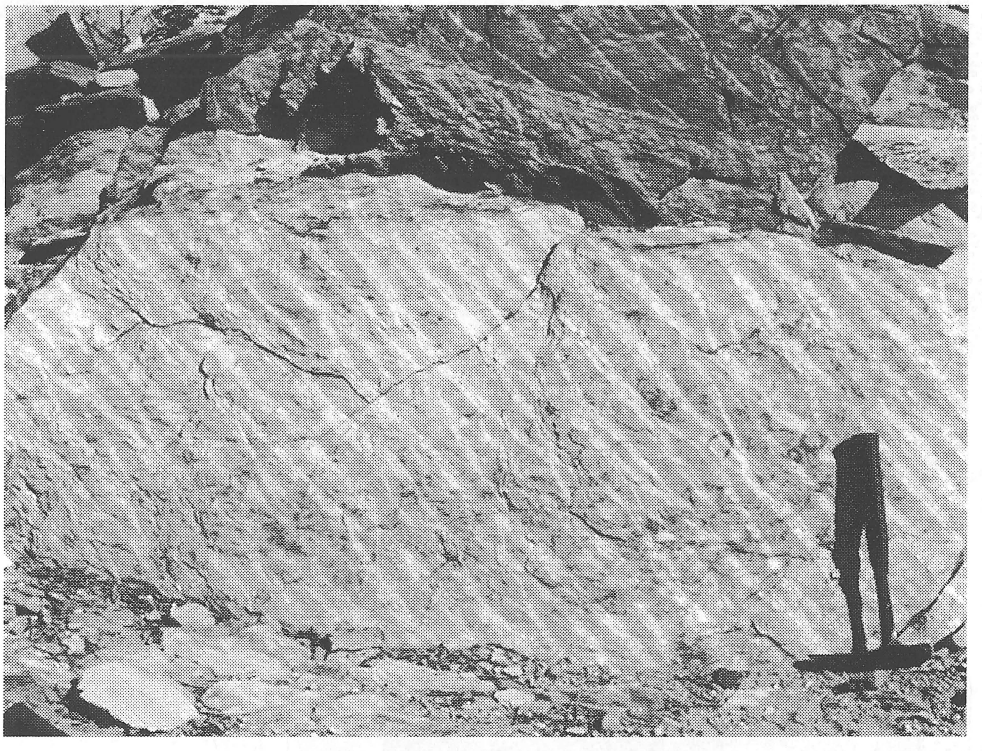

Figure 11. Kink bands in quartz-feldspar schist. AMG 936599. Hammer 32 cm long.

The shearing at the contact can be attributed to the regional north- to northwest-trending deformation event (D_3) (Westaway & Wyche, 1998). Other parallel structures suggested by discontinuities in aeromagnetic images and structures which host gold mineralisation in the Mount McClure deposits may also be related to this deformation event.

Evidence suggests the greenstone sequence is east-younging, based on sedimentary structures and differentiation trends in a gabbroic sill in DARLOT (Westaway & Wyche in press). Relationships between sedimentary and mafic rocks displayed in drill core from the Mount McClure gold mine also indicate younging to the east (Harris, J., 1994, Arimco Mining Pty Ltd, pers. comm.).

The greenstones in the Mount McClure region are poorly exposed, consisting of isolated pods of outcrop scattered throughout a deeply weathered laterite profile, which extends eastward for some distance into WANGGANNOO. It is therefore impossible to determine the stratigraphic relationships between different rock types. Scattered outcrop, augmented by rock chip samples from mineral exploration drillholes, indicate the greenstones consist of a mixed sequence of weathered sedimentary rocks and felsic volcanic rocks, fresher basalt and dolerite, and minor ultramafic units. Two small granite stocks 1-2 km in diameter intrude the greenstones at AMG 980576 and AMG 003573. The westernmost granite is associated with anomalous Au values (Harris, J., 1994, Arimco Mining Pty Ltd, pers. comm.). They have a similar composition and mineralogy to the Ken's Bore Granite, which crops out in WANGGANNOO and DARLOT to the east, and also contains visible gold in quartz veins.

Beale Well area

The major elements in the Beale Well area of the Yandal belt are a greenstone sequence in the southeast, and a large granite mass in the north and west intruding the greenstone (Fig. 12); an elongate mass of granite underlying the Express Bore – Alf Well area is concealed, and inferred from aeromagnetic data and fine-grained granite at the bottom of a RAB hole at AMG 997725. The greenstone sequence consists largely of metabasalt, together with a large lens of felsic volcanics in the west, small lenses of shale, calc-silicate rock, felsic volcanics, and ultramafics in the east (known only from RAB hole cuttings), and small dolerite bodies. The exposed granite comprises two different parts:

- In the west, the granite is strongly foliated Agb, and contains numerous lenses or rafts of amphibolite and metabasalt, and rare lenses of banded iron formation,

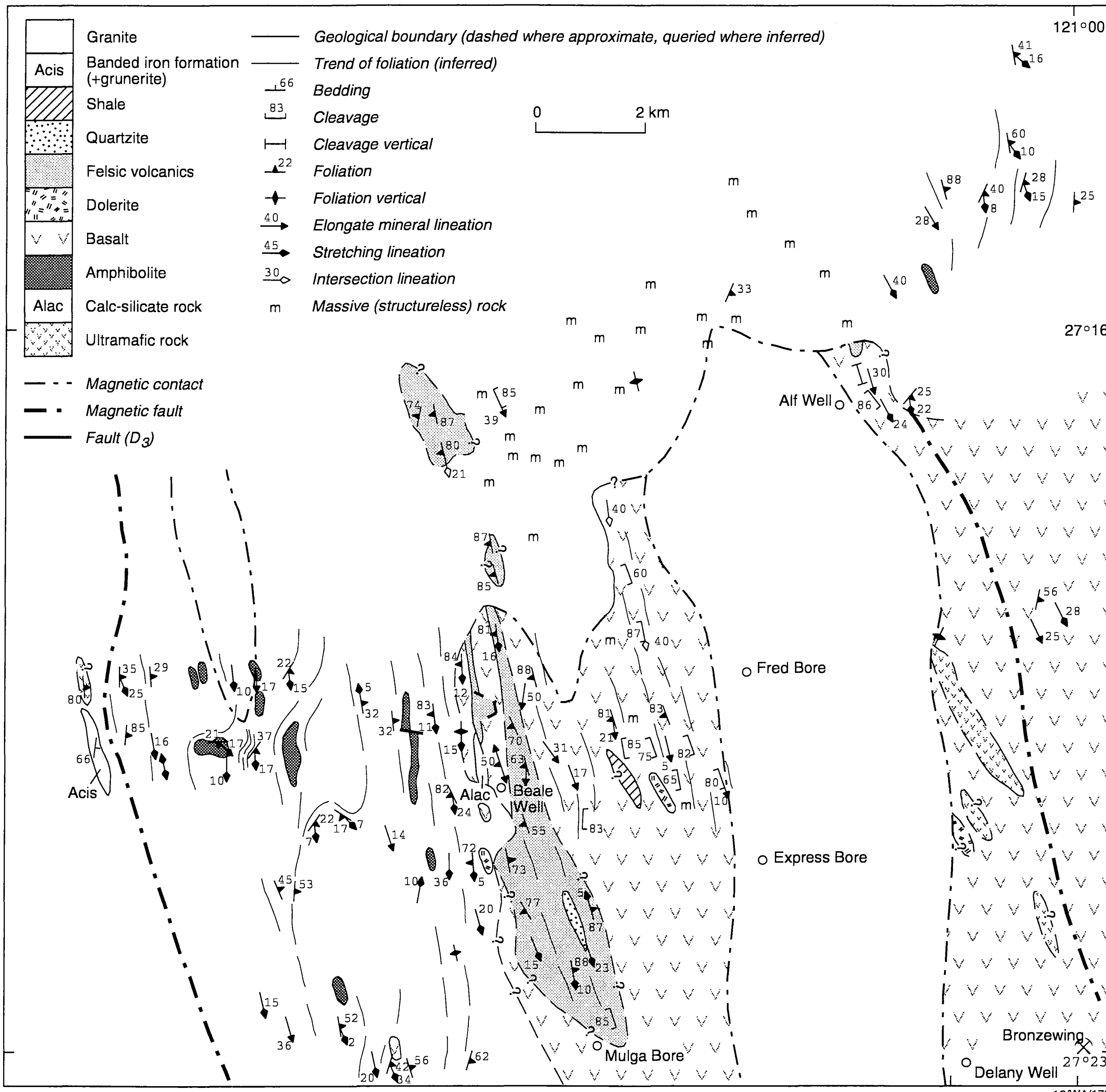

Figure 12. Solid-geology map of Beale Well area, Yandal greenstone belt, compiled from AGSO geological mapping 1994, RAB-hole bottom sample identification by AGSO 1994, and aeromagnetic interpretation.

ultramafic rock, and biotite schist;

• In the north, the granite is mostly massive AgL, but foliated in patches, and contains one small lens of amphibolite and two rafts of felsic volcanics on strike with the large lens in the greenstone belt to the south.

