XPLANATORY NOTES

GEOLOGY OF THE PINJIN 1:100 000 SHEET

by C. P. SWAGER

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

DEPARTMENT OF MINERALS AND ENERGY

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

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Cover photograph:
Spectacular isoclinal folds in chert and banded iron-formation at Round Hill. Photograph courtesy of Dr Bruce Goleby, AGSO.

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Geology of the PINJIN 1:100 000 sheet

by

C. P. Swager

Abstract

The western part of the PINJIN 1:100 000 sheet area is underlain by volcano-sedimentary greenstone sequences intruded by granitoids. To the east and southeast only granitoids are present. Several structural–stratigraphic greenstone domains, separated by regional faults, are distinguished.

The Yindi Domain in western PINJIN contains a west-younging sequence of basalt, metasedimentary rocks, felsic volcaniclastic rocks and some intermediate rocks. Lateral variations are observed throughout this domain.

The Edjudina Domain, bounded by the Claypan Fault to the west, and Pinjin Fault to the east, contains a prominent, central belt of banded iron-formation and sedimentary rock, mafic-to-felsic volcanic complexes and some basalt with minor komatiite. The internal structure of this domain is complex, particularly in the southern part of the sheet where there are numerous granitoids.

The Pinjin Domain contains interlayered felsic, intermediate, mafic and ultramafic rocks, with minor banded iron-formation, metamorphosed at amphibolite facies conditions. The Pinjin Fault forms the western boundary with the greenschist facies Edjudina Domain, and contains indicators for largely west-block-down movement. The eastern boundary with the Kirgella granitoid gneiss is transitional, marked by increasing volumes of foliated granitoid.

The Kirgella granitoid gneiss is part of a sparsely exposed belt of high-grade migmatitic gneiss, which has been extensively intruded by late stage monzogranite.

Metamorphic grade is greenschist facies in the western domains, with narrow zones of higher grade around granitoid plutons. Eastward, an abrupt increase in grade occurs across the Pinjin Fault, with increasing grades to upper amphibolite facies along the Pinjin Domain – Kirgella granitoid gneiss boundary.

Granitoids are divided into pre-regional-folding plutons — including the Kirgella granitoid gneiss and elongate, strongly foliated plutons — and post-regional-folding plutons, like the ovoid Galvalley Monzogranite which intruded just west of the Claypan Fault.

Modest gold production has taken place from several laterally persistent shears along, and directly west of, the Pinjin Fault.

KEYWORDS: Yilgarn Craton, Eastern Goldfields Province, regional geology, PINJIN SH51–10–3437.

Introduction

The PINJIN* 1:100 000 sheet (SH51–10–3437) lies between latitudes 30°00'S and 30°30'S and longitudes 122°30'E and 123°00'E (Fig. 1), and occupies the northeastern part of KURNALPI 1:250 000 sheet in the Eastern Goldfields region. The first edition of KURNALPI geological sheet (Williams, 1970) was prepared before the intensive nickel and gold exploration in the 1970s and 1980s respectively. This first-phase mapping project formed the basis for a regional stratigraphic model for the greenstone belt evolution involving several cycles of mafic to felsic volcanism followed by deposition of clastic rocks (Williams, 1970, 1976).

This report describes the structure, stratigraphy and petrography of the Archaean granitoids and greenstones on PINJIN. Mapping was carried out between July 1990 and August 1991, using 1:50 000 scale black-and-white

* Names of 1:100 000 and 1:250 000 scale map sheets are printed in capital letters.

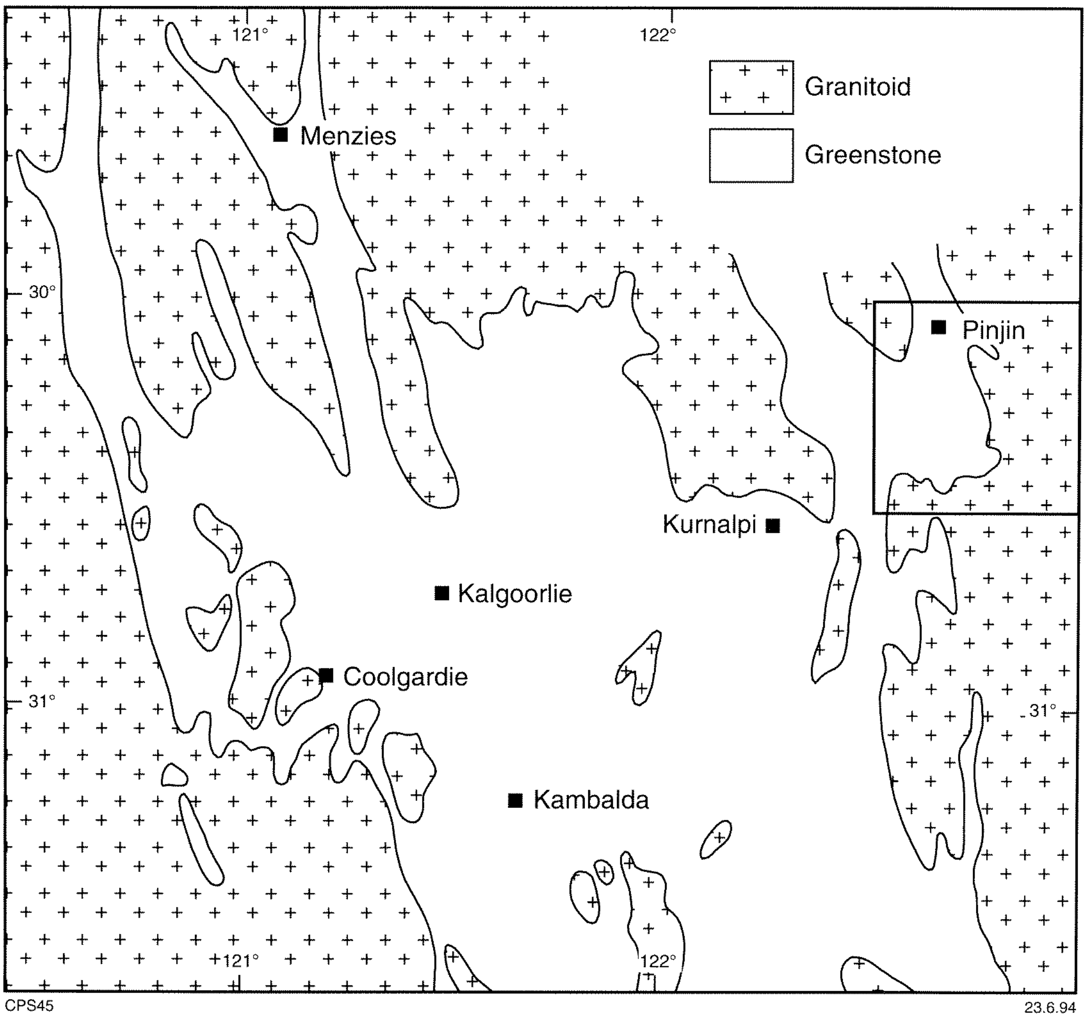

Figure 1. Location of PINJIN 1:100 000 sheet within the southern Eastern Goldfields Province

aerial photographs flown in 1979, and updated topographic data from 1:86 000 black-and-white aerial photographs taken in 1990.

Access, physiography and Cainozoic geology

The formed, unsealed Kurnalpi–Pinjin–Edjudina road runs along the western boundary in the south of PINJIN and traverses the northwestern quarter of the sheet (Fig. 2). This road is the major access route from Kalgoorlie–Boulder and links the two homesteads on the sheet, Yindi in the south and Pinjin in the north. Just south of Pinjin Homestead, the Kirgella Rocks – Lords Bore track leads to CUNDEELEE in the east. Pastoral fencelines and tracks provide reasonable access to PINJIN, with the exception of the eastern portion.

The physiography partly reflects the underlying geology. Greenstone areas are dominated by low rolling hills covered by open acacia, with some prominent ridges in the north and dominant hills near Old Pinjin Homestead in the central west. In the southwest corner the greenstones are covered by a deeply incised laterite plateau. Areas underlain by granitoid are generally flatter with lateritic plateaus and sandy plains. In the northeast corner low granitoid inselbergs are well-exposed along a land surface dipping gently east from a laterite plateau at Kirgella Rocks towards the southernmost extent of Lake Raeside in the northeast corner of PINJIN. The Lake Rebecca salt lake system, connected by areas of sand, silt and kopi dunes, stretches from the northwest to the southeast across the entire sheet (Fig. 2).

Seven broad types of Cainozoic deposits are recognized on PINJIN.

Laterite (*Czl*) and deeply weathered rock form plateaus and more subdued areas of reworked products, including pisolitic soils. Prominent laterite plateaus are developed over greenstone south of Yindi station (Rough Gap, 450–430 m AHD) and granitoid at Kirgella Rocks (420–400 m AHD). Platform outcrops of highly lateritized rock amidst fresh rock outcrops occur on the lake floor of Lake Rebecca east of Old Pinjin. Silcrete (*Czz*) occurs locally over granitoid, and consists of fine- to medium-grained,

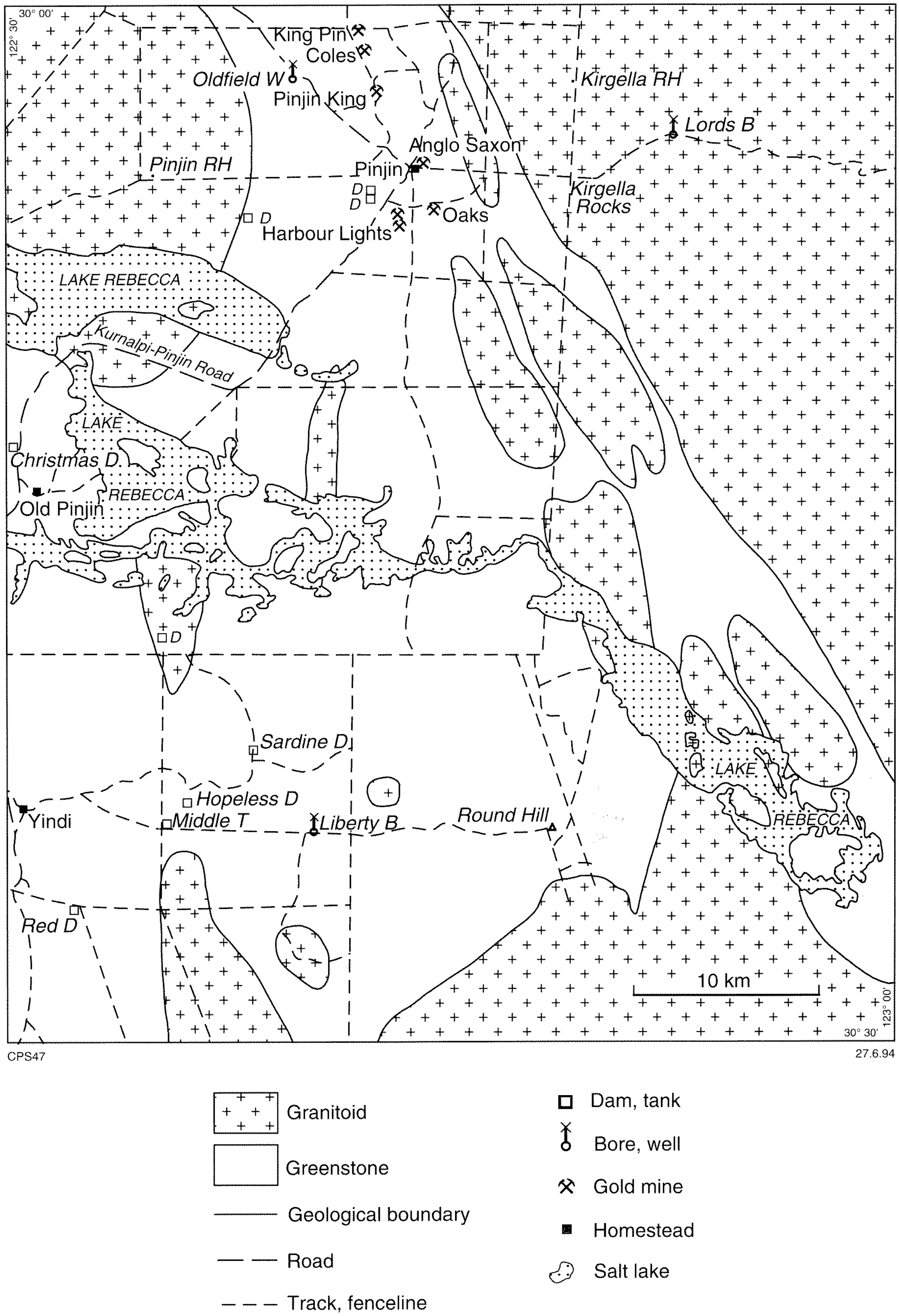

Figure 2. **Locality names, and major access roads and tracks on PINJIN. The main areas underlain by granitoid and greenstone are indicated**

irregular quartz grains in a very fine-grained siliceous or chalcedonic matrix.

Colluvium (*Czc*) occurs as reddish brown, ferruginous, sandy clay, fine sand, and/or gravel overlying greenstone, and fine- to medium-grained quartzofeldspathic sand (*Czg*) derived by weathering and erosion of granitoid. Scattered small granitoid pebbles and fragments may be present in the quartzofeldspathic sands (*Czg*).

Plains and dunes of yellow sand (*Czs*) cover extensive areas as sheets of variable thickness.

Salt lakes and claypans (*Czts*) contain interbedded clay and sand with evaporite minerals (gypsum, halite) and are surrounded by stabilized dunes of sand, silt, and gypsum (*Cztd*) which were blown from the dried-out playas.

Quaternary alluvium (*Qa*) in present-day drainage channels and floodplains consists of unconsolidated clay, silt, sand, and pebbles.

Geological setting

PINJIN lies within the Eastern Goldfields Province of the Archaean Yilgarn Craton (Gee, 1979), on the eastern margin of the Norseman–Wiluna belt, interpreted as a rift zone (Gee et al., 1981; Groves and Batt, 1984). More recently Barley et al. (1989) divided this belt into a western marginal basin association and an eastern volcanic arc association, of which PINJIN forms part.