Barwidgee area

In the Barwidgee region in the northeast, the Yandal greenstone sequence consists of a lower mafic sequence of basalt intruded by gabbros and dolerites, overlain by a sequence of highly weathered and poorly outcropping metasedimentary and felsic volcanic rocks. Prominent chert and ferruginous chert ridges occur at the base of the sedimentary sequence. The lower basalts structurally overlie and are in sheared contact with a coarse-grained monzogranite.

The old gold workings of the Corboys Find district are scattered over 5 km, and are mainly located in shears at the granite-mafic contact. Significant mineralisation also occurs in the Tuscana area, 700-800 m west of the granite-mafic contact, where gold is associated with shear zones in granite. It is likely that the shearing is associated with the north-northwest-striking Barwidgee Lineament, a prominent magnetic feature. Where the shear zone intersects the granite-greenstone contact, the mafic rocks may have imposed a permeability barrier to hydrothermal fluids migrating along fracture zones, explaining the association of gold mineralisation with the granite-greenstone contact.

The sheared granite-basalt contact is covered by sandy laterite, and weathered bedrock is exposed only in shafts, pits, and costeans. Shearing at the granite-greenstone contact is expressed as strongly foliated to schistose zones containing quartz-muscovite schist and quartz-augen gneiss (after granite), carbonate-chlorite-sericite alteration, and intense quartz veining and silicification. Shearing is most intense within 100-200 m of the contact. The intensity of foliation in the greenstones decreases rapidly away from the contact, and farther away, the shears become fracture zones, characterised by carbonate-chlorite schist in the basalt and sericitisation in the granite. This narrow zone of intense shear at the contact contrasts with the 6 km-wide zone of deformation and metamorphism at the western margin of the Mount McClure sequence to the south. Foliation and lineation trends in the basalts and sedimentary rocks range between 300° and 340°.

The basalts to the east of the granite crop out as low undulating hills. There is a grainsize variation from fine-grained basalt coarsening to dolerite to the east, with minor gabbroic intrusions. The basalts are bordered to the east by a 1-10 m-thick sequence of chert, which forms prominent ridges (eg. Mount Hilda). The chert has been recrystallised, but exhibits relict brecciation and lamination. The chert is overlain by a sequence of poorly exposed weathered schistose interbedded metasedimentary and felsic volcanic rocks. The sediments consist of a fine-grained quartz-muscovite-chlorite ±andalusite assemblage, are commonly schistose or kaolinised, interbedded with thin chert bands. Felsic volcanic rocks comprise limonitic fine-grained kaolin with quartz phenocrysts.

Structure

A solid-geology map of MOUNT KEITH is shown in Figure 13, and shows the Mount Keith and Yakabindie greenstone belts in the west, two areas of the Yandal greenstone belt in the northeast and southeast, granites, and inferred Proterozoic mafic dykes in the north. The Sheet area is cut by major north to north-northwest-striking faults, which include (from west to east): the Erawalla Fault (formerly Perseverance Fault of Bunting & Williams 1979, but changed by Liu et al. 1995) on the western side of the Mount Keith greenstone belt; the Perseverance Fault on the eastern side of the Mount Keith greenstone belt (following Liu et al. 1998, who changed it from the western side on geological grounds); two major faults inferred from aeromagnetic data in the central granite region; and the Mount McClure Fault in the southeast.

Mount Keith greenstone belt

Mount Keith mine area

Previous structural studies relevant to the Mount Keith mine area include the work of Eisenlohr (1987, 1992) in Lawlers – Six Mile Well area 20 km to the south, and the very detailed structural work of Bongers (1994) around the Mount Keith mine. The major structural events determined in these areas are set out in Table 1.

In summary, the two areas are characterised by a steeply dipping D_2 foliation that strikes north-northwest, and a gently plunging lineation in the foliation. There is, however, a significant difference in the two schemes, in that Eisenlohr regards his D_2 phase as a continuation of his D_1, whereas Bongers recognises a phase of folding (D_1) with $\sigma 1$ north-south and older than the north-trending D2 folds. Also, D_3 in Eisenlohr's scheme is extensional, whereas in Bongers' scheme it is contractional.

D_1 We did not see Bongers' (1994) D_1 structural elements. Her work became available only after completion of the AGSO survey.

D_2 structures in the area include foliation, lineation, and C-planes.

Foliation and lineation are imparted to the rocks by:

- Flattening and elongation, with or without recrystallisation, of quartz, and in some rocks by brecciation of quartz;
- Preferred orientation of amphibole prisms and needles, and of mica flakes and aggregates;
- Distortion and brecciation of microcline;
- Elongate aggregates of clinozoisite and titanite.

In weathered rocks, foliation is expressed as a rough schistosity or flaky parting in the largely clay assemblage. Komatiite in 'Spinifex Park' has two steep cleavages enclosing lozenges of less deformed rock (Fig. 14a); the cleavage intersection produces an intersection lineation. Foliation dips are everywhere steep to vertical, and overall strike north-northwest (Fig. 15a).

Lineation in the foliation is variously a stretching lineation, where the grains have been elongated by deformation, or a mineral elongation where undeformed elongate grains are preferentially oriented. Plunges are gentle to moderate (Fig. 15b) and generally northward in the south of the area, and southward in the north.

At one locality in the southwest (AMG 539862), vertical colour lamination in heavily weathered muscovite-clay rock (metasiltstone?) is cut by a moderately east-dipping cleavage which may be a local shallowing of the D_2 foliation.

Additional D_2 structures include C-planes and shear bands which indicate a consistently sinistral sense of shear at four out of five localities (Fig. 14b, c, d, e); boudins with sinistral shear (Fig. 14f), and gentle to close folds in rafts of banded iron formation in the eastern granite (Fig. 14g, h, i). The folds in these rafts are gently plunging, and show a vergence indicating west block up, ie, greenstone (to west) up and over granite (to east). This conflicts with Eisenlohr's (1992) conclusion that the eastern granite is upthrust over the greenstones to the west.

The sense of shear in the D_2 foliation is almost everywhere sinistral, implying a regional compressive stress oriented about east-southeast.

D_3 structures, which deform D_2 foliation, include:

- Steeply plunging gentle to isoclinal folds (Fig. 16a, b, c, d, e, f, g; Fig. 17a and b; Fig. 18), dextral at three localities, sinistral at one;
- Dextral kink bands (Fig. 16h) and conjugate kink bands with no sense of shear (Fig. 16i) deform S_2 in quartz-feldspar schist, shale, slate, and quartz-muscovite schist 5-6 km north of the Mount Keith mine.
- An east-west vertical shear zone with sinistral sense of shear (Figs. 16j, 19).

Most northerly-striking shear sense indicators in D_3 are dextral, implying north or north-northeast regional compression, as concluded by Bongers (1994). The east-west shear zone (Fig. 16j) is in the conjugate orientation for this compression.

Structural history of Mount Keith mine area

In the Mount Keith mine area, the present survey confirmed phases D_2 and D_3 of the structural synthesis of Bongers (1994). The history of the mine area, incorporating present results together with both Eisenlohr's and Bongers' results, is set out in Table 2.

McFarlane's Find area

The main structural element is a steeply dipping north-northwest-trending foliation S_2 in all the greenstone rock types (Fig. 15c). In places, lineation L_2 plunges gently to moderately north in the foliation (Fig. 15d), and is a stretching lineation in some places, an orientation of elongate grains elsewhere. The foliation is folded (F_3) on the outcrop scale, and plunges are gentle to moderate north or south. Vergence on all folds is sinistral, ie, east-side-north. Numerous mesoscopic kink bands and folds deform

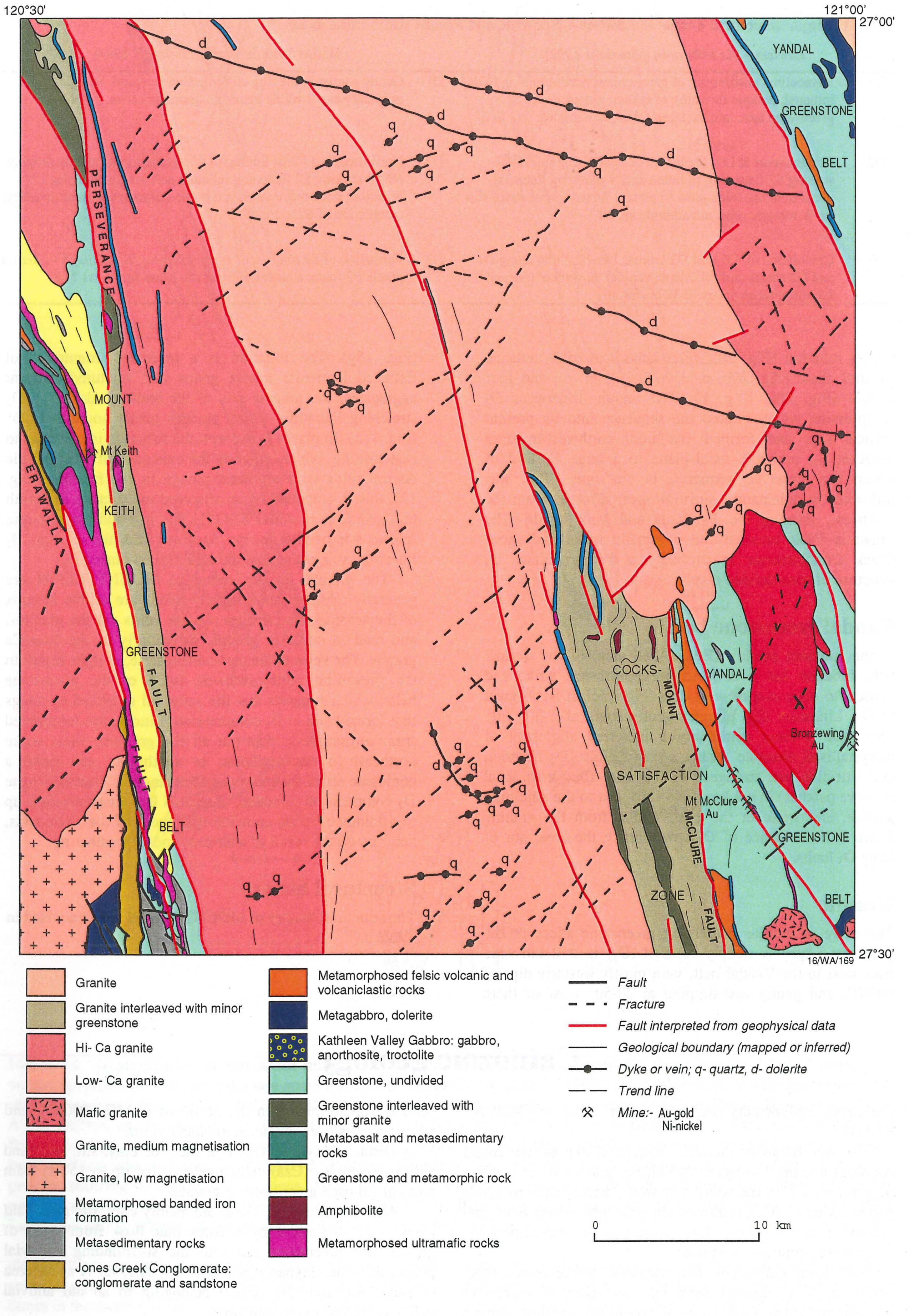

Figure 13. Solid-geology map MOUNT KEITH, compiled from AGSO mapping and RAB-hole bottom sample identification 1994, WMC mapping in Mount Keith mine area, and data from Naldrett & Turner (1977) in Six Mile area.

Table 1. Major structural events in Lawlers – Six Mile and Mount Keith mine areas

	Lawlers – Six Mile area (Eisenlohr 1992)		*Mount Keith mine area (Bongers 1994)*
D1	Homoclinal positioning of greenstones; north-trending folds initiated; oblique thrusting of eastern granite over greenstone belt; intense steep foliation in granite. σ1 E-W	D1	Gently southerly dipping chloritic cleavage and folded but originally east-striking veins in ultramafic rocks. σ1 N-S
D2	Continuation of D1; formation of steeply dipping NNW-striking S2 flattening foliation and N-plunging lineation; north-trending folds grew to present form; dextral strike-slip on W margin; peak metamorphism. σ1 E-W	D2	North-trending folds; folding of S1; formation of steeply dipping NNW-striking S2 flattening foliation and gently plunging L2 lineation; peak metamorphism; brittle deformation in ultramafics; crenulation of S2. σ1 E-W
D3	Crenulation of D1 and D2 fabrics; local faulting along D1 and D2 shears and foliations; vertical movement (normal faulting), felsic dykes. E-W extension	D3	Formation of discontinuous steeply dipping E-striking S3 foliation; gentle F3 folds; sinistral oblique-slip cross faults. σ1 N-S

the F_2 foliation (Fig. 20); nine kinks and folds indicate sinistral shear (Fig. 20b, c, e, h, i, j, l, m, o), and four dextral (Fig. 20a, f, g, k). The region underwent D_2 compression which rotated the sequence into its present vertical dip, and formed the north-northwest-trending foliation S_2, probably axial-plane to a large F_2 fold of which the preserved sequence is one limb. This was followed by dominantly sinistral shear directed from the southeast, forming the F_3 folds and kink bands. The Erawalla Fault between the ultramafic rocks and Jones Creek Conglomerate is probably a transpressional D_3 structure of considerable displacement.

Yandal greenstone belt

In the southern portion (Beale Well area) of the Yandal belt, foliation has a uniform north-northwest strike and vertical to steep east or west dips (Fig. 15e); it is assigned to D_2. Lineation (L_2) plunges gently south at 5-30° Fig. 15f), and is most commonly a preferred alignment of recrystallised elongate grains of amphibole. D_2 foliation and lineation are strongest in the west (but with local massive patches) in a 4 km-wide strip next to the adjoining granite, and weak in the east, farther from the granite. There is no evidence of D_1 structures in the area, nor of large D_3 faults.

Granite

The body of granite containing greenstone slices in the southeast (Agb) is steeply foliated (D_2) in a 2 km-wide zone next to the Yandal belt, with mostly westerly dips of 60-90°, and gently east-dipping at 20-50° west of there (Fig. 15g). The foliation is a preferred orientation of flattened lenticular quartz grains and fractured feldspar aggregates; the longest axis of the lenticles defines a D_2 stretching lineation, which plunges gently south at 0-35° (Fig. 15h). In places in the west the foliation is northeast to east-striking, which suggests the existence of macroscopic dextral folds with southeast plunge in the foliation (Fig. 12); this is supported by an observed mesoscopic fold with this geometry at AMG 874751. The inferred macroscopic fold axis is parallel to, but does not fold, the regional D_2 lineation, suggesting that the fold formed during D_2.

The granites in the centre of MOUNT KEITH are generally massive, but northerly trends are visible in parts of the aeromagnetic images. Quartz veins cut the granites, and tend to occur in groups, particularly in the Low-Ca granite. The veins strike east-northeast, ie, at right angles to the prevailing north-northwest trend of the greenstone belts, which suggests that the veins fill tensional openings that formed late in D_2 compression. Lineaments interpreted from aeromagnetic data cut all the granites. Most strike northeast to east-northeast, or southwest, and make a conjugate set of shears whose acute angle is bisected by the D_2 compression direction. Zones of low magnetisation up to a kilometre wide coincide with most of the lineaments, and may be the result of alteration and/or weathering.

Structural history

The structural history of MOUNT KEITH is summarised in Table 3.

Cainozoic geology

Cainozoic sedimentary deposits cover most of MOUNT KEITH.

In situ deposits include: silcrete (Czz) as horizontal cappings and breakaways on weathered granite at the margins of granite areas in the south and west; lateritic duricrust hills and breakaways (Czl) scattered along the greenstone belts; and yellowish brown silcrete (Czu, silica cap) on ultramafic rock. Transported deposits comprise:

• Proximal colluvium. This includes: pebble gravel, sand, and talus (Czc) derived from hills and rises of granite or greenstone; aprons of pebbly colluvium and alluvium derived from laterite (Czf); colluvial sand and gravel (Czg) derived from granite; ferruginous talus (Czi) adjacent to ridges of banded iron formation in the northeast (AMG 005005); and siliceous talus (Czq) adjacent to quartz veins.

• Distal colluvium. This is a sheet of clay, silt, and sand with rare pebbles (Cza), which extends for up to 15 km from areas of exposed greenstone or granite.

• Alluvial sediments. These are mainly clay, silt, sand, and gravel (Qa) deposited by streams that flow from areas of granite and greenstone out into the surrounding colluvial plains, and one claypan (Qac) at AMG 692742. A small area of sand, silt, and clay (Czsv) belonging to an old alluvial valley is located in the southwest.