Williams (1970, 1974, 1976) in an early structural–stratigraphic interpretation of KURNALPI distinguished three cycles of ultramafic, mafic to felsic volcanism that are each capped by sedimentary sequences and separated by unconformities. This stratigraphy was deformed by several episodes of regional folding and faulting.

The results of the recent mapping suggest the presence of several structural–stratigraphic domains, each with distinct lithologic, stratigraphic, structural and/or metamorphic features. From west to east, three greenstone-dominated domains are recognized — the Yindi, Edjudina, and Pinjin Domains, separated by, respectively, the Claypan Fault and the Pinjin Fault (Fig. 3). In addition to these greenstone domains with their many granitoid intrusions, a granitoid gneiss belt — the Kirgella granitoid gneiss with voluminous massive granitoids — can be defined in the northeast corner of the map sheet. The geology and structure of these domains is described and discussed in the section on **Regional geology and structure**.

Petrography

All Archaean rocks on PINJIN are metamorphosed, but original rock nomenclature is used wherever textures are preserved or can be inferred. However, particularly in the high-grade rocks on the east side of the greenstone belt, deformation and metamorphism have resulted in widespread modification and obliteration of primary textures. The resulting metamorphic textures are described in some detail, because they may provide important information on the evolution of the higher grade sequences.

Ultramafic rocks

Peridotite (*Aup*) is restricted to the Pinjin Domain where it occurs in several locally well-exposed layers east and north of Round Hill, and as part of a narrow, persistent ultramafic layer southeast of Pinjin Homestead. Complete serpentinization of the peridotite has occurred, but in several places fine- to medium-grained olivine orthocumulate textures can still be recognized. Diamond drilling in the early 1970s intersected minor pyrrhotite–pentlandite mineralization in metadunite in the large ultramafic body 4 km north of Round Hill (Endeavour Minerals/Noranda Australia, 1975). Locally, peridotite contains coarse, highly poikilitic pyroxene now converted to amphibole.

Peridotite, particularly north of Round Hill, is associated with metagabbro occurring either as isolated lenses within olivine cumulate or as substantial layers. This gabbro shows differentiation trends from pyroxenitic to quartz-bearing leucocratic varieties. The origin of the peridotite–gabbro layers may be intrusive or extrusive, as argued for similar bedding-parallel occurrences on KURNALPI (Swager, 1994). One argument in favour of an extrusive origin is the occurrence of fine- to medium-grained komatiitic basalt lenses within peridotite 2 km north of Round Hill. Such high-Mg basalt may represent late stage crystallization of a differentiated komatiitic magma (Gole, M.J., 1991, pers. comm.).

Pyroxenite (*Aux*) is a minor component of peridotite as well as gabbro, but is not everywhere distinguished as a separate entity on the map. In the Pinjin Domain a few thin pyroxenite layers were mapped. However, some of these mappable units are very strongly metamorphosed, and their origin as intrusive sills is only speculative. The rock consists of medium-grained, short prismatic amphibole after pyroxene, commonly with a slightly porphyritic nature, and a variably plagioclase-bearing matrix.

Tremolite schist (*Aur*) is the major rock type in the ultramafic layers in the Pinjin Domain. In some examples the texture is massive with unoriented acicular tremolite in a finer grained chlorite-bearing matrix, though in most cases a well-developed foliation is evident. Medium-grained magnetite porphyroblasts are found locally.

Talc–chlorite schist (*Aut*), with or without some carbonate, is restricted to several narrow, poorly outcropping zones in the central Edjudina Domain, such as directly adjacent to the Harbour Lights mineralized zone, and to at least two other zones or lenses northwest of Pinjin Homestead. The presence of the zones is confirmed by samples from mine dumps and recent percussion drilling.

Ultramafic rock (*Au*) consists of highly weathered material, mostly with the typical light-green colours, but without preservation of rock textures.

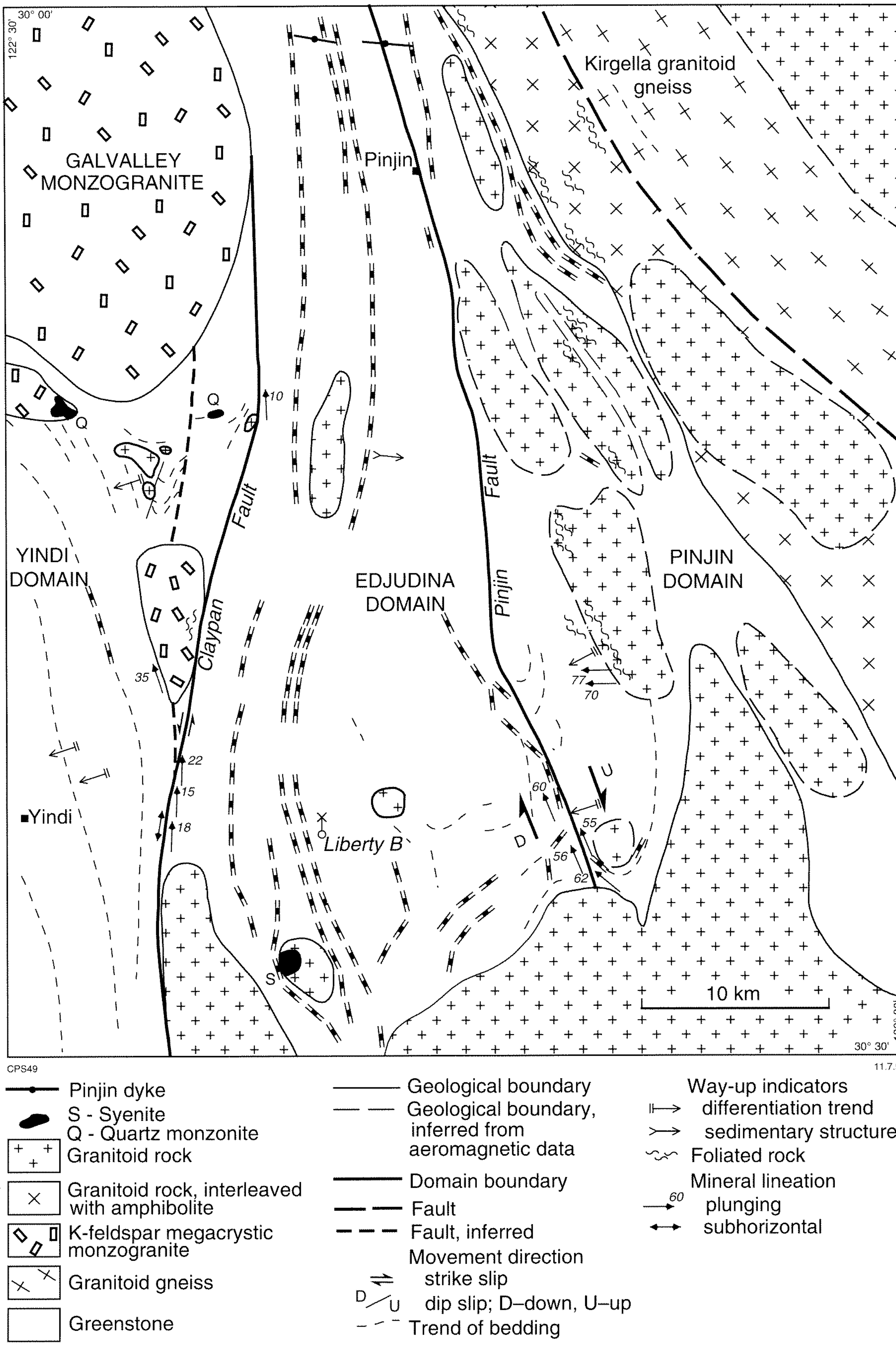

Figure 3. Structural–stratigraphic domains and major structural elements on PINJIN

Mafic rocks

Basalt (*A b*) is mostly massive and fine-grained, with local medium-grained zones possibly representing thicker flow units. Fragmental and thin hyaloclastite layers are only rarely observed in the rubbly outcrops of the main basalt ridge between Old Pinjin and Yindi Homesteads. Thin chert/slate and other sedimentary layers, doleritic and feldspar-phyric doleritic layers, and, in many cases, schistose, plagioclase-phyric felsic porphyry sills define the layering within the basaltic sequence.

All original mineral constituents have been transformed but primary textures are recognizable, even where weak deformation has occurred: short prismatic pyroxene is replaced by amphibole; igneous plagioclase by less calcic plagioclase and epidote, and by sericite; and fine-grained oxides are transformed to leucoxene or, locally, sphene.

Feldspar-phyric basalt (*Abp*) and variolitic basalt (*A bv*) locally form mappable units within massive basalt sequences. The feldspar phenocrysts are up to 2 cm long, and are commonly retrogressed to sericite–epidote aggregates. Dolerite and gabbro with coarse feldspar phenocrysts (*A op*) may be the subvolcanic equivalents of these porphyritic basalts. Variolitic basalt (*A bv*) is pillowed, but outcrop is not good enough to determine younging directions. In hand specimen the varioles are light coloured, discrete or coalesced, and appear to be independent of the igneous texture in the matrix.

Komatiitic basalt (*A bm*) is characterized by unoriented or sheaf-like acicular pyroxene replaced by amphibole. Where it is deformed, tremolite–chlorite schists have developed. Little or no komatiitic basalt occurs within the western basalt unit on PINJIN, but further along strike to the northwest, on MULGABBIE, substantial layers have been mapped by Morris (1994).

Amygdaloidal basalt (*Abi*), exposed mainly between Liberty Bore and Round Hill, is characterized by variably sized, quartz-filled amygdales, small phenocrysts and/or aggregates of plagioclase, and, locally, medium-grained hornblende–feldspar–quartz aggregates. In addition, fragmental and flow-top breccia layers, commonly with extensive epidote alteration, were observed locally. These basalts are variably foliated whereby in the more strongly deformed domains the quartz amygdales were flattened into ovoid aggregates within an amphibole–feldspar matrix. Minor amounts of carbonate are found throughout the matrix, but at Wild Dog Dam extensive carbonate alteration has occurred. The rocks are extensively recrystallized adjacent to monzogranite 2 km east of Liberty Bore where hornblende and, in some layers, clinopyroxene porphyroblasts have formed. Locally this basalt is transitional to more leucocratic, possibly andesitic rocks with small hornblende phenocrysts.

Doleritic-textured basalt (*Abd*) to the north and east of Round Hill may be the lateral equivalent of the finer grained amygdaloidal basalt (*Abi*). In hand specimen, the fine- to medium-grained doleritic texture is defined by clearly visible plagioclase and hornblende prisms. There are also small ovoid quartz 'eyes' (?amygdales) and, locally, feldspar phenocrysts. Irregular variations in textures and grain size are common, and locally intensive epidote alteration has occurred.

Basaltic schist, strongly metasomatized, (*Abs*) forms a mixed unit which includes strongly carbonated basalt and complex interleaved biotite–amphibole–clinopyroxene schists. The latter calc-silicate rocks form a narrow layer within the main basalt unit southeast of Old Pinjin, and appear to be continuous several kilometres northwestward along strike to an amygdaloidal basalt–metasedimentary rock package. The complex layering in these rocks is defined by variably hornblende-bearing, zoisite–biotite and diopside–amphibole schists interleaved with fine-grained slates. The schists consist of fine-grained biotite–quartz with a well-developed preferred orientation, with numerous unoriented zoisite crystals, hornblende porphyroblasts, and irregular hornblende–biotite aggregates that appear to have grown across the foliation. Different layers and domains contain different amounts of the main constituents. Sphene occurs as both irregular and euhedral grains. One layer shows coarse clino-amphiboles that enclose and replace clinopyroxene, and are in turn overgrown or replaced by unoriented tremolite–actinolite prisms in equilibrium with sphene, zoisite, and biotite. Such textures suggest retrogression of metasomatized mafic rocks.

Basaltic schist to amphibolite (*Aba*) is characterized by a strongly developed foliation which has largely masked the original igneous texture, and by the presence of hornblende rather than actinolite. Fine- to medium-grained hornblende and elongate plagioclase are aligned within the foliation, as are the minor phases epidote/zoisite, sphene and, locally, biotite, quartz, or carbonate. In the least deformed domains thin sections reveal the precursor plagioclase laths, despite their rotation and recrystallization.

The basaltic schist to amphibolite unit includes strongly altered epidote–garnet-bearing amphibolites, found mostly in small patches or domains close to granitoids. Epidote and clinozoisite occur as elongate grains within the foliated matrix, as medium-grained porphyroblasts, and as massive aggregates enclosing small grains of hornblende and sphene. At two localities the calc-silicate assemblages also contain clinopyroxene, either in massive medium-grained layers or as fine-grained crystals with plagioclase, epidote, biotite, and minor K-feldspar. Garnets form fine- to locally medium- to coarse-grained porphyroblasts which enclose epidote, biotite and, locally, other phases.

Garnet amphibolites which are present in the basalt–metasedimentary rock sequences may be derived from mafic sediments rather than from basalt precursors. These garnets have grown across the main foliation and enclose fine-grained amphibole–feldspar–opaque trails. Locally, euhedral garnet grains are surrounded by narrow lighter coloured haloes of cummingtonite replacing matrix hornblende.

Amphibolite (*Ama*) is characterized by a totally recrystallized texture dominated by polygonal to moderately elongate granoblastic hornblende and plagioclase. Banding is defined by variations in the amount and grain size of hornblende and plagioclase; by the presence of other phases (clinopyroxene, cummingtonite); and/or by quartz–feldspar–hornblende layers. This banding is parallel to the mineral foliation — defined by a shape-preferred orientation of all constituents. Precursor textures are destroyed, although, locally, stretched feldspar or quartz aggregates may be relics of phenocrysts or amygdales. Fine- to medium-grained anhedral sphene is a common accessory component.

Clinopyroxene (diopside) occurs as poikilitic medium-grained porphyroblasts, commonly as prismatic crystals parallel to the foliation or layering. The clinopyroxene can be present as a minor or as a major constituent. In some localities diopside–plagioclase assemblages are retrogressed to tremolite/actinolite–zoisite. In one example, fine-grained rock without quartz is overprinted by much coarser grained quartz-bearing tremolite–plagioclase 'veins' in which tremolite encloses anhedral clinopyroxene relics. Such metamorphic segregations probably developed during late stage hydration.

Cummingtonite is found locally in massive amphibolite layers in which it has replaced hornblende or tremolite–actinolite still preserved as relics. Garnet is quite rare in these amphibolites, but is a more common constituent in the interleaved mafic and intermediate schist layers (*Amx, Ais*).

Sericitization of plagioclase, with or without some prehnite alteration of ?hornblende, is locally pronounced, but restricted to specific bands or layers.

The medium-grained fragmental mafic schist unit (*Amx*) is part of the mixed felsic and intermediate mafic schist association (*Ais, Afs, Aba, Abf*) directly east of the Pinjin Fault.

These mafic schists are characterized by the presence of ovoid to rectangular felsic schist fragments in a quartz–feldspar–hornblende matrix. The fragments or pebbles are feldspar-phyric, vary from small (3–10 mm) to large (4–10 cm), and occur in distinct, but discontinuous layers. Locally, felsic pebbles are accompanied by hornblende-bearing pebbles (*Ais*) only slightly less mafic than the matrix. The fragmental layers are interleaved with and/or transitional to fine-grained basaltic to doleritic rock with small quartz aggregates, and irregular leucocratic to melanocratic amphibolite. These mafic rocks are interleaved on all scales with felsic feldspar-phyric schists.

The entire package is metamorphosed under amphibolite facies conditions, and widespread recrystallization has destroyed many original textures. The felsic fragments and/or pebbles consist of fine- and even-grained quartz–feldspar with scattered plagioclase phenocrysts, some minor amphibole and/or biotite, and small quartz aggregates. Locally, small elongate fragments consist only of fine- to medium-grained plagioclase. The hornblende-bearing matrix varies from quite leucocratic and quartz-bearing to melanocratic, but is always more mafic than the fragments. Foliation is not everywhere well-developed, and unoriented matrix hornblende prisms can be observed, even in layers where the ovoid and elongate fragments are aligned. Fine- to coarse-grained garnet occurs as both anhedral and euhedral crystals, commonly poikilitic, and in several cases enclosing and partly surrounded by cummingtonite.

The amphibolitic layers show similar features to those described earlier (*Aba, Ama*). Layering is defined by small variations in grain size and composition. The main amphibole is hornblende, but thin layers of cummingtonite exist in apparent equilibrium. These amphiboles may be quite randomly oriented in one layer but in the adjacent one display a well-developed preferred orientation. Locally, medium- to coarse-grained sheaves of tremolite–actinolite have grown in a fine-grained hornblende matrix, but the sheaves are partly replaced by randomly oriented cummingtonite prisms.

Clinopyroxene (diopside) is usually restricted to distinct layers where it may be the main medium- to coarse-grained constituent. The diopside encloses trails of fine-grained hornblende and sphene. Garnet is a minor constituent, restricted to some layers.

Medium-grained gabbroic-textured rock consists of long, poikilitic hornblende prisms with interstitial recrystallized plagioclase and quartz, with local anhedral garnet. In one altered example carbonate and epidote–zoisite are prominent minor phases in an apparently retrogressive zone. Elsewhere, in a layer still containing coarse clinopyroxene porphyroblasts, all plagioclase is sericitized or replaced by zoisite.

The *Abf* unit comprises very closely interleaved amphibolite – basaltic schist (*Aba*), intermediate schist (*Ais*), and felsic schist layers (*Afs*), as well as fragmental mafic schist (*Amx*). The complex and close interleaving of these rocks cannot be represented on the map scale, because any rock type may dominate from locality to locality. In a general sense, however, mafic and intermediate rocks are the most common.

Mafic intrusive rocks

Dolerite and gabbro (undivided) (*Ao*) comprise mainly medium-grained rocks, with common pyroxene-phyric ('spotted') and leucocratic quartz-bearing varieties. Hornblende pseudomorphs of the original pyroxene is the dominant texture with partly sericitized or epidotized plagioclase restricted to the groundmass. The phenocrysts tend to be short and prismatic, whereas in leucodolerite hornblende pseudomorphs are long prisms. Quartz, where present, occurs as small fine-grained aggregates. Opaques are largely replaced by leucoxene.

Dolerite occurs in all domains on PINJIN, mostly as narrow sills in the basalt sequences at Yindi and Old Pinjin. A large complex of medium-grained dolerite–gabbro at Liberty Bore shows local weak layering, and appears to have, at least at some localities, intruded (possibly co-magmatic) amygdaloidal and doleritic-textured basalts to the east.

Distinctive plagioclase-phyric dolerite–gabbro (*Aop*) sills are present in the basaltic sequence at Old Pinjin, including one layer up to 150 m thick. Spectacular plagioclase phenocrysts (1–4 cm) and/or aggregates are the dominant constituent (up to 80%) giving the rocks an anorthositic texture. Associated rock types include medium-grained gabbro with widely dispersed plagioclase phenocrysts (5–10 mm), quartz gabbro, and pyroxenitic gabbro. The porphyritic gabbros may represent sub-volcanic equivalents of feldspar-phyric basalt occurring in the same sequence.

Differentiation of gabbro (*Aog*) is indicated by various medium-grained rock types including pyroxenite, gabbro–norite, leucogabbro and/or quartz gabbro. Two prominent, but laterally not very persistent, sills are exposed in the basalt sequence northeast of Yindi Homestead. Aeromagnetic signatures suggest that the western sill, up to 250 m wide, is continuous over a strike length of approximately 14 km. From east to west rock types include pyroxene-phyric gabbro (about 30 m thick); weakly banded gabbro (30–40 m); doleritic-textured leucogabbro (120 m); quartz gabbro and granophyric gabbro, locally with amphibole sheaf textures (50 m); followed by pyroxene-phyric gabbro (40 m thick). The differentiation trend in both sills suggests younging westward.

Other prominent gabbros, but with unconvincing younging indications, are present in the centre of the map area along the Pinjin Fault. In the southern occurrence, gabbro is generally well-layered or banded, with interleaved medium-grained gabbro with short prismatic pyroxene, fine- to medium-grained layers with long prismatic pyroxene, and fine-grained layers with acicular pyroxene locally arranged in sheaves. Quartz gabbro includes medium- to coarse-grained granophyric textures, with 2–3 cm-long pyroxene prisms. Further north, isolated gabbro exposures show a wide variety of textures, including regular banding and fine bluish quartz grains. Local differentiation trends suggest younging is westward. These occurrences probably involve multiple intrusive episodes rather than a single body differentiated in situ.

East of the Pinjin Fault small gabbro bodies are found within or associated with serpentinized peridotite. These gabbros may well be extrusive rather than intrusive in origin — representing differentiation products of komatiitic volcanism. One small gabbro lens 2 km northeast of Round Hill shows westward differentiation from medium- to coarse-grained (2 cm) pyroxenite to fine- to medium-grained gabbro.

Intermediate rocks

Intermediate volcanic rock (*Aiv*) or andesite occurs in the extreme southwest corner of PINJIN, apparently as a thin interval within a metasedimentary and/or felsic volcaniclastic sequence. The dull green, variably foliated rocks are characterized by plagioclase and hornblende porphyroclasts. Little-deformed zones show a very fine-grained matrix consisting of numerous, almost acicular, amphibole and plagioclase prisms with accessory opaques and quartz. This matrix contains fine- to medium-grained plagioclase laths and short prismatic amphibole phenocrysts which locally show a well-developed flow foliation. Elsewhere, in addition to the phenocrysts, small aggregates are present, dominated by either hornblende or plagioclase with some biotite and quartz. In well-foliated rocks chloritization of matrix hornblende and biotite, as well as epidote–zoisite alteration of plagioclase, has occurred. Locally, recrystallized hornblende crystals and medium-grained garnet have grown across the foliation at various angles.

Intermediate schists (*Ais*) are hornblende–biotite–quartz–feldspar schists with variable hornblende contents and, locally, relics of feldspar phenocrysts. The main amphibolite facies schist belt lies directly east of the Pinjin Fault, and includes interleaved felsic schists and amphibolites. Other smaller occurrences of intermediate schists are near Hopeless Dam and intermittent exposures along strike northward to Rutters Dam.

The intermediate schists have a fine-grained matrix of feldspar and quartz, with variable amounts of biotite commonly with a well-developed preferred orientation. In several places biotite is extensively chloritized without much retrogression of other phases, although epidote, muscovite and, locally, carbonate are present. Very fine-grained opaques, sphene and other minor phases are arranged in trails parallel to the foliation. Plagioclase clasts, small ovoid quartz aggregates and plagioclase–quartz–biotite fragments locally suggest a volcaniclastic origin.

Hornblende — as short prismatic or highly acicular crystals — is present as fine-grained matrix material as well as medium- to coarse-grained porphyroblasts which enclose opaque trails continuous into the matrix. The hornblende may be present in veins or lenses at an angle to the foliation, uniformly distributed through the rock, or as highly irregular aggregates.

Garnet is found in leuco- and melanocratic varieties of the schist (*Ais*). It is fine to coarse grained, and commonly encloses trails continuous with the external foliation.

These intermediate schists — with hornblende from 5 to 40% and biotite from 1 to 10% — are transitional in both composition and texture to felsic schists (*Afs*, *Afv*) on the one hand, and mafic schist/amphibolite (*Amx*, *Aba*) on the other. As described before, these rock types are closely interleaved on all scales, from several metres to several centimetres. Some of the more hornblende-rich varieties within the intermediate schists may well be derived from interleaved dolerite–gabbro. However, whole-rock geochemistry of selected samples from east of Pinjin Homestead have distinct calc-alkaline (andesitic to dacitic) compositions (Table 1).

Felsic rocks

Felsic volcanic and volcaniclastic rocks (*Afv*) are characterized by feldspar phenocrysts, with or without quartz phenocrysts, in a very fine-grained quartzo-feldspathic matrix. Fine biotite, scattered throughout the matrix or in small aggregates, is partly replaced by chlorite. The rocks are mostly weakly foliated. Layering is defined by different amounts, ratios and grain sizes of phenocryst

Table 1. Whole-rock geochemistry of intermediate schists and amphibolite from the northern Pinjin Domain, and basalts and felsic volcanics from the Edjudina Domain

Sample number	*110493*	*110499*	*110500*	*110501*	*110494*	*110491*	*110495*	*110497*	*110502*	*110504*
					Percentage					
SiO_2	62.5	56.3	59.3	66.2	52.1	52.6	51.0	52.3	71.5	76.6
TiO_2	.62	.76	.76	.60	1.48	0.88	0.60	0.67	0.47	0.16
Al_2O_3	15.3	14.8	16.5	16.0	13.2	15.4	14.5	14.2	12.3	11.4
Fe_2O_3	1.94	1.71	2.14	2.03	2.39	2.56	2.00	2.45	1.57	1.05
FeO	3.91	6.07	4.69	3.21	10.2	7.00	7.13	7.34	1.89	0.90
MnO	.11	.20	.15	.09	.20	0.22	0.26	0.21	0.11	<0.05
MgO	2.85	3.41	3.13	1.17	5.55	5.69	7.53	7.30	0.56	0.13
CaO	6.61	9.70	6.94	3.81	9.22	11.8	11.8	11.1	1.95	0.84
Na_2O	4.40	2.54	3.52	4.00	2.44	1.83	2.27	1.92	4.04	4.14
K_2O	.25	.48	.62	1.45	.23	0.30	0.07	0.06	3.09	2.89
P_2O_5	.13	.20	.17	.14	.15	0.07	0.06	0.07	0.09	<0.05
LOI	.90	3.02	1.03	1.19	1.67	1.22	1.85	2.13	1.46	1.05
					Parts per million					
Ba	79	132	419	321	148	95	39	26	883	599
Ce	40	37	39	37	15	14	<6	<6	61	76
Cr	69	116	95	39	51	416	379	523	4	4
Cu	21	24	23	32	47	64	6	22	<4	<4
Ga	16	16	17	17	20	14	12	14	15	14
La	17	17	25	17	13	8	<5	<5	33	37
Li	7	11	13	22	13	<6	<6	<6	8	10
Ni	61	57	48	21	68	178	112	160	3	<3
Pb	9	6	11	7	<4	<4	<4	<4	16	12
Rb	2	13	20	46	3	13	<2	<2	81	90
Sc	13	15	16	12	35	37	39	40	8	3
Sr	220	436	304	221	161	97	79	208	101	53
V	123	128	143	96	365	275	245	265	40	<3
Y	17	19	21	16	35	41	13	15	37	38
Zn	70	80	74	75	80	88	71	61	95	52
Zr	164	174	168	148	130	63	42	48	250	298

GSWA sample numbers
Analyses by Mineral Science Laboratory, Chemistry Centre, Department of Minerals and Energy, Western Australia

Pinjin Domain:
110493, 110499–110501: intermediate schists (*Ais*) with variable hornblende and garnet
110494: amphibolite (*Aba*), interleaved with intermediate schists (*Ais*)

Edjudina Domain:
110491: amphibolitic basalt (*Aba*)
110495: basalt (*Ab*)
110497: komatiitic basalt (*Abm*)
110502: feldspar–quartz porphyryy (*Afp*)
110504: felsic volcanic/rhyolitic schist (*Afv*)

phases, and by interleaved, thin, fragmental, tuffaceous or biotite-rich beds (*Afx, Aft*).

The two main exposures of felsic volcanic/volcaniclastic sequences lie between Liberty Bore and Round Hill, and around Oldfield Well. Stratigraphically these two 'felsic centres' lie, respectively, to the west and east of a metasedimentary rock–BIF unit. The Liberty Bore–Round Hill felsic centre is partly interleaved with amygdaloidal basalt and dolerite (*Abi, Abd, Ao*), and commonly contains both feldspar and quartz phenocrysts. Whole rock geochemistry indicates rhyolitic compositions. On the other hand, the foliated felsic sequence around Oldfield Well tends to be dominated by small feldspar phenocrysts or porphyroclasts (1–3 mm).

Felsic tuffaceous rocks (*Aft*) are characterized by a very fine-grained, finely bedded or banded matrix with few scattered small quartz and feldspar phenocrysts. Locally, west of Oldfield Well, very fine-grained elongate feldspar crystals surround irregular (resorbed) rounded quartz grains and small rock fragments, suggesting crystal-lithic tuffs. In the higher grade domain east of the Pinjin Fault, some very finely bedded layers with local collapse structures are still preserved amidst intermediate schists and amphibolites. Layering in the very fine-grained quartzofeldspathic matrix is defined by variations in biotite content and grain sizes.