• Aeolian sediments. Extensive sheets of sand (Czs) occupy the plains between bedrock exposures. It overlies

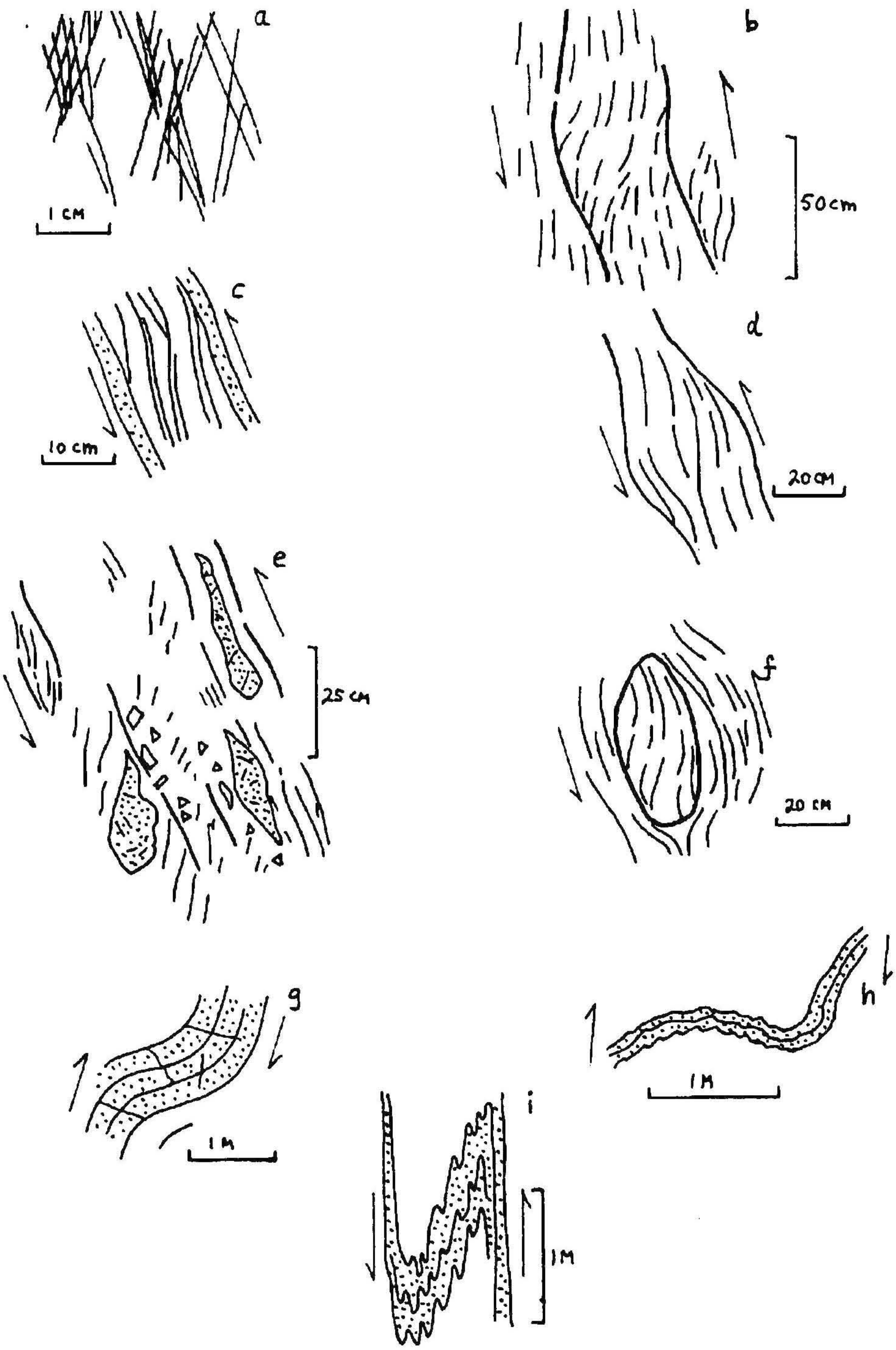

Figure 14. D_2 structures, Mount Keith mine area. a–f sketch maps looking vertically down, north at top of page. g – i vertical profiles. (a) Intersecting close-spaced cleavages in komatiite, AMG 582837. (b) C-planes in quartz-muscovite schist showing sinistral shear sense, AMG 582837. (c) Competent beds in silicified shale acting as C-surfaces with sinistral shear, AMG 562908. (d) Boudin-like swelling in silicified shale bounded by C-surfaces with sinistral shear, AMG 562908. (e) Brecciated S_2 foliation and quartz lenticles with sinistral shear sense, AMG 564910. (f) Silicified boudin in shale bounded by C-surfaces with sinistral shear, AMG 562908. (g) Profile of subhorizontal gentle fold in banded iron formation raft in granite, showing west-block-up vergence, AMG 605897. (h) Profile of subhorizontal folds in banded iron formation raft in granite, showing west block up vergence, AMG 599898. (i) Profile of gently south-plunging tight folds in banded iron formation raft in granite, showing east block up vergence, AMG 606920.

distal colluvium (Cza), from which it has formed by aeolian reworking (cf. Mabbutt 1977, p. 215), sufficiently so to form dunes in the south and east.

• Lacustrine sediments. These make up an extensive area in the northwest, and comprise mostly quartz and gypsum dunes with minor silt and clay (Czd), accompanied by a few small playa lakes filled with evaporites, sand, and clay (Czp). The sediments are part of the east-directed Lake Way – Lake Maitland palaeochannel. Smaller areas of similar sediments are located at Wanjarri recreational centre, and at AMG 740960. One very small area of clay and subordinate dune sand (Czb) in the Lake Way – Lake Maitland palaeochannel

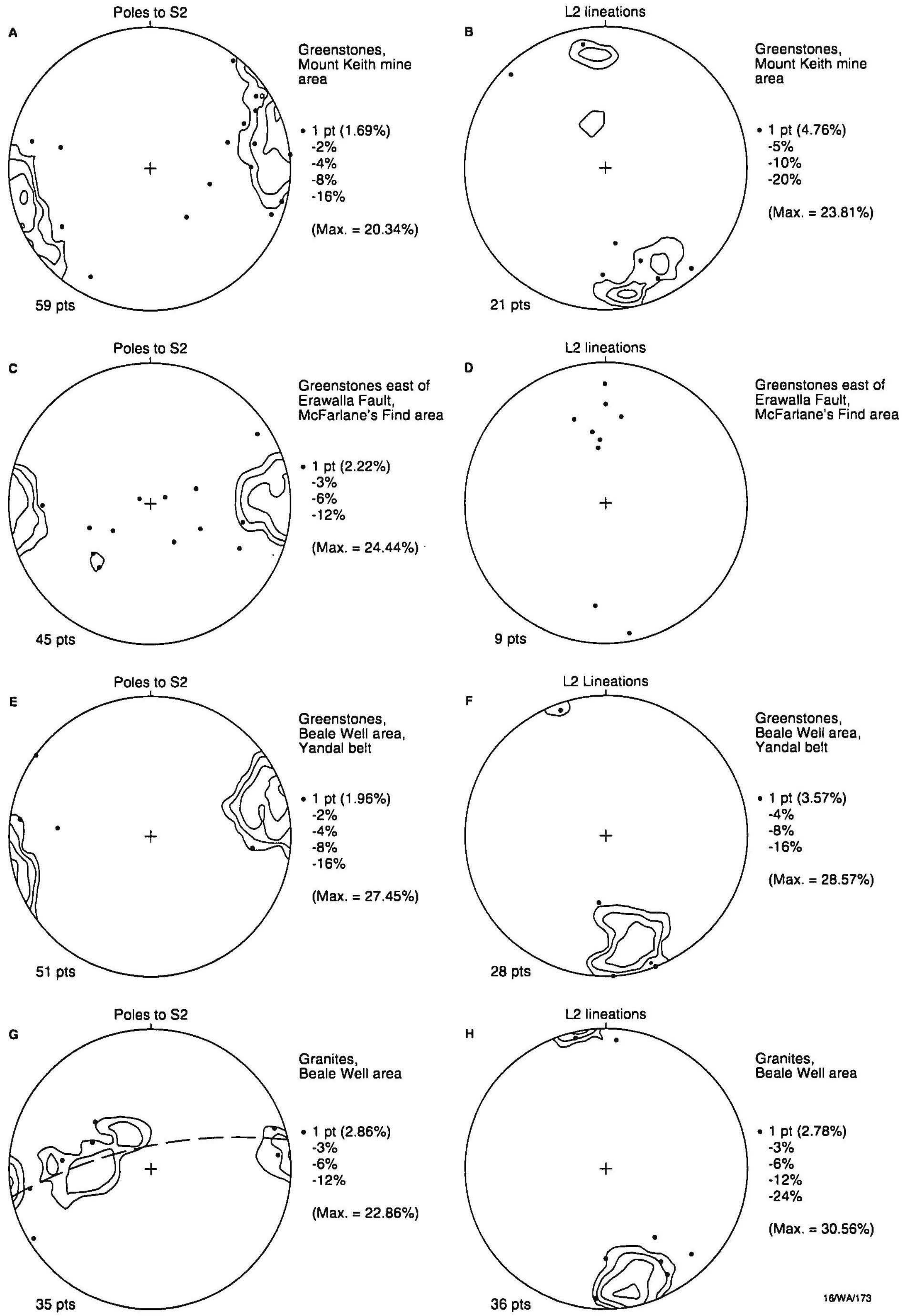

Figure 15a-h. Stereograms of structural elements in MOUNT KEITH. a-d Mount Keith greenstone belt. e-f Yandal greenstone belt. g-h Granites adjoining west side of Yandal belt.