Feldspar–quartz porphyry (*Afp*) forms a distinct body within the felsic volcanic centre southeast of Liberty Bore. The eastern part of the porphyry contains large, irregular, zoned plagioclase phenocrysts (up to 1 cm) and scattered, small bluish quartz phenocrysts in a fine- to medium-grained matrix of feldspar (including granophyric plagioclase), quartz and biotite, with minor opaques, apatite, zircon, and secondary muscovite and epidote.

Westward, both plagioclase and rounded quartz phenocrysts occur within a matrix of perthitic and granophyric feldspars, quartz, and biotite.

Felsic fragmental rock (*Afx*) occurs as thin layers and lenses within the extensive felsic volcanic sequences. One mappable occurrence lies to the southeast of Liberty Bore. This occurrence shows coarse irregular fragmental texture within biotitic felsic volcanic rocks overprinted by a well-developed foliation.

Quartzofeldspathic micaceous (or felsic) schists (*Afs*) are the strongly deformed and recrystallized equivalents of various felsic volcanic, subvolcanic, and/or volcaniclastic precursors. The schists are now characterized by a pervasively developed foliation, with remnant feldspar and/or quartz clasts. The foliation is commonly controlled by a preferred orientation of mica, biotite, or muscovite, with a variably developed shape-preferred orientation of feldspar and quartz. In mica-rich layers this feldspar–quartz foliation is well developed, in contrast to mica-poor domains where equigranular textures are dominant. Biotite is at least partly replaced by unoriented white mica or chlorite, and most feldspar clasts are epidotized or sericitized.

The foliation wraps around elongate feldspar porphyroclasts which may be boudinaged. Commonly both asymmetric (sinistral and dextral) clast to foliation relationships were observed in the same hand specimen or thin section, suggesting that regional shortening controlled foliation development. Locally, feldspar phenocrysts can only be inferred from coarser muscovite aggregates. Quartz phenocrysts are less well-preserved because they have been flattened into ovoid, elongate, fine-grained aggregates. Both biotite and muscovite are also present as small porphyroblasts, but with different textural relationships: biotite as unoriented booklets wrapped by the foliation; muscovite as unoriented poikilitic late-stage crystals. The felsic schists east of the Pinjin Fault commonly show better preserved biotite (i.e. less muscovite or chlorite alteration), and contain scattered garnet, staurolite, and/or andalusite porphyroblasts indicating the higher metamorphic grade in this domain. The metamorphic textures are described in more detail in the section on **Metamorphism**.

The gold mineralized zone in the biotitic felsic schist between Oaks and Anglo Saxon is characterized by carbonate–quartz–biotite alteration and is interpreted as lying on the western edge of the Pinjin Domain. Samples from the Anglo Saxon open-pit mine include tightly folded, finely layered, felsic volcaniclastic schists.

Metasedimentary rocks

Grey slate and siltstone (*Ash*) is commonly well-foliated and recrystallized into very fine- to fine-grained siliceous mica schists. The foliation is defined by biotite, muscovite, quartz and/or feldspar, but bedding is preserved. These rocks are commonly poorly exposed, or, alternatively, in the case of interflow slates in basalt sequences, are silicified and lateritized. Distinctive porphyroblasts include biotite and, more locally, medium- to coarse-grained garnet and largely sericitized andalusite. The best exposures are on both sides of the Claypan Fault.

Well-foliated quartzofeldspathic micaceous metasedimentary rocks (*Asf*) including slate, siltstone and fine sandstone, are fine to medium grained, locally contain small clasts of feldspar, and include chloritic micaceous schist layers. This rock association possibly represents a distal epiclastic sequence, and is interleaved with more feldspar-rich schists of more likely volcaniclastic origin. The main belt lies directly north of Pinjin Homestead, where it contains gold mineralization in narrow quartz vein systems.

The general classification for sedimentary rock (*As*) is largely a mixture of the *Ash* and *Asf* rock types in strongly weathered and/or poorly exposed sequences — as in the platform outcrops on Lake Rebecca, and the slate-dominated sequence hosting the prominent BIF layers at Round Hill and west of Pinjin Homestead.

Oligomictic conglomerate (*Aso*) contains feldspar-phyric felsic volcanic rock and rare interspersed quartz pebbles in a quartzofeldspathic matrix. The small occurrence along the southern map boundary is the northernmost part of a more extensive sequence on ROE (Smithies, 1994). The conglomerate lies within a feldspar-phyric, felsic volcanic – volcaniclastic sequence exposed further to the south.

Chert and silicified slate (*Ac*) occur as thin layers within the western basalt sequence and within the mixed felsic–mafic schist belt east of the Pinjin Fault. Coarse, grey–white banded chert ridges in this eastern belt can be traced for hundreds of metres, and are the product of surface silicification of probably already quartz-rich beds. The chert layers in the western basalt sequence are less continuous, and are commonly transitional to less silicified fine slate layers.

Banded iron-formation (*Aci*, *Acis*) occurs both in oxide (*Aci*) and silicate (*Acis*) facies. Oxide facies BIF consists of fine-grained quartz–magnetite, with or without minor, mostly chloritized, biotite. It is generally finely bedded and interleaved with fine-grained chert and siliceous slate. The BIF layers commonly show intrafolial folding, including spectacular rootless isoclinal folds, with variable plunges and plunge directions. A distinctive BIF/sedimentary rock sequence — with two zones of BIF layers approximately 500 m apart and forming prominent ridges in the north — can be traced by its aeromagnetic signature from northwest of Pinjin Homestead to southwest of Liberty Bore (where it appears to be faulted and folded about the felsic complex to the east), possibly reappearing at Round Hill (Fig. 3). Other BIF layers occur to the west of this major sequence, and appear individually less extensive though still defining a distinct belt.

Other thin oxide facies BIFs are interleaved with amphibolite and felsic schist in the higher metamorphic grade sequence in the Pinjin Domain.

Silicate facies BIF (*Acis*) is restricted to some discontinuous layers or lenses in the Pinjin Domain southeast of Round Hill. The main silicate phase is grunerite, with local thin lenses or layers of clinopyroxene and fine-grained recrystallized quartz. Another lens within amphibolite largely enclosed by granitoid consists of magnetite, chlorite with both fine-grained foliated and medium-grained unoriented plates, and minor grunerite–cummingtonite.

Felsic porphyries

Granitoid porphyry (*Apg*) occurs as small dykes and sills, but locally may form more substantial elongate stocks. Little-deformed occurrences show plagioclase and/or K-feldspar phenocrysts (2–7 mm) with or without distinct quartz phenocrysts and scattered small biotite aggregates in a fine-grained matrix. More leucocratic varieties appear to contain few and widely scattered small garnets. Strongly deformed porphyry is characterized by quartz ribbons, sericitization of biotite, and partial destruction of phenocrysts by microfracturing and/or recrystallization.

Plagioclase-phyric biotitic felsic porphyry (*App*) commonly occurs as strongly foliated sills and dykes (0.5–4 m wide) in the western basalt–sedimentary rock sequence. The same association can be traced along strike southward onto KURNALPI (1:100 000 sheet) where the porphyritic schists locally form closely spaced swarms (Swager, 1994). Most sills appear perfectly parallel to the regional layering, but there are several examples of clearly crosscutting dykes, particularly on the Lake Rebecca platform outcrops.

The well-foliated rocks are characterized by many small plagioclase phenocrysts (1–4 mm) and a few, widely scattered quartz phenocrysts. Fine-grained biotite forms small aggregates and occurs scattered through the matrix.

Monzogranite porphyry (*Apm*) occurs as intrusive sills and irregular stocks in the western basalt mainly northeast of Yindi Homestead. Locally, closely spaced sills and dykes are only separated by narrow basaltic schist screens. This monzogranite porphyry is characterized by numerous coarse K-feldspar megacrysts (1–2 cm) in a porphyritic matrix with small sericitized plagioclase phenocrysts (1–3 mm), highly elongate, irregular, rounded quartz grains, and small biotite aggregates in a very fine-grained matrix of feldspar, quartz and biotite. The coarse K-feldspar megacrysts form stubby prismatic crystals and enclose some fine- to medium-grained plagioclase phenocrysts. A weak regional foliation is present.

The monzogranite porphyries are quite similar to Galvalley Monzogranite, apart from the porphyritic texture which suggests higher level or smaller volume intrusion.

Plagioclase–hornblende porphyry (*Aph*), probably tonalitic in composition, is present at only a few places. The fine-grained matrix of feldspar, quartz, biotite, hornblende with epidote/zoisite, and sphene, contains medium-grained hornblende, hornblende aggregates, and zoned plagioclase phenocrysts (2–4 mm). The dyke northeast of Liberty Bore is deformed and extensively retrogressed.

Granitoids

Biotite monzogranite (*Agm*) is the dominant granitoid phase on PINJIN. Both K-feldspar porphyritic and equigranular plutons are present, with the latter texture more common in the smaller stocks. K-feldspar, plagioclase and quartz are present in roughly equal amounts, are fine to medium grained, and are accompanied locally by coarse-grained K-feldspar megacrysts. Commonly quartz has recrystallized into fine-grained aggregates. Brown to green-brown pleochroic biotite (1–3%) occurs as small isolated flakes, or in small aggregates locally accompanied by euhedral epidote–zoisite and/or sphene. Fine opaques, short prismatic apatite, and zircon are common accessories. Secondary muscovite, locally as medium-grained poikilitic grains, chlorite, and epidote have replaced biotite and plagioclase to various degrees.

With the development of the initial foliation, quartz grains and aggregates are stretched out, as are biotite aggregates; however, only minor brittle deformation has taken place in feldspars. At higher strains, quartz 'ribbons', well-developed preferred orientation of biotite and muscovite, and boudinaged and/or partly recrystallized feldspar clasts all contribute to the foliation. West of Sardine Dam K-feldspar is perthitic in a small foliated monzogranite outcrop.

In the small pluton east of Claypan Dam scattered K-feldspar phenocrysts are well aligned with a weak but pervasive foliation, possibly suggesting initial foliation development during syntectonic emplacement.

The Galvalley Monzogranite (*Agmg*; named and defined by Morris, 1994) is a major ovoid pluton of which only the southeast quarter lies on PINJIN. It is characterized by numerous coarse K-feldspar megacrysts (up to 7 cm) and quite common small mafic enclaves. The prismatic megacrysts appear randomly oriented in the small exposures on PINJIN, but show a well-developed preferred orientation parallel to the regional foliation at the type locality (Morris, 1994), and further north. The K-feldspar grains enclose small plagioclase, quartz, biotite, epidote, and sphene. Pegmatite and aplite dykes occur locally.

Just two kilometres north of Christmas Dam monzogranite with unoriented medium-grained K-feldspar phenocrysts may be a satellite pluton of the Galvalley Monzogranite. This small pluton contains both small mafic enclaves (?cognate) and large greenstone xenoliths (accidental enclaves).

The Goat Dam Monzogranite (*Agmo*; named and defined by Smithies, 1994) is an approximately ovoid pluton at the southern boundary of the map, and lying largely on ROE. On PINJIN this pluton contains sizable greenstone xenoliths along which considerable post-emplacement deformation occurred.

Syenogranite (*Agy*) occurs in two small plutons within the BIF–metasediment belt in the Edjudina Domain. In hand specimen the syenogranites are very similar to monzogranite, but tend to be more leucocratic. The two plutons are medium grained, slightly porphyritic, with K-feldspar as the dominant phase (40–50%) and both brown and olive-green biotite as the mafic phase (1–2%). Thin sections reveal prominent granophyric intergrowth of feldspar (albite) with quartz. Plagioclase, now epidotized and albitic, may be independent, surrounded by a perthite rim, or, more rarely, form the core for a granophyric mass of quartz–albite symplectite. Accessory and secondary minerals are apatite, zircon, epidote, muscovite, and rutile. Small mafic enclaves are present.

The northern syenogranite pluton contains a widely spaced foliation, with local narrow, more intensely deformed zones parallel to the regional foliation.

A small syenite plug (*Ags*) occurs on the west side of the southern syenogranite pluton, 7 km south of Liberty Bore. The characteristic pink-coloured, fine- to medium-grained K-feldspar makes up 80% of the rock, with additional fine-grained plagioclase, fine- to medium-grained clinopyroxene (8%) and very minor amounts of bluish, alkaline amphibole. Minor phases are biotite, leucoxenated Fe-oxide, zircon, apatite, and possibly traces of quartz.

Quartz syenite to quartz monzonite (*Agq*) occurs as a small, irregular body on the eastern boundary of the small monzogranite pluton north of Christmas Dam, and as a small, barely exposed dyke southwest of Ten Mile Well. These rocks are slightly feldspar-porphyritic, contain only 10–15% quartz, have amphibole as the recognizable mafic phase, and include many mafic enclaves, possibly both accidental and cognate.

The feldspar phenocrysts are characterized by spectacular zoning and perthitic textures including (i) medium- to coarse-grained perthite, locally up to mesoperthite; (ii) perthite with several small plagioclase inclusions in the same optical orientation suggesting grain-scale intergrowth; and (iii) medium-grained plagioclase (oligoclase to albite) core entirely rimmed by K-feldspar, or by antiperthite and K-feldspar. These phenocrysts are contained in a fine- to medium-grained matrix of plagioclase, K-feldspar, quartz, amphibole, clinopyroxene, and small euhedral epidote (pistacite) with sieve texture. Amphibole (8%) is fine- to medium-grained hornblende or actinolite, and encloses minor biotite, sphene and epidote. It is locally accompanied by, and has ?replaced, clinopyroxene (1%). Sphene, apatite, magnetite and zircon are accessory phases.

Granodiorite (*Agg*) occurs in small intrusions, is slightly plagioclase-phyric, contains biotite as the mafic phase, and is weakly foliated, particularly at the margins. Plagioclase (50%) is fine to medium grained in the matrix, with zoned, prismatic medium- to coarse-grained crystals as phenocrysts. K-feldspar (15%) is finer grained, is almost interstitial to, but also enclosed by, plagioclase prisms. Quartz (30%) occurs in distinct, fine-grained aggregates, probably representing precursor single crystals. Deep reddish brown pleochroic biotite (4%) is mostly fine grained in small aggregates, with some sphene, epidote and, locally, short prismatic apatite.

Tonalite to quartz diorite (*Agt*) forms a very small body in the central part of the Pinjin Domain. The rock is medium grained, equidimensional, and weakly foliated throughout. Unoriented plagioclase (andesine) and hornblende prisms control the texture, with fine-grained quartz aggregates, and, very locally, medium-grained apatite. Toward the margin fine- to medium-grained brown biotite appears as a second primary mafic constituent.

Granitoid, undivided, (*Ag*) is used for small, mostly strongly deformed and/or weathered occurrences — in general they are probably leucocratic monzogranite. The well-foliated occurrences along the greenstone–granitoid contact in the Kirgella Rockhole area are commonly K-feldspar-phyric, interleaved with amphibolite and pegmatite.

Banded granitoid gneiss (*Ang*) is exposed at Kirgella Rockhole and several kilometres east of Lords Bore. The gneiss is part of a belt stretching northward; more exposures occur on YABBOO. Regional aeromagnetics (Anfiloff and Milligan, 1989) indicate a distinct belt characterized by moderate magnetic response and a strong north-northwesterly trend, suggesting that the Kirgella granitoid gneiss on PINJIN lies on the western contact of a major gneiss belt. The gneiss is intruded by, and, at the locality east of Lords Bore forms a block entirely surrounded by, little-deformed monzogranite, which dominates outcrop in the northeast corner of PINJIN (Figs 2 and 3).

The gneissic banding is defined by monzogranite layers with different biotite or K-feldspar phenocryst contents; by darker fine-grained, possibly tonalitic, layers; and by early granitoid sills and dykes. The banding is crosscut by diffuse medium- to coarse-grained, possibly pegmatoidal veins and irregular aggregates, suggesting high-grade metamorphism resulting in local melting. These magnetite-bearing pegmatoidal patches are locally accompanied by deep-grey quartz aggregates, indicating possible granulite facies conditions (Myers, J. S., 1991, pers. comm.).

At Kirgella Rockhole the banding is folded about gently doubly plunging fold axes with an upright axial plane foliation parallel to the regional structure in the greenstones. The pegmatoidal veins contain this foliation, but also appear to be controlled by fold limbs and fold hinges. High-grade metamorphism and melting may thus have occurred during upright folding.

The folded gneisses were then crosscut by late pegmatites which are correlated with the main monzogranite emplacement.

The Kirgella granitoid gneiss was part of a Sm–Nd study by McCullough et al. (1983) that included gneisses from Pioneer Dome and Connolly Siding on WIDGIEMOOLTHA and BOORABBIN respectively. These authors obtained model ages between 2480 and 2890 Ma, raising more questions than giving answers.

Proterozoic mafic and ultramafic dykes

Fine-grained, east-northeast-striking Proterozoic mafic and ultramafic dykes (*Pdy*) crosscut the sequence in the north of the map area. The Pinjin dyke (*Pdyi*) contains fine-grained dolerite, medium-grained gabbro and quartz gabbro, as well as fragmental rocks suggesting greenstone xenoliths within the mafic dykes. Where the dyke crosscuts the felsic volcanics in the Oldfield Well area, the presence of irregular quartz–feldspar veins and porphyries suggest local melting during emplacement.

A northwest-trending dyke is defined by small, irregular, gabbro plugs exposed as platform outcrops on Lake Rebecca, southwest of Nowhere Else Dam. The plugs crosscut strongly foliated metasedimentary rocks and are little or not deformed themselves. Of the four lake platform outcrops, only one is not weathered, but rock texture is clearly recognized in all occurrences. This texture is dominated by an interlocking network of medium-grained plagioclase prisms, fewer anhedral to euhedral clinopyroxene grains, and the interstices filled with secondary chlorite and prehnite. Small amounts of pale amphibole appear to be primary, and skeletal apatite and magnetite are abundant accessories. Biotite is extensively chloritized. The gabbro is metamorphosed at very low-grade conditions (prehnite–pumpellyite), in contrast to the enclosing, medium- to high-grade greenstones. Further south along strike, a narrow dolerite–gabbro dyke of the same suite crosscuts foliated gabbro and granitoid.

Regional aeromagnetics (Anfiloff and Milligan, 1989) reveal the presence of many other concealed dykes, including northeast- and northwest-trending sets.

Metamorphism

Binns et al. (1976) in their review of the regional metamorphism of the Eastern Goldfields Province distinguished medium grade (upper greenschist to lower amphibolite facies) in the western half and a narrower high-grade zone (mid to upper amphibolite facies) in the eastern part of the greenstones on PINJIN. The change from low to medium grade as defined by Binns et al. (1976) lies just below the greenschist–amphibolite facies boundary of Turner (1981).

Figure 4 shows the division into low- medium- and high-grade zones following the mineral parageneses listed by Binns et al. (1976) and Ahmat (1986). The distribution of metamorphic zones is very similar to that proposed by Binns et al. (1976), with the main difference in the western half of PINJIN where the medium-grade zones are restricted to marginal areas around granitoid plutons. The most remarkable feature is the contrast in metamorphic grade across the Pinjin Fault with low- to medium-grade rocks in the west and medium- to mainly high-grade assemblages in the east, suggesting relatively late stage west-block-down movement (see **Regional geology and structure**).

The occurrence of andalusite (andalusite–biotite, andalusite–staurolite) and the frequent presence of cummingtonite, both as an accessory and locally as a major phase, suggest generally low to intermediate pressures (Miyashiro, 1973). Widely scattered, but not uncommon, garnet indicates intermediate, rather than low, pressures (4 ± 1 kb; Yardley, 1989). However, further detailed work is required to establish reliable geobarometry, particularly in the high-grade zone.

The high-grade classification of the Pinjin Domain (Fig. 4) is based on the occurrence of clinopyroxene in both amphibolite and silicate facies banded iron-formation. Other assemblages in mafic and semi-pelitic rocks in the northwest of this domain are compatible with both medium- and high-grade assemblages. The metamorphic grade probably increases towards the migmatitic Kirgella granitoid gneiss, with totally recrystallized polygonal–granoblastic amphibolite layers and lenses within the eastern granitoid-dominated half of the Pinjin Domain. The migmatization in the banded gneisses may be contemporaneous with the high-grade metamorphism.

Approximate temperatures of (?peak) metamorphism can be inferred in general terms from the mineral parageneses across the Pinjin Domain. Staurolite–garnet–andalusite–biotite assemblages suggest temperatures around 600°C, whereas further eastward metamorphic clinopyroxene indicates temperatures well in excess of 700°C (Yardley, 1989; Spear and Cheney, 1989). At such temperatures melting would occur in the granitoid gneiss, and migmatitic features are indeed observed. J.S. Myers (pers. comm., 1991) suggested possible indicators for granulite metamorphism in the gneiss, but two-pyroxene assemblages have not been found in the metabasites.

The epidote–clinopyroxene (–garnet–sphene) calc-silicate assemblages in metasomatized mafic rocks record lower temperatures (medium grade) than the clinopyroxene amphibolites and are commonly found within several hundreds of metres of granitoid contacts (Fig. 4; Ahmat, 1986).

The relationships between porphyroblasts and regional foliation provide information on the relative timing of metamorphic rocks. Inclusion trails in porphyroblasts are outlined by small opaques, quartz, and/or other matrix relics. In many cases these trails are continuous with, and parallel to, the regional foliation in the matrix, suggesting late stage mineral growth. Incipient quartz pressure shadows adjacent to garnet, and small relative rotations of external and internal foliations, indicate some continued deformation after the porphyroblasts ceased growing. Locally in a staurolite schist layer, the internal foliation is at high angles to the external foliation, indicating development of a new foliation in the matrix after staurolite growth.

In general, however, peak metamorphism as indicated by porphyroblast phases is relatively late in the structural history. This observation is valid for porphyroblasts in metasedimentary and felsic schists (andalusite, staurolite, garnet), in intermediate schists and amphibolites (hornblende, garnet, clinopyroxene).

Cummingtonite is not present as porphyroblasts, but its occurrence in well-foliated monomineralic layers interleaved with clinopyroxene–hornblende layers, and as an accessory phase enclosed by and adjacent to late stage garnets, indicates that it is part of the main assemblage. Locally, well-foliated cummingtonite layers have haloes of

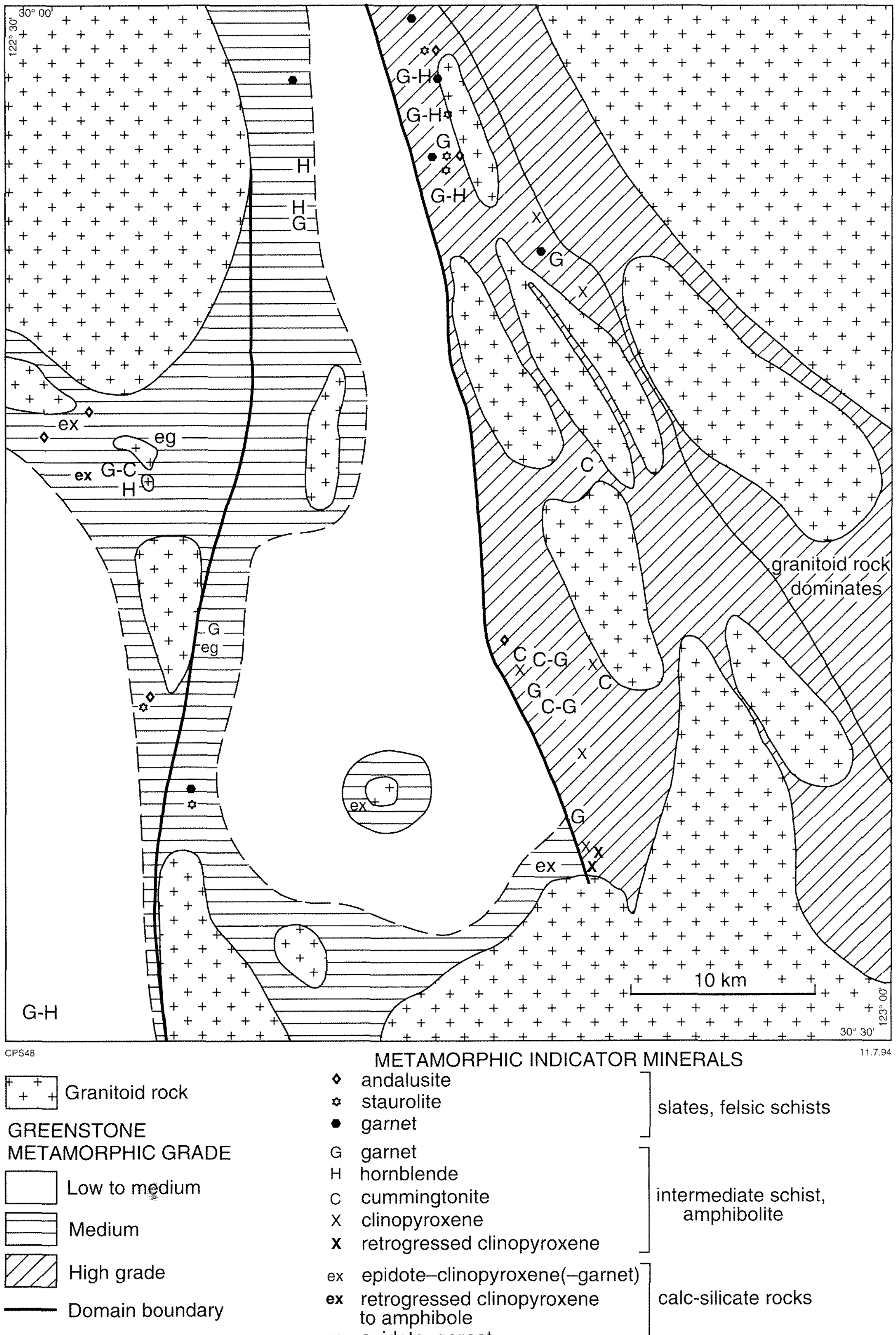

Figure 4. Distribution of metamorphic indicator minerals, and the division of PINJIN into low-medium, medium, and high metamorphic grade domains, following the mineral parageneses of Binns et al. (1976) and Ahmat (1986)

unoriented cummingtonite at a high angle to the layering, indicating a second, late growth stage.

Many porphyroblasts are well preserved and not retrogressed to any great extent. Some exceptions are the sericitized andalusite and/or staurolite in the western metasedimentary belt. In the high-grade Pinjin Domain tremolite–actinolite has locally replaced some clinopyroxene and hornblende–cummingtonite, in places as unoriented sheaves.

Regional geology and structure

Three structural–stratigraphic greenstone domains are distinguished on PINJIN on the basis of lithologic, stratigraphic, structural, metamorphic, and/or magnetic features (Fig. 3). The domains are separated by major shear zones and intruded by syn-tectonic granitoids. A belt of high-grade granitoid gneiss lies to the east of the Pinjin Domain.

The Yindi Domain is dominated by a major basalt sequence exposed in the hills around Old Pinjin and east of Yindi Homestead. These basalts continue along strike to the northwest onto MULGABBIE (Morris, 1994) where they contain thin ultramafic layers/lenses and are overlain by felsic volcanic and volcaniclastic rocks. Differentiation trends in gabbro indicate a westward-younging sequence, forming the eastern limb of a major regional syncline (Yilgangi syncline of Williams, 1970; Morris, 1994).

Northeast of Old Pinjin, the lower part of the basaltic sequence is interleaved with substantial metasedimentary layers. South of Yindi it appears that the basalt–gabbro sequence thins dramatically and is absent near the southern boundary of PINJIN, where only sedimentary rocks with thin dolerite sills and local minor andesite are found. Further southward, onto ROE, basalt reappears until it is again the dominant rock type in the belt. Similar lateral changes and wedging out of lithologies is documented in the same domain on KURNALPI 1:100 000 sheet to the southeast (Karonie–Yindi Domain of Swager, 1994).