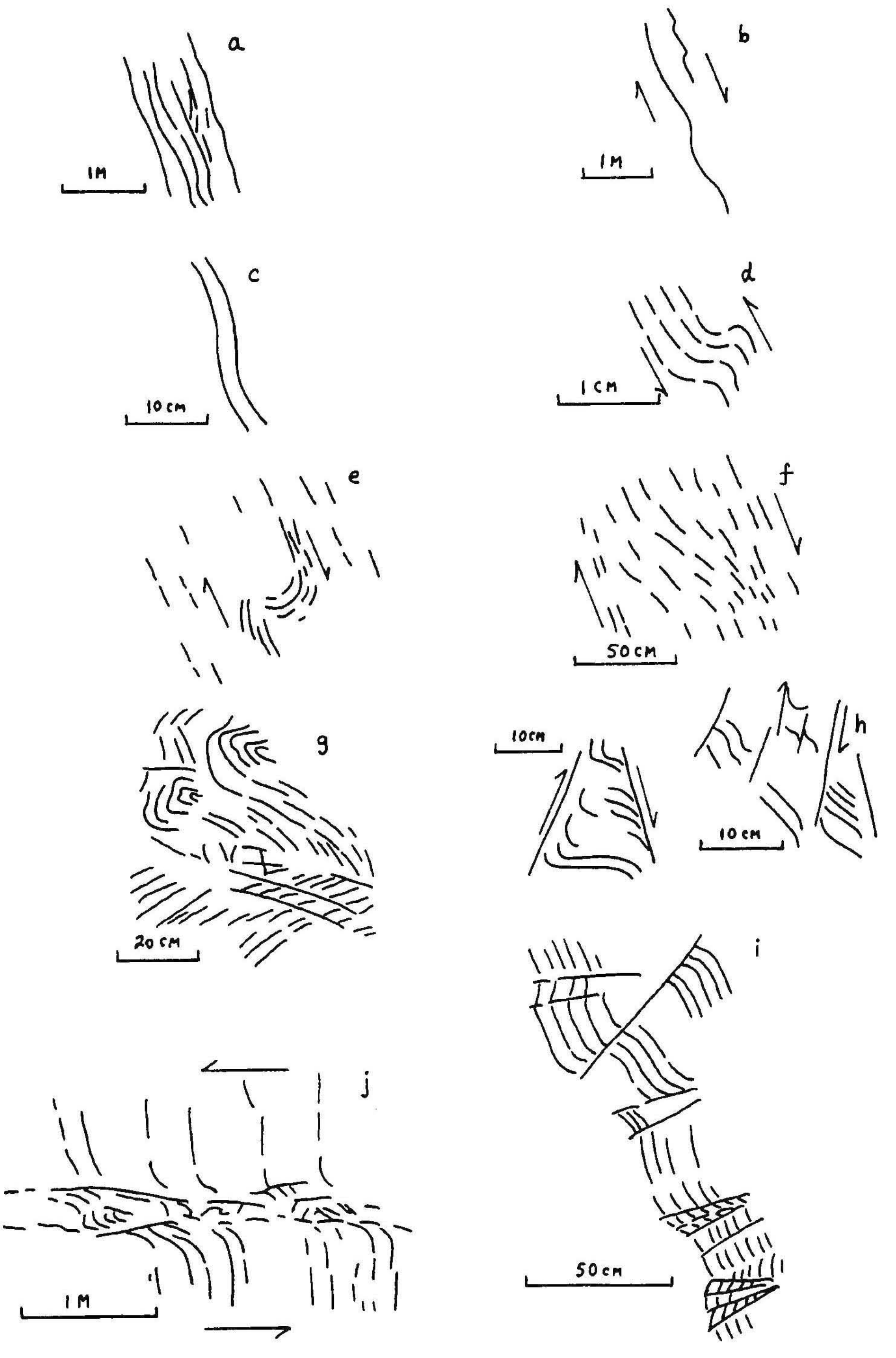

Figure 16. D_3 structures, Mount Keith area. All sketch maps looking vertically down, north at top of page. (a) Vertically plunging warp in chert, AMG 546921. (b) Steeply plunging gentle warp with dextral vergence deforming D_2 schistosity in silicified quartz-feldspar schist, AMG 566897. (c) Steeply plunging open warp deforming D_2 foliation and lineation in talc schist, AMG 548832. (d) Sinistrally verging fold deforming D_2 schistosity of quartz-muscovite schist, AMG 536855. (e) Dextrally verging fold with gentle southeasterly plunge deforming D_2 schistosity in quartz-muscovite schist, AMG 558907. (f) Dextral warp deforming D_2 slaty cleavage, AMG 557907. (g) Steeply east-plunging folds in shale, AMG 557907. (h) Dextral chloritic shear zones deforming D_1 or D_2 schistosity in komatiite, AMG 551840. (i) Conjugate kink bands deforming D_2 schistosity in quartz-muscovite schist, AMG 558907. (j) Sinistral vertical shear zone cutting D_2 schistosity in heavily weathered mafic schist, AMG 567943; same locality as Figure 9.

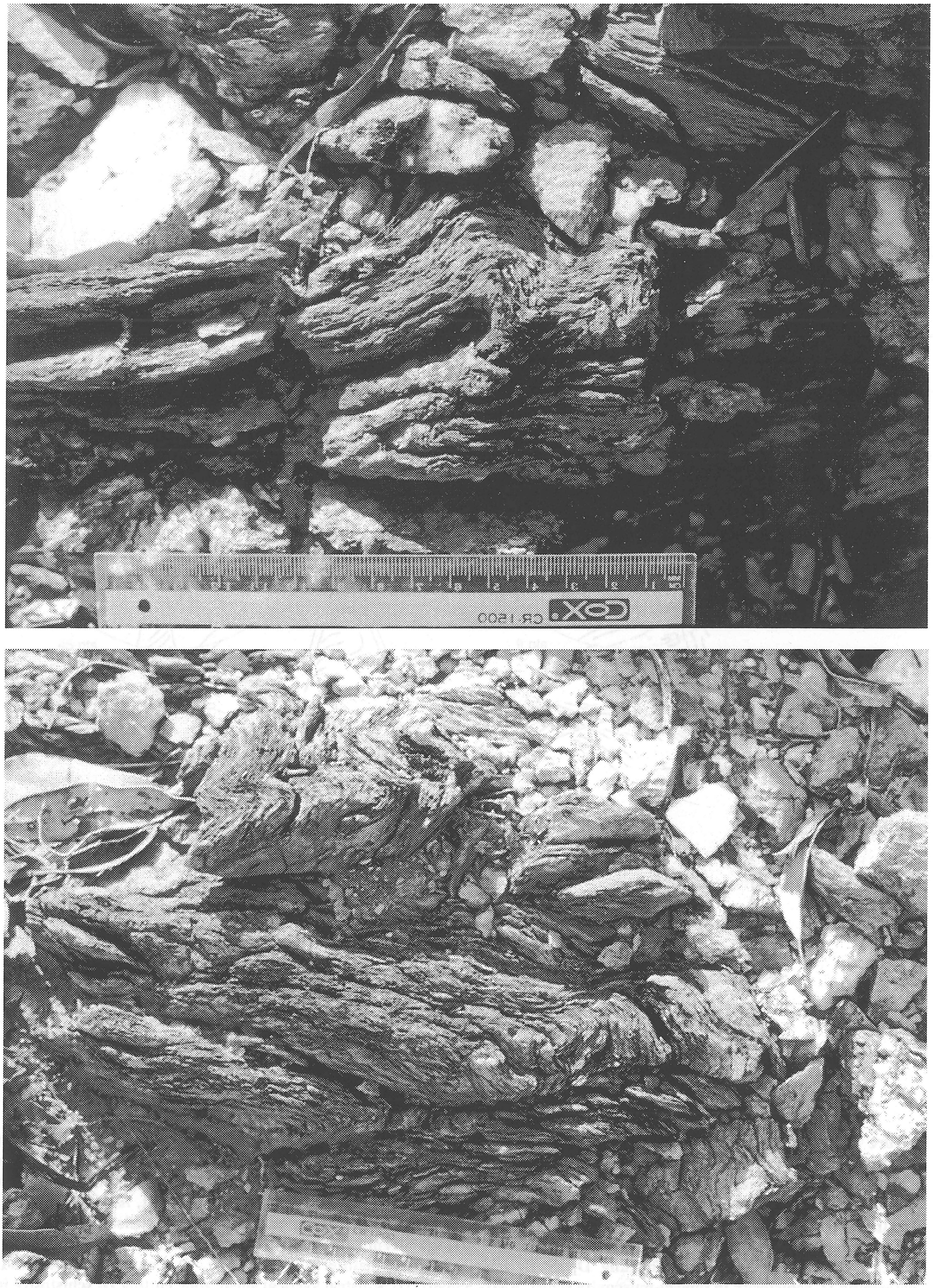

Figure 17a and b. D_3 kink folds in muscovite schist. AMG 606688. Scale 15 cm long.

Figure 18. Disharmonic vertically plunging D_3 boxfold in shale and schistose quartz-clay rock. AMG 603683. Scale in millimetres.

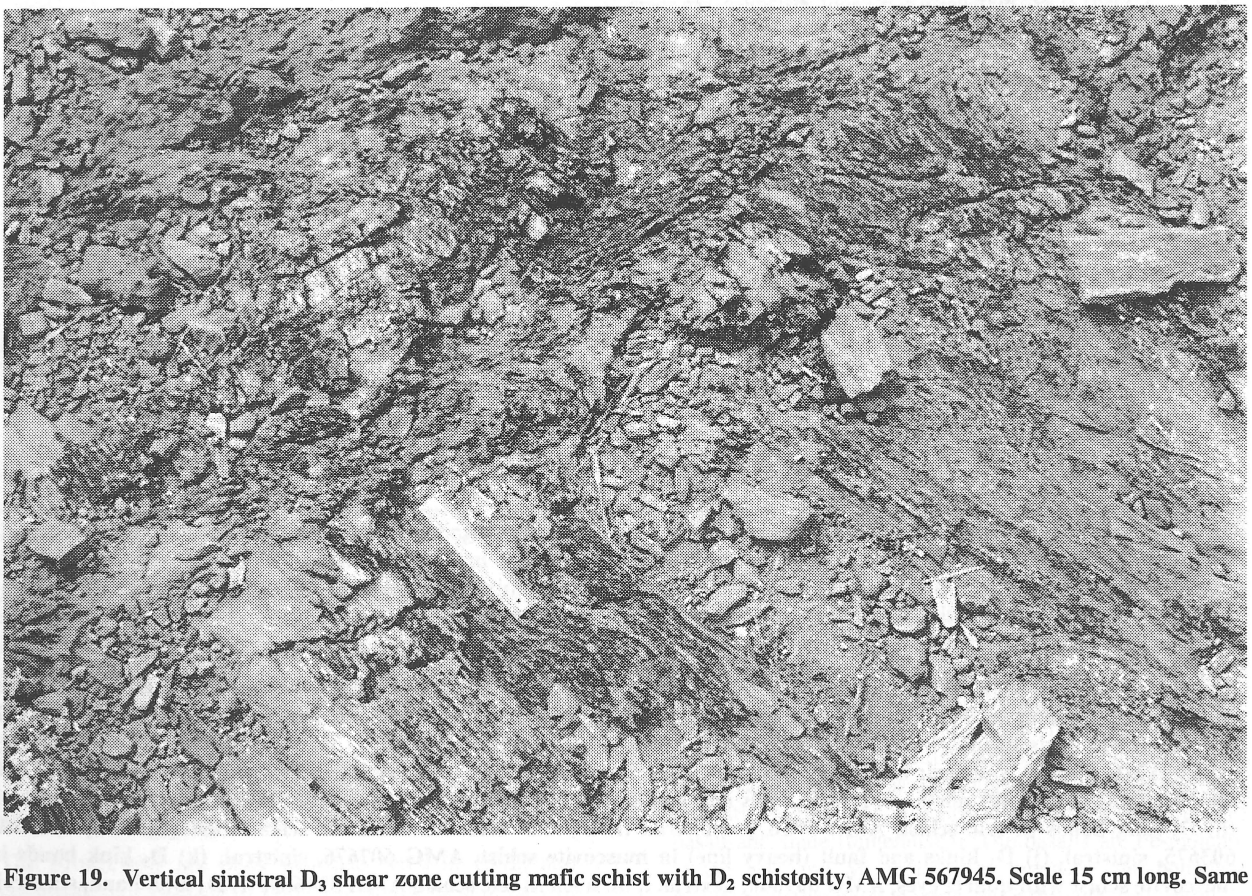

Figure 19. Vertical sinistral D_3 shear zone cutting mafic schist with D_2 schistosity, AMG 567945. Scale 15 cm long. Same locality as Figure 16j.

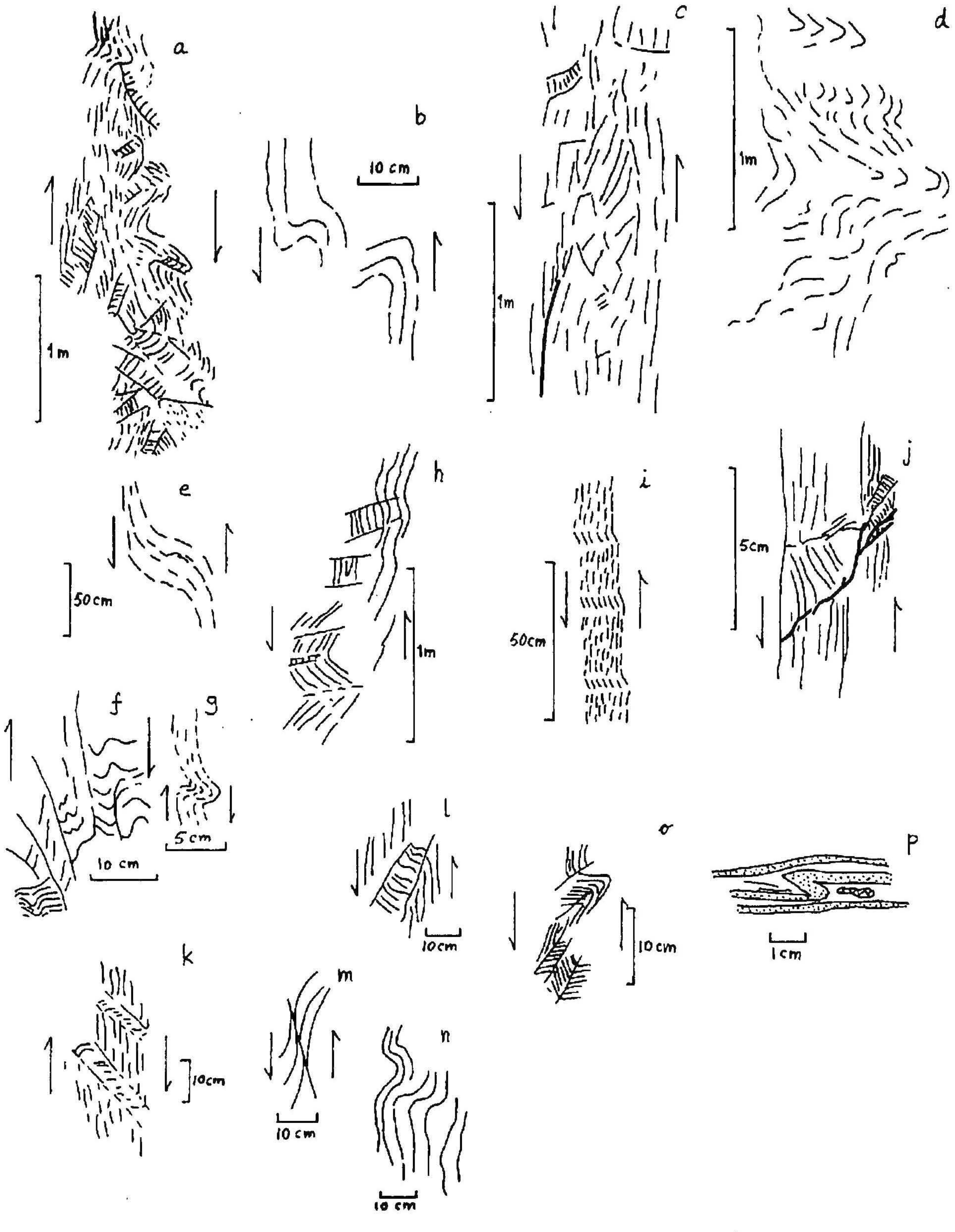

Figure 20a-o. Plan view sketches [north to top except (p) north to right] looking down on kink bands and folds, McFarlane's Find area, Mount Keith greenstone belt; (a) D_3 kink band and folds in muscovite schist, AMG 601707, dextral. (b) F_3 folds in muscovite schist with quartz eyes, AMG 591680, sinistral. (c) D_3 shear structure in quartz-clay schist, AMG 599699, sinistral; heavy line indicates small fault. (d) Profile of F_3 reclined fold in muscovite schist, AMG 602701; folds plunge 40° north. (e, f, g) F_3 folds and contortions in muscovite schist, AMG 606688, dextral and sinistral. (h) D_3 kink bands in talc schist, AMG 591672, sinistral. (i) D_3 kink folds in muscovite schist with quartz eyes, AMG 603675, sinistral. (j) D_3 kinks and fault (heavy line) in muscovite schist, AMG 607676, sinistral. (k) D_3 kink bands in muscovite schist with quartz eyes, AMG 609660, dextral. l, m, n All in talc schist, AMG 594657; (l) D_3 kink band, sinistral; (m) D_2 foliation and C-plane, sinistral; (n) F_3 folds; (o) D_3 kink bands in talc schist, AMG 597649; sinistral. (p) Possible F_1 steeply plunging intrafolial fold in bedding S_0 in siltstone of Jones Creek Conglomerate, AMG 596653; rotated by larger F_2 or F_3 folds at same locality (not shown).

Table 2. Structural history of Mount Keith mine area.