Such large-scale lateral variations are observed throughout this belt, apparently within a westward-younging sequence. These variations may be partly original volcanic–sedimentary features, but probably also result from structural stacking of basalt and sedimentary/volcanic rock sequences.

The eastern boundary to this domain is formed by the Claypan Fault.

The Edjudina Domain between the Claypan Fault and the Pinjin Fault (Fig. 3) is dominated by a central north-striking metasedimentary rock–BIF belt. This association is like a marker unit that can be traced northwestward for more than 50 km onto EDJUDINA. However, southward onto ROE, though it is still present, the unit is strongly disrupted by voluminous granitoid intrusions (Smithies, 1994). On either side of this marker unit, sequences include felsic volcanic complexes with interleaved and laterally equivalent basaltic, intermediate volcanic, and metasedimentary rocks. Very few reliable younging indicators have been found and both eastward- and westward-younging is tentatively suggested by sedimentary structures and differentiation trends. Williams (1976) proposed a syncline with the marker unit in the core of the fold. However, the stratigraphy in this domain is not established unequivocally, and it is not clear whether the present day sequence includes repetition by folding and/or thrusting.

Felsic complexes are present on either side of the marker unit. In the north a complex at Oldfield Well is west of the marker unit, and continues northward onto YABBOO. In the south a complex between Liberty Bore and Round Hill lies to the east of the marker unit. The latter felsic complex consists of rhyolitic tuffs and subvolcanic porphyries (Table 1) with adjacent and some interleaved doleritic basalt. The felsic rocks around Oldfield Well may be rhyodacitic in composition because they tend to have fewer quartz phenocrysts or relics thereof.

A large scale, irregular fold may be inferred in the southern part of this domain from several observations. The irregularly folded/faulted slate–BIF association can be traced between Liberty Bore and Round Hill as a broad hinge zone south of the felsic complex, and a short disrupted eastern limb from Round Hill to approximately 6 km further north (Fig. 3). Layering and/or foliation attitudes in the felsic complex also suggest small-scale folding. The overall structure may be strongly influenced by large volumes of granitoid. However, the sedimentary rock – BIF unit also continues southward onto ROE.

The Pinjin Domain contains well-foliated, complexly interleaved felsic, intermediate, mafic and ultramafic rocks metamorphosed at medium to high grades, i.e. lower to upper amphibolite facies (Binns et al., 1976; Ahmat, 1986). Lithologies include felsic volcanic schist, metasedimentary schist, BIF, and thin, ultramafic schist–serpentinite layers/lenses. In general felsic schist tends to be more common towards the west and northwest. Thin BIF layers in this domain are interleaved with amphibolite and felsic schist, rather than metasedimentary rocks as in the Edjudina Domain. In general, metamorphic grade increases eastward, but the entire domain is at a higher grade than the Edjudina Domain. The domain is bounded to the west by the Pinjin Fault and to the east by the Kirgella granitoid gneiss, the contact of which is largely masked by granitoid intrusions.

Textures in relatively little-deformed areas clearly suggest volcanic precursors for the felsic schists, but, particularly in the central map area, felsic fragmental rocks commonly have an intermediate to mafic matrix. More uniform intermediate schists show calc-alkaline (andesitic to dacitic) geochemical characteristics (Table 1; Fig. 5) and are accompanied by mafic or basaltic schists. The common interleaving and transitions between rock types indicate that despite strong deformation and metamorphism the

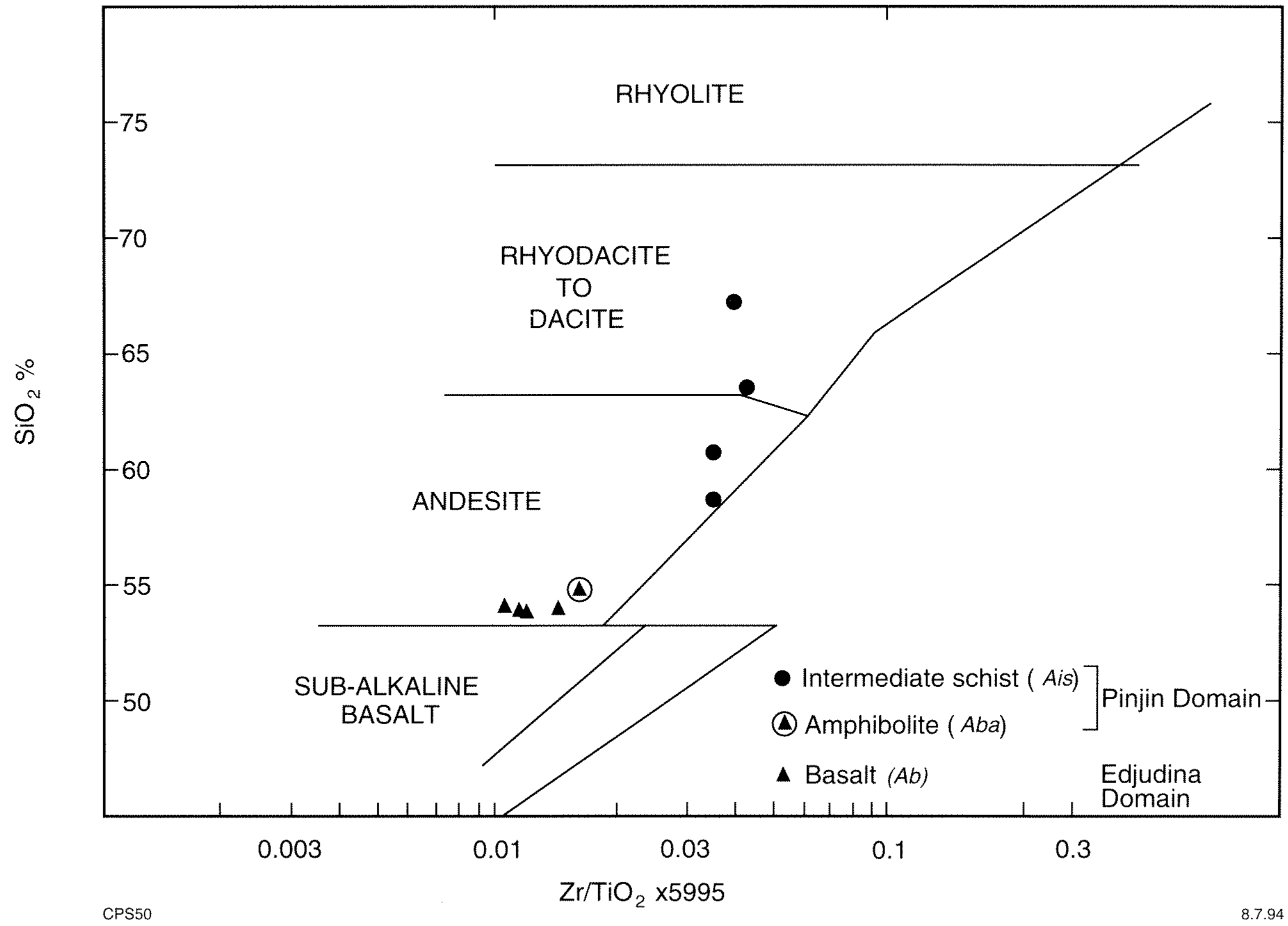

Figure 5. SiO_2–Zr/TiO_2 x5995 plot showing the distinct dacitic to andesitic composition of medium-high grade intermediate schists in the Pinjin Domain. For comparison, low-medium grade metabasalts from the Edjudina Domain are also plotted

rocks still largely represent a single association. This suggests an environment with contemporaneous and/or repeated mafic, intermediate and felsic volcanism. Thin interleaved BIF and chert layers, as well as locally very thin komatiite flows, form marker horizons (?beds, ?shear zones) within the sequence. Again no definitive evidence exists about the extent of 'internal' thrust repetition within this domain.

Asymmetric en echelon fold geometries occur adjacent to the Pinjin Fault south of Lake Rebecca, and suggest a right lateral component of movement (Fig. 3). Farther south a poorly exposed ultramafic layer outlines a larger scale fold closure, cored at least partly by intrusive granitoid. The main foliation in amphibolite is clearly folded in this structure. However, differentiation in gabbro associated with ultramafic rocks on either limb of the structure suggests the same westward-younging direction (Fig. 3).

The eastern boundary of this domain with the Kirgella granitoid gneiss is obscured by voluminous monzogranite intrusions within amphibolite, with ubiquitous interleaving at all scales. Most exposed granitoid–greenstone contacts, apart from small crosscutting dykes and stocks, are approximately layer-parallel, suggesting emplacement as sheets. Furthermore, the monzogranites contain a weak to strong foliation, parallel to that in the greenstones. The granitoid foliations have an intermediate, to locally steep, westerly dip.

The Kirgella granitoid gneiss occurs in the northeast corner of PINJIN. Although only a few small outcrops exist, they are part of a major belt of high-grade gneiss exposed further north on YABBOO, but largely obscured by later intrusive monzogranites. The boundary between the Kirgella granitoid gneiss and the Pinjin Domain (Fig. 3) is inferred from regional aeromagnetics, which indicate a zone of moderate magnetization with a pronounced north-northwesterly structural grain (Anfiloff and Milligan, 1989) coinciding with the inferred gneissic belt.

The granitoid gneiss contains evidence for an early tectono-metamorphic history involving formation of the gneissic banding, followed by upright folding about north-northwest fold axes and accompanied by high-grade metamorphism with some partial melting or migmatization. The contact of granitoid gneiss with greenstones is not exposed and/or is obliterated by the intrusive granitoids.

At Kirgella Rockhole amphibolite and foliated leucogranitoid with coarse pegmatite and granitoid porphyry are closely interleaved, with increasing granitoid volumes towards the contact. The amphibolites record high-grade metamorphic conditions (upper amphibolite facies), which may be correlated with the high-grade (?up to granulite) metamorphism in the granitoid gneiss. The strongly foliated leucogranitoid with shallow north-plunging mineral lineations suggests late stage movement along the gneiss–greenstone contact.

Williams et al. (1976) described similar greenstone – granitoid gneiss contacts on EDJUDINA along strike to the north. They distinguished, from east to west, banded migmatites (eastern marginal zone) intruded by several homogeneous granitoids; layered greenstones with numerous granite, aplite and pegmatite intrusions generally increasing eastward (lit-par-lit zone); and a broad zone up to 5 km wide of contact-metamorphic greenstones.

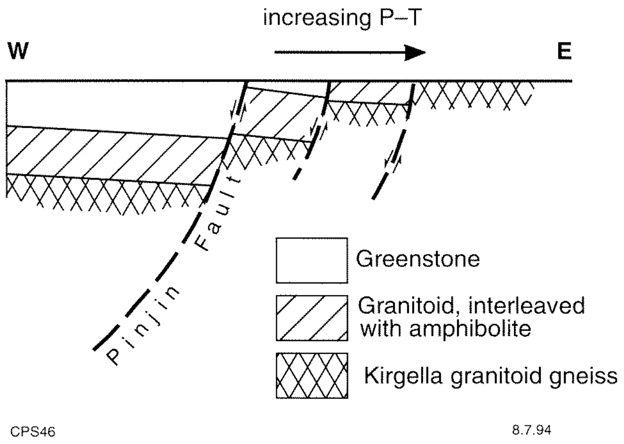

Figure 6. Possible interpretation of Pinjin Fault: observed metamorphic zonation suggests a late stage extension

Regional shear zones

The Claypan Fault separating the Yindi and Edjudina Domains was originally proposed as a regional structure by Williams (1970, 1976). It is a mylonitic zone developed in felsic schists and granitoid sills and dykes north of Middle Tank, characterized by subhorizontal to gently north-plunging mineral lineations (Fig. 3). Numerous quartz veins contain considerable tourmaline, which also occurs along foliation planes in the felsic schists. The main foliation contains some good movement indicators, including asymmetric quartz porphyroclasts and a weak S–C fabric indicating sinistral or left-lateral movement. The same displacement direction is indicated by more common, variably developed spaced shear bands (C–C' fabric). Eastward, both mineral and intersection lineations show the same shallow north-plunging orientation. In the area south of Claypan Dam, sinistral shear bands were also found in felsic schists adjacent to the monzogranite pluton (Fig. 3).

The Pinjin Fault is characterized on a regional scale by en echelon folds; by a jump in metamorphic facies, with a high-grade domain to the east; and by different lithological associations on either side. In the well-exposed Round Hill area, the shear is a complex zone, up to one kilometre wide, of interleaved rock types with truncated folds and en echelon folds, whereas in the Pinjin Homestead area the shear is inferred from the contrast in metamorphic grade (Figs 3, 4).

Regional movement indicators such as the asymmetric folds, and the contrast in metamorphic grade, suggest, respectively, dextral and vertical east-side-up displacement components. These conclusions are confirmed by the kinematic indicators associated with north-plunging mineral lineations on steeply west-dipping foliations (Fig. 3), with asymmetric quartz aggregates and S–C fabrics indicating west-block-down east-block-up displacement.

The contrast in metamorphic grade suggests substantial vertical movement along the Pinjin Fault, and raises questions about the nature and attitude of the shear zone on a crustal scale. At the surface steeply west-dipping mylonitic foliations suggest a normal or extensional shear zone, presumably flattening out at depth (Fig. 6).

Regional structural correlation

Regional structures can be correlated to a certain extent with the deformation history proposed for the greenstone belts of the Kalgoorlie Terrane to the west (Table 2), but PINJIN also exhibits features that are not reconciled with compressional deformation.

The regional synclinal structure (Yilgangi syncline) directly east of Pinjin is interpreted as a D_2 regional compressional structure, and the main upright foliation in the Yindi Domain as S_2. There is no unequivocal evidence for D_1 thrusts resulting in large scale repetition. However, if the lateral changes within the Yindi Domain represent original stratigraphic features, they probably are at least accentuated by early thrusts. However, further mapping may show that this regionally extensive belt is a complexly stacked sequence.

The internal structure of the Edjudina Domain is less well understood. It may form a single, east-younging steeply tilted succession with the main foliation correlated with S_2. However, the lithologic associations involving two mafic-to-felsic complexes separated by a regionally continuous metasedimentary rock – BIF sequence, may suggest an originally simpler succession with slates/BIF representing the stratigraphic top. In that case a thrust may separate the slate–BIF sequence from the overlying mafic-to-felsic association to the east. Williams (1970, 1976) proposed a syncline with slate–BIF in the fold core, but such a fold appears incompatible with the eastward younging of the slates.