	This study	*Eisenlohr (1992)*	*Bongers (1994)*
D1	Formation of S-dipping cleavage in chloritic and talcose rocks, uplift, deposition of Jones Creek Conglom. (Bongers, 1994). σ1 N-S		D1
	Homoclinal positioning of greenstones (Eisenlohr 1992)	D1	
D2	Main folding about N-S axes, development of NNW-striking flattening foliation with sinistral shear sense and gently plunging lineation, metamorphism, intrusion of eastern granite into greenstone, high-angle thrusting of greenstone over granite. σ1 ESE-WNW	D2	D2
D3	Dextral shear along D2 foliation, producing steeply plunging warps, folds, and crenulations, kink bands grading to isoclinal folds, and rare E-W sinistral shear zones. σ1 N-S to NNE-SSW	D3	D3

Table 3. Structural history of MOUNT KEITH

Event	*Time (Ma)*[1]	*Magmatism*	*Deformation and remarks*
	~2400	Mafic dykes	Dykes used ESE-striking D4 fractures
D4	Post-~2640		Conjugate fractures: NE- and ESE-striking in N, NE- and SE-striking in S
D3	~2660-~2640		Steeply to gently plunging small folds, crenulations, and kink bands, variously caused by sinistral shear (Mount Keith mine area) or dextral shear (McFarlane's Find)
D2	Late		Major N- to NNW-striking (dip-slip high-angle?) faults and quartz veins in AgL and AgH granites.
D2	~2660	Low- and High-Ca granites in centre and NE, moderately magnetised granite Ag_m in SE; syn- to post-D2	Regional upright NNW-trending folds, steep axial-plane flattening foliation (sinistrally transpressive in Mount Keith mine area) and gently N- or S-plunging axial lineation; low-grade metamorphism; foliation in granites (except in later-emplaced parts); deposition of Jones Creek Conglomerate.
D2	>2660	Agb granite	Abundant rafts of greenstone, strong mylonitic foliation and lineation
D1	Post-2675 2685-2675?	 Granite and High-Ca granite in SW	S1 cleavage (S-dipping) Source of Jones Creek Conglomerate
Pre-D1	~2700		Volcanism and sedimentation

[1]In Kalgoorlie Terrane (Swager et al. 1992, Swager 1997); for comparison only

straddles the boundary with LAKE VIOLET.

• Evaporite. Calcrete (Czk) has deposited from groundwater in the Lake Way – Lake Maitland palaeochannel in the east, and smaller areas in the centre of MOUNT KEITH are located downslope from defeated streams that flow towards the same palaeochannel.

Economic geology

Numerous small abandoned gold mines dating from the 1890's are present in the Mount Keith and Yandal greenstone belts, and details of past production are summarised in Table 4. Production in recent times has come from the Bronzewing and Mount McClure mines in the Yandal belt.

Gold

Bronzewing gold deposit

The Bronzewing ore body was discovered in 1992, and commenced production in 1994. The following summary of the deposit is from Phillips et al. (1998). The deposit is concealed by Cainozoic cover rocks, and was discovered by reconnaissance drilling to bedrock based on geological targeting and regolith study. It occurs in a west-facing sequence of basalt, dolerite, shale, and mafic wacke, intruded by a sill of granodiorite. The rocks are folded by a major south-plunging antiform, and have been metamorphosed to greenschist facies. The sequence at the deposit itself comprises: tholeiitic basalt-dolerite with minor ultramafic rocks; ultramafic rocks including 100 m of komatiite; pillow basalt (mineralised); a differentiated tholeiitic sill ranging from peridotite to granophyre; and basalt and shale (mineralised). The basalts are Fe-tholeiite to the east and Mg-tholeiite to the west, the boundary between the two passing north-south through the Central

Table 4. Gold and silver production from mining centres in and near MOUNT KEITH. Data supplied by GSWA.

Centre	*Name*	*Period*	*Ore (t)*	*Au (kg)*	*g/t*	*Alluv Au*	*Total*	*Ag (kg)*
Bronzewing	Bronzewing	1909-11	136.65	2.569	18.8		2.569	0
Bronzewing	Hawk	1909-10	74.17	2.034	27.42		2.034	0
Bronzewing	Malbie	1909-11	264.67	5.289	19.98	0.06	5.349	0.06
Kathleen Valley	Mt Pascoe	1936	104.9	1.006	9.59		1.006	0
Kathleen Valley	Mt Pascoe Perseverence	1900	47.75	0.892	18.68		0.892	0
Kathleen Valley	Mt Pascoe South	1935-37	47.24	1.001	21.19		1.021	0
Kathleen Valley	Mt Pascoe South	1939	32	0.295	9.2		0.295	0
Kathleen Valley	Pascoe Leases	1902-03	259.08	3.517	13.57		3.517	0
Kathleen Valley	Beth Heno (McFarlane F.)	1970	4.06	0.018	4.52		0.018	0
Corboys	Alta Garfagnana	1935-36	142.24	2.722	19.14		2.722	0
Corboys	Black Jack	1943-44	505.97	6.406	12.66		6.406	0
Corboys	Corboy's Reward North	1925-39	1934.21	39.172	20.25		39.172	0
Corboys	Golden Fleece	1931	61.47	0.511	8.31		0.511	0
Corboys	Corboy's Reward	1925-27	718.31	12.031	16.75		12.031	0
Corboys	Corboy's Reward	1934-36	966.72	19.621	20.3		19.621	0
Corboys	Ida	1939-41	359.66	3.485	9.69		3.485	0
Corboys	Laughing Jack	1925-26	104.65	0.988	9.44		0.988	0
Corboys	Lucca	1935-36	124.97	2.136	17.09		2.136	0
Corboys	Merrington Consols	1934-37	188.47	2.569	13.63		2.569	0
Corboys	North End	1931	18.29	0.337	18.42		0.337	0
Corboys	Toscana	1925-27	733.55	35.379	48.23		35.418	0.156
Corboys	Tuscana	1928	35.56	0.805	22.63		0.805	0
Corboys	Wandilla	1925-27	45.72	0.817	17.86		0.817	0
Corboys	Waratah	1926	43.18	0.973	22.52		0.973	0
Corboys	Waratah	1943-46	292.61	3.32	11.35		3.32	0
Corboys	Waratah	1935-39	364.74	18.286	50.13		18.286	0
Corboys	Waratah Leases	1932-42	1207.05	17.696	14.66		17.696	0
Corboys	Waratah South	1926	193.55	3.928	20.3		3.928	0
Corboys	Waratah Leases	1927-31	639.06	28.796	45.06		28.796	0
Corboys	Barwidgee	1946-49	492.76	6.481	13.15		6.481	0.008
Corboys	Mt Fisher East	1949-52	318.01	21.231	66.76		21.231	0
Corboys	Old Toscana	1932-50	1053.59	30.41	28.86	0.163	30.573	0
Corboys	Rumble Rest	1978	17	0.29	17.06		0.29	0
Corboys	Rumble Rest	1976	17	0.356	20.94		0.356	0
Corboys	Vinaurum	1943-49	693.93	15.578	22.45		15.578	0
Corboys	Vinaurum	1937-42	2404.87	54.166	22.52		54.166	0
Mt Keith	Aurora	1911-15	2113.28	67.075	31.74		67.075	0
Mt Keith	Aurora	1916-20	2185.67	51.329	23.48		51.329	0
Mt Keith	Aurora	1911	8.13	1.443	177.48		1.443	0
Mt Keith	Chicane	1914	68.07	0.518	7.6		0.518	0
Mt Keith	Dunbar	1916-17	37.85	2.619	69.21		2.619	0
Mt Keith	Comtesse	1937	38.35	3.043	79.33		3.043	0
Mt Keith	Pomme D'Or	1934-37	4919.22	60	12.2		60.197	0
Mt Keith	Coolgardie	1937-39	2648.71	22.554	8.51		22.554	0
Mt Keith	Gem	1917	33.02	0.422	12.77		0.422	0
Mt Keith	Winifred	1913-14	201.17	3.328	16.54		3.328	0
Mt Keith	Queen of Scots	1911-13	63.5	1.892	29.8		1.892	0
Mt Keith	Grand Schlam	1913-14	998.73	21.107	21.13		21.107	0
Mt Keith	Miss Deal	1916-21	2196.59	57.211	26.05		57.211	0
Mt Keith	Little Schlam	1913-14	197.1	5.179	26.28		5.179	0
Mt Keith	Jessie May	1935	108.97	1.649	15.13		1.649	0
Mt Keith	South Wiluna West No 1	1935	45.72	0.609	13.33		0.609	0
Mt Keith	Starlight	1913	86.87	1.692	19.48		1.692	0
Mt Keith	Starlight	1915	223.52	1.231	5.51		1.489	0
Mt Keith	Talbingo	1912	6.6	0.452	68.43		0.452	0
Mt Keith	Wiluna South	1936-37	126.75	4.467	35.24		4.467	0
Mt Keith	Wiluna South	1934-36	456.69	12.689	27.79		12.689	0
New England	Auckland	1905	17.27	0.479	27.73		0.479	0
New England	Empire	1910-11	721.36	6.713	9.31		6.713	0
New England	Glennis	1899	815.85	20.136	24.68		20.136	0
New England	Eric	1911	18.29	0.249	13.59		0.249	0
New England	Federal	1938-39	292.61	3.55	12.13		3.55	0
New England	Golden Way	1910-11	130.05	1.178	9.05		1.178	0
New England	Golden Way	1905	80.26	1.788	22.27		1.788	0
New England	Harris' Reward	1910	87.38	1.355	15.51		1.355	0
New England	Honeycomb	1911	10.16	0.12	11.85		0.12	0

and Discovery pits. Abundant chloritoid rock associated with the deposit represents altered mafic rock with silicon added and calcium removed, and indicates that kilometre-scale alteration affected the region. A broad halo of alteration is well defined in the mafic rocks around the deposit itself, and comprises an outer zone of chlorite-calcite rock, followed inwards by ankerite-biotite rock and then by muscovite-pyrite rock; the inner two zones are associated with the highest gold grades. North-striking dextral shear zones cut the deposit sequence, and are linked by subsidiary shears, forming pods of altered basalt in mafic schist. Gold is located in quartz veins in the mafic schist where the shear zones converge or diverge, or intersect northeast or southeast-striking cross-faults. The veins are of two styles: early laminated quartz veins (with the better gold grades) parallel to the prevailing north-northwest schistosity, and late (because they truncate the early) quartz veins in the brittle northeast or southeast-striking cross-faults. The ore fluid was a low-salinity H_20-CO_2 mixture containing H_2S and Au-S complexes. In essence, an H_20-CO_2 metamorphic fluid infiltrated and reacted with sheared Fe-rich mafic rocks, and precipitated Fe-sulphide, carbonate, and gold. Resources at March 1997 were 38.1 Mt at 2.9 g/t for 110.6 t gold. Production to March 1997 was 13.96 t gold. Total metal at Bronzewing is 124.57 t gold (AGSO OZMIN database, May 1998).

Mount McClure gold deposits

The Mount McClure deposits were discovered between 1987 and 1990, and production began in 1992 (Otterman & Miguel 1995). The following account is summarised from Harris (1998). Lotus and Cockburn in MOUNT KEITH are the northernmost of a line of seven deposits, the other five (Anomaly 45, Success, Parmelia, Challenger, and Dragon) being in located in SIR SAMUEL and DARLOT. Lotus-Cockburn are hosted in an east-facing, west-dipping, and north-northwest-striking sequence of felsic and mafic volcanic and sedimentary rocks and komatiite, intruded by conformable sills of dolerite up to 200 m thick and by cross-cutting (post-ore) intermediate dykes. The volcanic rocks carry appreciable amounts of volcanogenic sulphide. Metamorphic facies is low to mid-greenschist. Lotus and Cockburn, both concealed by Cainozoic cover, are the economic parts of a single mineralised system, separated by 600 m of sporadic ore. A major northerly-striking steep shear zone cuts obliquely through the sequence, and higher gold values are associated with this zone regardless of rock type. Thus, mineralisation is found in komatiite in the southwest of Cockburn, thence progressively northward in sulphidic chert, basalt, dacitic tuff, and dolerite (northeast Cockburn), and in dolerite, basalt, and andesitic pyroclastics at Lotus. The ore at Lotus consists of quartz veins with minor pyrite, carbonate, and chlorite in altered dolerite. The veins are subparallel to foliation, tightly folded and gold is visible in some. At Cockburn, gold occurs in a stockwork of quartz-carbonate±chlorite irregular veins, and in boudinaged and tightly folded quartz-chlorite-carbonate-pyrite veins subparallel to foliation and with rare visible gold. Bismuth minerals, galena, molybdenite, and scheelite occur in the veins with highest gold values. Host rock alteration at both deposits changed the mafic rocks to assemblages of biotite, chlorite, and carbonate together with an increase in sulphide content. Sericite alteration and silicification affected felsic rocks. At both deposits, epidote veins and hematite alteration affects all rocks, but is unrelated to the gold mineralisation. Even later veins of coarse-grained quartz-calcite-chlorite-sulphide cut all rocks, including the post-ore intermediate dykes. In summary, a brittle-ductile shear zone channelled metamorphic fluid that deposited vein minerals and gold in low-pressure sites and altered the enclosing host rocks. Favourable structure was particularly important at Cockburn, where ore occurs in iron-poor foliated felsic rocks adjoining dolerite, as well as in iron-rich sulphidic chert, tuff, and tholeiitic basalt and quartz dolerite. In addition to the Archaean lodes, Cainozoic laterite in the overburden at Lotus carries gold, and has been mined. There is also supergene enrichment of gold in saprock. Resources at March 1996 were 12.7 Mt at 2 g/t for 25.4 t gold. Production to March 1996 was 9.2 t gold, for a total of 34.6 t gold (AGSO OZMIN database, May 1998).

McFarlane's Find (Betheno)

Old workings here exploited quartz veinlets in a 2 m-wide west-dipping shear cutting limonitic to kaolinitic shale and silty shale (Asarco 1984).

Corboys Find, Corboys Reward, and Tuscana

The Corboys mines are located at the sheared and quartz-veined contact between sheared granite to the west and a north-northwest-trending basaltic sequence to the east. The sequence comprises vesicular basalt, dolerite-gabbro, chert and banded iron formation 1-10 m thick, pelitic to ultramafic metasedimentary rocks, quartz-muscovite±kaolin rocks, and felsic volcanics (mainly rhyolite). The rocks were pervasively and steeply foliated (S_2), crenulated, which produced parasitic folds and a crenulation cleavage striking 300°, and then fractured (striking 240-250°; Allied Minerals 1973; Great Victoria Gold, 1988).

The gold at Corboys (Reynolds Australia Metals 1991) is confined to zones of alteration and foliation at the intersection of southeast-striking strike-slip faults with shear zones striking northeast, north, and northwest. The alteration produced carbonate, chlorite, muscovite, quartz veins, and silicification, and was most intense within 100-200 m of the granite-basalt contact. The shear zones are splays from a major 350°-striking shear zone parallel and close to the granite-basalt contact. To the north, the main shear zone intersects the Barwidgee Lineament, which strikes about 335°. The Tuscana mine is located in altered and foliated granite west of the contact with basalt on the continuation of the main shear to the south, at the intersection with a southeast-striking fault.

Nickel

The ultramafic rocks in the Mount Keith greenstone belt have been intensively explored for nickel. Many prospects have been found, but production is restricted to the Mount Keith deposit, which began production in 1994.

Mount Keith nickel deposit

The following summary is from Dowling & Hill (1993) and Hopf & Head (1998). The deposit is a large-tonnage low-grade disseminated nickel sulphide deposit hosted by olivine cumulate. Mineralisation extends for more than 2 km along strike and to at least 500 m depth. Mineralisation was discovered in 1968 during drilling of an ultramafic outcrop, and after an interrupted history of geophysical surveys, drilling, and surface mapping, together with several changes of ownership, open-cut mining and milling began in 1994. The ore body occurs in the easternmost of three komatiite units in a west-facing sequence of interbedded volcanic rocks, shale, chert, basalt, volcaniclastic rocks, komatiite, layered gabbro, and high-Mg and tholeiitic basalt. The komatiites comprise spinifex-textured flows and olivine orthocumulate. Nickel mineralisation occurs within elliptical thicker zones of layered adcumulate-mesocumulate in the komatiites. The eastern komatiite comprises olivine orthocumulate about 30 m thick at the base, overlain by olivine adcumulate (100-200 m) grading up to olivine-sulphide adcumulate-mesocumulate (about 200 m thick), overlain by interlayered hornblende-olivine orthocumulate, pyroxenite, gabbro, and plagioclase cumulates (about 50 m thick) at the top. The sequence has been metamorphosed to midgreenschist facies. Ultramafic rocks have been serpentinised, and carbonated along fractures and shears; arsenic was also introduced during the carbonation. The primary ore consist mainly of pentlandite, plus subordinate pyrrhotite, millerite, and heazlewoodite, and minor chalcopyrite, violarite, and gersdorffite. Supergene violarite, pyrite, and marcasite occur in the oxidation zone and elsewhere where weathering has taken place. The sulphides occur as medium to coarse-grained lobate patches interstitial to olivine (now pseudomorphed), as very fine-grained disseminated blebs in olivine, and as fine-grained aggregates in cracks, cross-cutting veinlets, and along grain boundaries. The ore formed when crystallisation of olivine in the centre of a lava channel led to sulphur saturation in the melt and exsolution of sulphide melt. Subsequent re-equilibration of the olivine with residual sulphide-rich melt, and/or release of nickel during serpentinisation and carbonation, upgraded the nickel content of the ore. Published resources at March 1997 are 588 Mt at 0.60% Ni, giving a total commodity of 3.6 Mt of metal, which includes production to March 1997 of 77 143 t of metal (AGSO OZMIN Database, May 1998).

Copper

Three abandoned copper mines in the southwest are part of the Kathleen Valley group, which produced 424 t of ore between 1908 and 1966. The copper occurred in pyrite-chalcopyrite-quartz veins (which also contained gold and silver) in northwesterly-striking shear zones that cut the Kathleen Valley Gabbro (Bunting & Williams 1979). Copper also occurs in the Mount Keith nickel deposit, but has not been exploited.

Corundum

Corundum has been mined in the past from aluminous metasedimentary rocks interlayered with mafic rocks at AMG 586571 (Carter 1976). The mine produced 55 t of ore in 1952 (only recorded production).

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