The irregular large-scale fold between Liberty Bore and Round Hill is most likely a structure refolding the already tilted and foliated sequence. It may have evolved during late (D_3) movement along the Pinjin Fault and/or emplacement of granitoids to the south.

The variation in plunge, plunge direction, and tightness of small scale folding in the BIFs suggest several folding episodes, but overprinting criteria are rare.

The relationship between the Yindi and Edjudina Domains is not clear. The domains are separated by the Claypan Fault which shows evidence for sinistral strike-slip movement. However, this may only be the last displacement episode during regional shortening (D_3), masking a much longer movement history. Lithologically the Edjudina Domain is similar to the upper part of the sequence (felsics overlain by slate and BIF) in the Yindi (Karonie–Yindi) Domain, but shows lateral mafic to felsic transitions over much shorter distances.

The folds within the Pinjin Domain adjacent to the Pinjin Fault appear to be late stage (D_3). The larger scale fold outlined by an ultramafic layer may be a D_2 structure, but the younging evidence suggests another asymmetric en echelon fold, possibly complicated by (?syntectonic) granitoid emplacement in the (?low pressure) fold hinges. The D_3 en echelon folds locally contain axial plane foliations.

However, the extensional nature of the Pinjin Fault is unlike the compressional deformation further west, where all the regional D_2–D_3 shears and faults commonly show substantial reverse movement components. The Pinjin Fault shows normal movement indicators including those in deformed granitoids intrusive into the shear zone. These microstructures, and the preserved contrast in metamorphic grade are compatible with a late-stage extensional event. If the regional upright foliation in the Pinjin Domain is correlated with D_2 in the west, then this extensional faulting must have occurred after D_2.

Whether the upright folding of the banding in the Kirgella granitoid gneiss can also be correlated with D_2 is speculative. The early gneissic banding, possibly in a subhorizontal attitude, can thus be related to a ductile D_1 deformation at deeper crustal levels, in contrast to the more brittle thin-skinned D_1 thrusting at higher levels. Such speculations have already been discussed by Archibald et al. (1981) and will be debated in the next section.

Overall, the increasing metamorphic grade and the increasing amount of intrusive granitoid in the Pinjin Domain towards the Kirgella granitoid gneiss with its high-grade (upper amphibolite – granulite) metamorphism are all compatible with late stage uplift of lower crustal levels. This may possibly involve a number of extensional faults, the most obvious of which is the Pinjin Fault . Other shears may be present along the gneiss contact.

Archibald et al. (1981) and Ahmat (1986) proposed differential uplift models to explain the juxtaposition of low- and high-grade domains. Ahmat (1986) also indicated that this uplift occurred during 'granitoid doming and diapirism', in other words during the later stages of the regional tectono-metamorphic event.

This late emplacement of the high-grade gneiss at higher crustal levels suggests a comparison with metamorphic core complex geometries. The apparent lack of rotation of the upright foliation and layering suggests relatively high-angle rather than low-angle bounding faults, resulting in a relatively steep metamorphic gradient with relatively small amounts of extension (Fig. 6). Metamorphic assemblages suggest vertical displacements of up to a few kilometres.

The tectonic forces driving the 'doming' are not understood, and could be either late-stage extension resulting in uplift, or continued shortening resulting in thickening at deeper crustal levels and the subsequent rise of high-grade gneisses.

Recent mapping in the Leonora and Melita areas has documented high-grade gneiss domes with very narrow high P–T greenstone rims. These have been interpreted as early core complexes — formed during continued extension at the time of greenstone volcanism and early deformation (Williams et al., 1990); or during post-D_1 to pre-D_2 events (Witt, 1994).

Structural setting of granitoids

The setting of the larger granitoid plutons can be discussed in terms of their internal structures and their geometrical relationships with external structures such as folds, shear zones, and the regional foliation (Table 2; and Witt and Swager, 1989).

The Kirgella granitoid gneisses are interpreted as the oldest granitoids. One possible interpretation, as discussed in the previous section, is that the early gneissic banding evolved during horizontal D_1 deformation, implying that the gneiss precursors were emplaced, probably as horizontal sheets, not later than D_1, and possibly as early as during greenstone volcanism. This D_1 banding was then folded during D_2 shortening. However, another interpretation is that the gneiss is not derived from early, low-level intrusive sheets, but is a remnant of an older sialic basement on which the greenstone sequences were laid down or were tectonically emplaced (Griffin, 1990).

Roddick and Libby (1984) obtained a Rb–Sr whole rock date of 2557 ± 35 Ma from banded granitoid gneiss at Barret Well on YABBOO, approximately 45 km northwest along strike from the Kirgella granitoid gneiss in the same belt. This age was interpreted as dating migmatization of the gneiss — suggested by Williams et al. (1976) to be related to late granitoid emplacement. The date, however, is younger than recent single zircon U–Pb ages for late granitoids, and must be viewed with some caution.

The Galvalley Monzogranite and a much smaller, unnamed pluton at Claypan Dam were emplaced as southward-tapering, tear-shaped plutons along, and just west of, the Claypan Fault. Over large outcrop areas both plutons are characterized by a foliation defined by aligned K-feldspar megacrysts, elongate mafic enclaves, and, more locally, by elongate quartz and weak compositional banding. The absence of well-developed biotite seams in the matrix suggests that the fabric formed at least partly

Table 2. Regional deformation history and granitoid emplacement history in the Kalgoorlie Terrane

	REGIONAL DEFORMATION HISTORY (a)	GRANITOID INTRUSION (b)
D_4	regional shortening, oblique N–striking faults; dextral (Kalgoorlie)	late–tectonic granitoid
D_3	continued, regional ENE–WSW shortening transcurrent faults NNW–trend; sinistral en–echelon folds Formation of syntectonic, clastic basins	post –D_2 to syn –D_3 granitoid
D_2	regional, upright folds NNW - strike	pre– to syn– D_2 granitoid
D_1	thrust stacking recumbent folding	?
	greenstone volcanism	

(a) Swager, 1989 ; Swager and Griffin, 1990
(b) Witt and Swager, 1989

as a flow foliation. Anastomosing foliation patterns closer to the contacts indicate subsequent solid state deformation. The parallelism of flow foliation and regional fabric indicates syntectonic emplacement. The small satellite pluton north of Christmas Dam does not show a preferred orientation of phenocrysts, and has stoped its way into the folded and foliated sequence with very little disturbance of greenstone structures. If this satellite pluton is closely related in time to the Galvalley Monzogranite, then syntectonic emplacement is possibly at a relatively late stage during regional shortening (post-D_2 to syn-D_3 of Witt and Swager, 1989).

Two small syenogranite plutons intrude the slate–BIF marker units in the Edjudina Domain (Fig. 3). The northern pluton is elongate and contains a reasonably well-developed foliation parallel to the regional fabric. The southern pluton is more rounded to slightly ovoid in map outline, includes a small syenite plug, and is tightly wrapped by chert and BIF layers. The lower time limit for emplacement of these plutons is poorly constrained, but they were deformed at some stage during D_2–D_3.

The major monzogranite plutons along the southern boundary of the map are poorly exposed, but show evidence of strike-parallel shear zones, mostly along larger greenstone xenoliths or screens. Both vertical (west-block-up) and dextral movements, probably small scale, are inferred from S–C fabrics. South of Round Hill a major pluton has intruded across the Pinjin Fault showing contact-parallel foliation, with down-dip lineations, at high angles to the regional trend. A narrow metamorphic halo is suggested in basaltic amphibolite to the west of the shear. These plutons can be compared with the post-D_2 to syn-D_3 granitoids of Witt and Swager (1989).

A number of elongate monzogranite plutons are inferred from aeromagnetics in the high-grade Pinjin Domain (Fig. 3). These syntectonic plutons have aspect ratios up to 4:1, and are parallel to the regional layering, with a variably developed foliation in the same orientation. Extensive granitoid–greenstone interleaving outside the plutons may mimic the almost sheet-like emplacement of the larger plutons which probably incorporate narrow greenstone screens. The plutons may have been emplaced from early stages (D_1) onwards in the deformation history.

Further to the east, massive monzogranites have swamped the banded gneisses. Late tectonic emplacement is suggested by the lack of strong deformation and the observation that monzogranite and related pegmatite crosscut the folded gneiss. The contrast with the more deformed elongate plutons in the Pinjin Domain is pronounced, but their relationship is not known.

Syenite, and possibly related quartz syenite to quartz monzonite, occurs as small stocks within larger syntectonic monzogranite and syenogranite plutons. These felsic alkaline rocks (Libby, 1989) may have developed under similar conditions, possibly as late-stage intrusions at relatively shallow levels (Libby, W. G., 1992, pers. comm.). Johnson and Cooper (1989) obtained Rb–Sr whole rock ages for the Gilgarna Rock syenite which is exposed 9 km northwest of Yindi Homestead on MULGABBIE and which is identical to the small syenite occurrence on southern PINJIN. Johnson and Cooper (1989) found different ages for an earlier medium-grained phase — 2629 ± 41 Ma; and a later coarse-grained phase — 2542 ± 14 Ma. These authors suggested that in these late tectonic, little-disturbed rocks the dates represent magma crystallization ages. However, the long interval

Table 3. Gold production statistics of the major producers in the Pinjin Mining Centre

	Ore (t)	*Gold (kg)*	*Production period*
Pinjin mining centre			
Anglo Saxon	9755.7	183.024	1899
			1904-1916
			1935-1936
			1938-1940
Anglo Saxon North	781.05	7.418	1905–1910
Coles	1349.53	12.973	1909–1910
Harbour Lights	351.25	8.721	1905–1908
Harbour Lights North	148.34	7.110	1906
King Pin	682.28	21.417	1908–1910
Lilly of Australia	305.33	7.597	1906–1907
Oaks	366.80	7.549	1905–1907
Pinjin Consols	133.10	3.253	1905–1906
Pinjin King	1713.58	27.481	1905–1908
Pinjin North	164.09	4.840	1907–1908
Pinjin Queen	110.24	4.316	1905–1906
Unification	634.02	10.364	1911–1912

Sources: Department of Mines (1954)
Unpublished records of the Department of Minerals and Energy

between the two mineralogically and geochemically similar syenites suggests the dates should be viewed with some caution.

Economic geology

The Pinjin Mining Centre, which is part of the Yerilla District in the North Coolgardie Mineral Field, is the only gold-producing area on PINJIN. Most activity occurred in the period between 1904 and 1916. Table 3 shows the recorded gold production from PINJIN. The Anglo Saxon mine was the biggest producer, with approximately 185 kg Au recovered until 1940, but with additional small-scale production since then, as well as a short-lived openpit operation in the late 1980s. Ore was trucked to the Porphyry plant west of Yarri on EDJUDINA, and separate tonnage and grade data do not appear to be available.

Two, virtually parallel, mineralized trends can be recognized: the Oaks – Anglo Saxon trend continues over approximately 3 km of strike length; and the Harbour Lights – King Pin line over approximately 12 km strike length. The Oaks–Anglo Saxon mineralized trend contributed the bulk of the gold, and lies along the inferred Pinjin Fault, at the western edge of the amphibolite facies Pinjin Domain (Figs 3 and 4). Host rocks are feldspar-phyric biotitic felsic schists which contain disseminated pyrite and carbonate alteration in and adjacent to fine irregular quartz–carbonate–biotite veins. The presence of biotite in the alteration assemblages suggests upper greenschist–amphibolite facies conditions (Witt, 1991).

The Harbour Lights – King Pin mineralized belt lies directly west of the Pinjin Fault in the Edjudina Domain. Variably chloritic carbonate–sericite schists, derived from sedimentary/volcaniclastic precursors and interleaved at several places with thin talc–chlorite–carbonate schists, host zones of disseminated pyrite mineralization. Minor galena, stibnite, and scheelite have been reported. Biotite does not appear to be present, although very little fresh material is available.

Gold exploration of a major Tertiary palaeochannel underlying Lake Rebecca has been described by Smyth and Button (1989) and, in more general terms, by Smyth and Barrett (1994).

Nickel exploration in the early 1970s was concentrated on the ultramafic bodies in the Pinjin Domain. Although some pyrrhotite–pentlandite mineralization was encountered in the massive serpentinized olivine cumulates several kilometres north of Round Hill, no economic deposits were found (Endeavour/Noranda, 1975).

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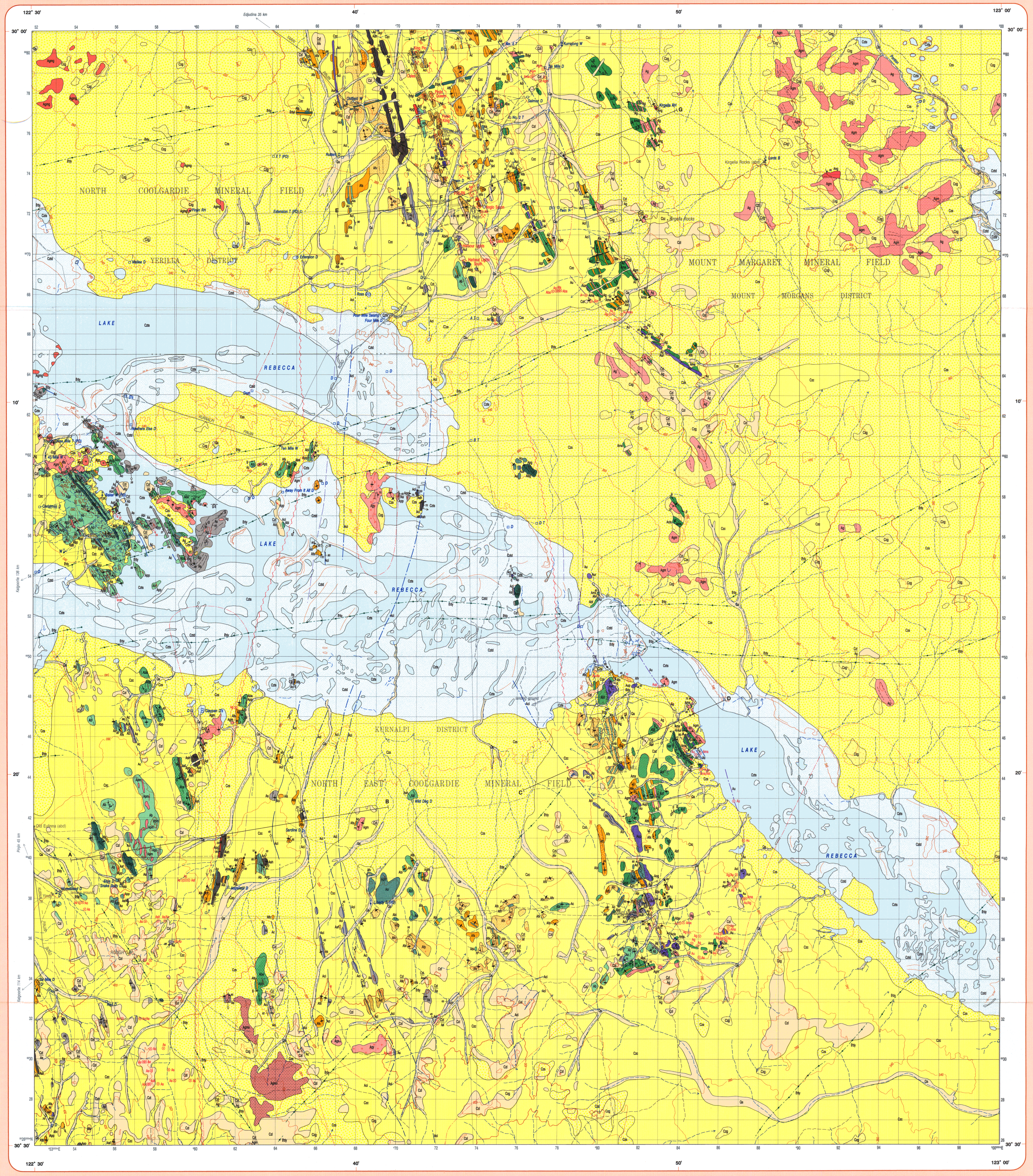
Appendix

Gazetteer of localities

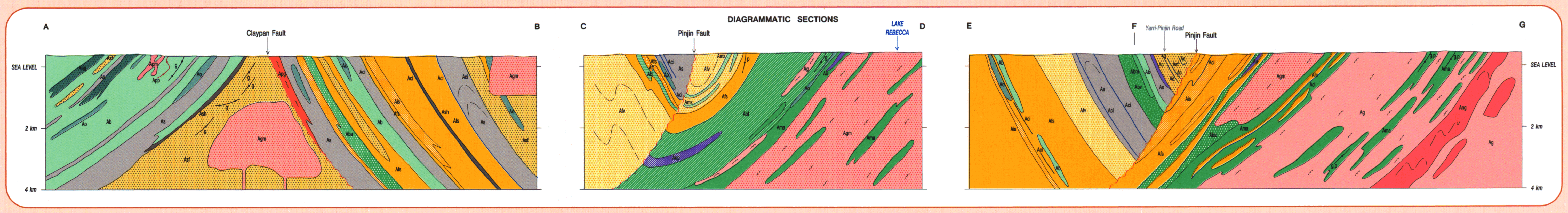
	AMG coordinates	
	Easting	*Northing*
Anglo Saxon mine	474000	6672500
Christmas Dam	452150	6657400
Claypan Dam	460300	6647300
Coles mine	471000	6678950
Harbour Lights mine	473150	6670150
Harbour Lights South mine	473300	6669500
Hopeless Dam	461600	6638500
King Pin mine	470850	6680000
Kirgella Rockhole	482800	6677300
Kirgella Rocks	483350	6671800
Liberty Bore	468900	6637700
Lords Bore	488250	6674550
Middle Tank	460350	6637200
Nowhere Else Dam	456750	6661500
Oaks mine	474700	6670650
Oldfield Well	467350	6677500
Old Pinjin Homestead	454350	6656200
Pinjin Homestead	473900	6672300
Pinjin King mine	472100	6676600
Pinjin Queen mine	471700	6677950
Pinjin Rockhole	459650	6672150
Rough Gap hills	456950	6635250
Round Hill	481800	6637200
Rutters Dam	467200	6674800
Sardine Dam	465300	6641350
Ten Mile Well	464150	6660500
Wild Dog Dam	470800	6642850
Yindi Homestead	452900	6638250

PINJIN

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA



DIAGRAMMATIC SECTIONS



PHANEROZOIC — CAINOZOIC — QUATERNARY

Qa — Alluvium—clay, silt, sand, and gravel; in stream channels and flood plains

Czts — Evaporite interbedded with clay, silt, and sand in playas
Cztd — Sand, silt, and gypsum in stabilized dunes adjacent to playas

Czc — Colluvium—gravel and sand as sheetwash and talus; includes laterite fragments
Czg — Quartzo-feldspathic sand over granitoid rock
Czs — Sandplain—yellow sand with some pisolitic laterite pebbles; includes stabilized dunes
Czl — Laterite
Czz — Silcrete

PROTEROZOIC

Ɏdy — Mafic dykes; mafic and ultramafic dykes inferred from aeromagnetic data where dashed
Ɏdyi — Pinjin Dyke

ARCHAEAN

Veins and dykes: q — quartz, g — granitoid, p — pegmatite

Ag — Granitoid rock, undivided; includes strongly weathered rock
Agm — Biotite monzogranite; even-grained and K-feldspar porphyritic textures; locally weakly foliated
Agmg — **GALVALLEY MONZOGRANITE**: prominent K-feldspar megacrysts; local foliation defined by aligned K-feldspar and biotite
Agmo — **GOAT DAM MONZOGRANITE**: with minor biotite
Agg — Granodiorite; plagioclase-phyric; with biotite
Agy — Syenogranite; with minor biotite
Ags — Syenite
Agq — Quartz syenite to quartz monzonite; with hornblende and local minor clinopyroxene; numerous mafic enclaves
Agt — Tonalite to quartz diorite; with hornblende and biotite

Ang — Banded granitoid gneiss; locally migmatitic

Apg — Granitoid porphyry; sill or dyke; prominent feldspar, quartz and/or biotite phenocrysts
Apm — Monzogranite porphyry; characteristic K-feldspar megacrysts and small plagioclase phenocrysts; massive to weakly foliated; substantial dykes and stocks
App — Plagioclase porphyritic, biotitic felsic schist; numerous euhedral plagioclase and rare quartz phenocrysts; strongly foliated; narrow sills and dykes
Aph — Plagioclase-hornblende porphyry

As — Sedimentary rock, undivided
Ash — Grey slate, siltstone, and quartzo-feldspathic mica schist; well foliated; with biotite, and local garnet, andalusite and/or staurolite porphyroblasts
Aso — Oligomictic conglomerate; abundant felsic porphyry and rare chert clasts in quartzo-feldspathic matrix
Asf — Quartzo-feldspathic, micaceous slate, siltstone, and sandstone; well foliated; interlayered with feldspar-phyric schist of felsic volcanic and volcaniclastic derivation; includes chloritic and carbonate-bearing schist
Ac — Chert, locally grey-white banded; includes variably silicified grey to black slate, finely layered and locally pyritic
Aci — Banded iron-formation, oxide facies; quartz-magnetite(-biotite) rock interlayered with chert; interpreted from aeromagnetic data where dashed
Acis — Banded iron-formation, silicate facies; grunerite(-hornblende) layers interlayered with chert

Afv — Felsic volcanic and volcaniclastic rock; variably foliated; with prominent feldspar and/or quartz phenocrysts or clasts; includes fragmental rocks, and crystal-lithic and finely layered tuffs
Afp — Feldspar-quartz porphyry; with biotite; volcanic and/or subvolcanic derivation
Aft — Felsic tuffaceous rock; finely banded; foliated; fine- to medium-grained quartz and feldspar phenocrysts
Afx — Felsic fragmental volcanic rock
Afs — Quartzo-feldspathic micaceous schist; felsic volcanic, subvolcanic and/or volcaniclastic derivation; with local staurolite, garnet and/or andalusite

Aiv — Intermediate volcanic rock; andesite with feldspar and hornblende phenocrysts; epidote and/or carbonate alteration common; includes feldspar-quartz-chlorite-hornblende schist
Ais — Intermediate schist; hornblende-biotite-quartz-feldspar schist with variable hornblende content; locally feldspar-phyric and garnetiferous; local relict fragmental layers; with interlayered felsic schist and amphibolite

Ao — Mafic intrusive rock, undivided; dolerite, gabbro
Aop — Dolerite-gabbro, with coarse plagioclase phenocrysts
Aog — Gabbro, with minor pyroxenite and quartz gabbro

Ab — Basalt, undivided; includes feldspar-hornblende or chlorite schist; includes strongly weathered rock
Abp — Basalt, with medium- to coarse-grained feldspar phenocrysts
Abd — Basalt, dolerite-textured; amygdaloidal; local epidote alteration
Abm — Komatiitic basalt with quenched pyroxene (amphibole) texture; variolitic
Abv — Basalt, variolitic; pillowed; komatiitic affinity
Abi — Basalt to basaltic andesite; amygdaloidal, feldspar-phyric; with hyaloclastite and fragmental/tuffaceous layers; hornblende-feldspar schist with ovoid quartz aggregates
Abs — Basaltic schist, strongly metasomatized; includes carbonated rock, biotite-hornblende and clinopyroxene-tremolite schist
Aba — Basaltic schist to amphibolite; local epidote alteration; includes garnet- and clinopyroxene-bearing layers
Abf — Basaltic schist and amphibolite (Aba, Ama) interlayered with intermediate schist (Ais) and felsic schist (Afs); regular to lensoidal banding

Ama — Amphibolite and quartz-feldspar-hornblende schist; pervasively foliated and recrystallized; commonly banded; clinopyroxene-, cummingtonite-, and/or garnet-bearing layers; with small hornblende-quartz-feldspar aggregates
Amx — Mafic fragmental schist, medium-grained; irregularly layered; includes garnet-amphibole-feldspar rock with felsic schist fragments, banded amphibolite, and gabbroic-textured rock; with interlayered Afs, Afv and Ais

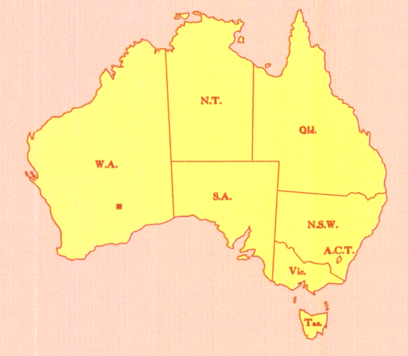
Au — Ultramafic rock, undivided; interpreted from aeromagnetic data where dashed
Aup — Peridotite, serpentinized; with local pyroxene phenocrysts
Aux — Pyroxenite
Aut — Talc-chlorite schist; with local carbonate
Aur — Tremolite schist; with local magnetite porphyroblasts; with minor talc-chlorite schist

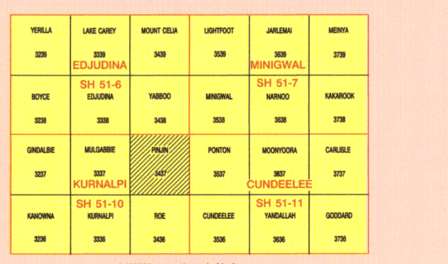
Metamorphosed at middle greenschist to upper amphibolite facies

Geological boundary
accurate
approximate
interpreted, based on aeromagnetic data
Fault
inferred
Shear zone
major
major, interpreted, based on aeromagnetic data
minor
interpreted movement
Minor fold, showing direction of plunge — 26
Bedding, showing strike and dip
inclined — 47
vertical
overturned — 70
Igneous layering, showing strike and dip
inclined — 40
Way-up indicators
igneous layering or differentiation
sedimentary structure
Dominant metamorphic foliation, showing strike and dip
inclined — 88
vertical

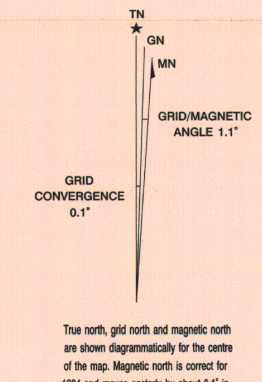
Strongly foliated rock
Cleavage, showing strike and dip
inclined — 80
vertical
Mineral lineation, showing direction of plunge
horizontal
plunging — 35
on foliation plane — 30, 85
Intersection lineation, showing direction of plunge
horizontal
plunging — 75
Fracture or joint, showing strike and dip
inclined — 70
vertical
Air photo lineament
foliation or layering trend in greenstone
fracture pattern in granitoid rock
foliation trend (section only)
Aeromagnetic trend
Mineral field boundary
Formed road
Track
Fence, generally with track

Townsite, population less than 1000 — Pinjin
Homestead — Yindi
Building
Horizontal control; minor
Breakaway
Sand dune
Contour line, 20 metre interval — 380
Watercourse, ephemeral
Bore — B
Well — W
Windpump
Dam — D
Tank — T
Rockhole — RH
Position doubtful — (PD)
Mining centre — PINJIN
Mine (gold) — Oaks
Opencut (gold) — Anglo Saxon
Battery, abandoned
Mining area, tailings, mullock
Mineral exploration drillhole or costean, showing subsurface data — Asf





1:100 000 maps shown in black
1:250 000 maps shown in brown



True north, grid north and magnetic north are shown diagrammatically for the centre of the map. Magnetic north is correct for 1994 and moves easterly by about 0.1° in 4 years.

DEPARTMENT OF MINERALS AND ENERGY
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MINISTER FOR MINES
L.C. RANFORD, ACTING DIRECTOR GENERAL

PIETRO GUJ
DIRECTOR, GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

SCALE 1:100 000

1000 Metres 0 1 2 3 4 5 6 7 8 9 10 Kilometres

TRANSVERSE MERCATOR PROJECTION
Grid lines indicate 1000 metre interval of the Australian Map Grid Zone 51

Geology by: C. P. Swager 1990—1991

Cartography by the Cartographic Services Branch, Surveys and Mapping Division, Department of Minerals and Energy, Western Australia

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PINJIN

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