EXPLANATORY NOTES

GOVERNMENT OF WESTERN AUSTRALIA

# KALGOORLIE

## 1:250 000 SHEET

## WESTERN AUSTRALIA

SECOND EDITION

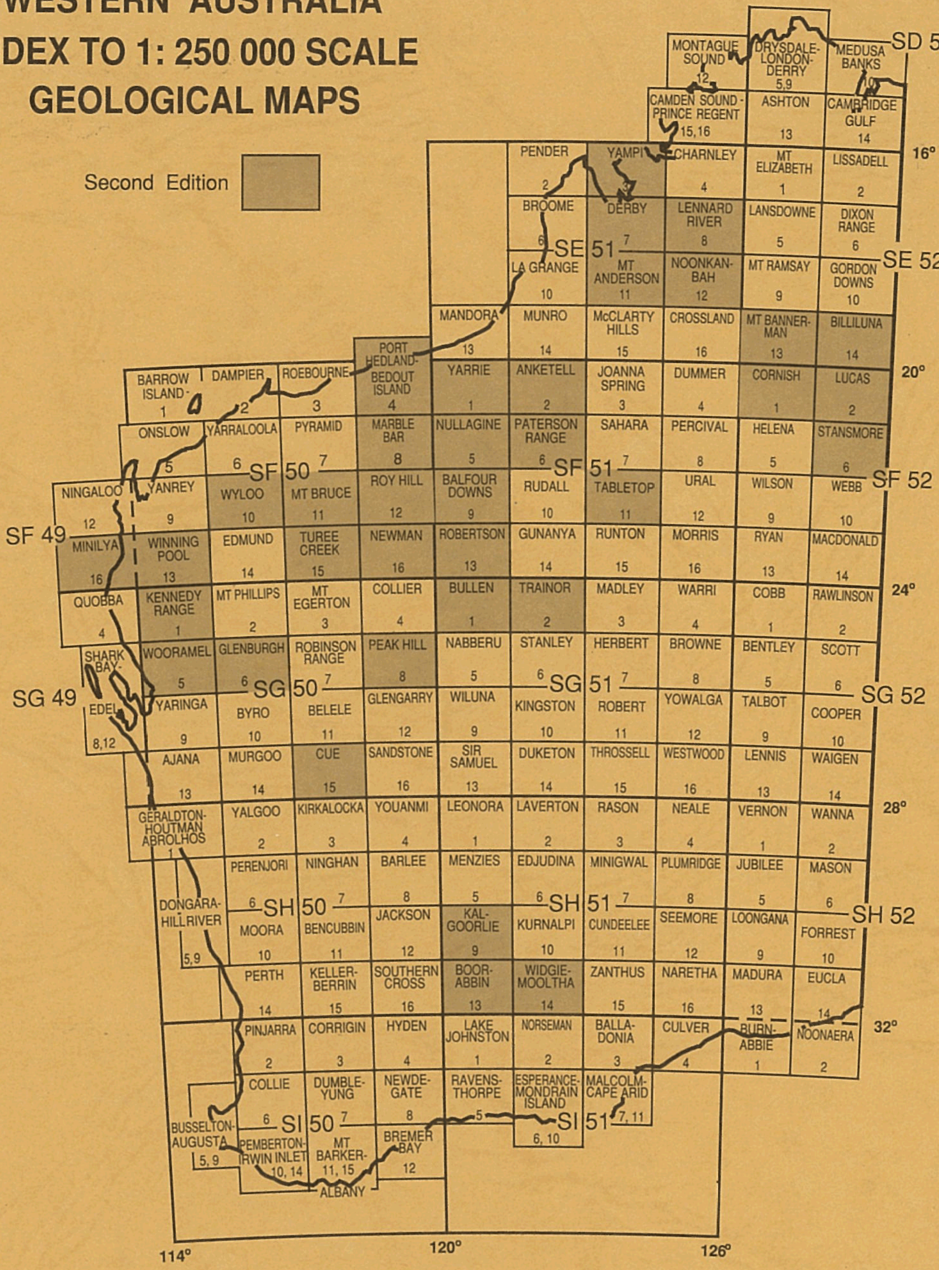
SHEET SH 51-9 INTERNATIONAL INDEX

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

DEPARTMENT OF MINERALS AND ENERGY

# WESTERN AUSTRALIA
# INDEX TO 1: 250 000 SCALE
# GEOLOGICAL MAPS

Second Edition

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GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
1:250 000 GEOLOGICAL SERIES—EXPLANATORY NOTES

# KALGOORLIE

## WESTERN AUSTRALIA

**SECOND EDITION**

**SH 51–9 INTERNATIONAL INDEX**

by

S. WYCHE

Perth, Western Australia 1998

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*by S. Wyche*

## INTRODUCTION

The KALGOORLIE* 1:250 000 sheet (SH 51-9) is bounded by latitudes 30°00'S and 31°00'S and longitudes 120°00'E and 121°30'E.

The City of Kalgoorlie–Boulder (population of about 26 000), near the eastern boundary of the sheet, has been a major gold-mining centre for more than 100 years. KALGOORLIE is traversed by the Great Eastern Highway and Goldfields Water Supply Pipeline in the southeast and the Kalgoorlie–Meekatharra Highway and Kalgoorlie–Leonora Railway in the east. The Perth–Kalgoorlie Railway crosses the southern part of KALGOORLIE, and the Kalgoorlie–Esperance Railway extends southward from Kalgoorlie. The town of Coolgardie lies about 38 km southwest of Kalgoorlie, and there are settlements at Ora Banda, Broad Arrow, Bullabulling, and Kurrawang. Credo, Carbine, Mount Burges, Mungari, and Bardoc are occupied homesteads. The Department of Conservation and Land Management has established an outstation at Timberfield in the west. The Mount Walton Toxic Waste Disposal Facility is located about 20 km northeast of Mount Walton.

There are numerous active and abandoned mining areas in the eastern half of KALGOORLIE, and greenstones in this area are readily accessible along formed roads or exploration and station tracks. Greenstones between Mount Walter and Mount Walton in the west can be reached from Boorabbin, via the Great Eastern Highway south of KALGOORLIE, or from Bullabulling, via the railway access road. Those in the northwest can be approached via the Menzies–Diemals road to the north or Timberfield to the south.

### PREVIOUS INVESTIGATIONS

The first edition of the Kalgoorlie 1:250 000 geological map was published in 1968, and early geological investigations are listed in the accompanying Explanatory Notes (Kriewaldt, 1969). The four 1:100 000 geological maps that cover the eastern two-thirds of KALGOORLIE — DUNNSVILLE (Swager, 1994), DAVYHURST (Wyche and Witt, 1994), KALGOORLIE (Hunter, 1993), and BARDOC (Witt, 1994) — have been published by the Geological Survey of Western Australia (GSWA). These maps and their associated Explanatory Notes were used extensively in the preparation of the second edition of the Kalgoorlie 1:250 000 geological map.

Contoured aeromagnetic maps, derived from surveys flown with a 200-m line spacing, covering KALGOORLIE (1:100 000 — Geological Survey of Western Australia, 1993c), BARDOC (Geological Survey of Western Australia, 1996), and parts of DAVYHURST and DUNNSVILLE

* Capitalized names refer to standard map sheets. Where 1:100 000 and 1:250 000 sheets have the same name, the 1:250 000 sheet is implied unless otherwise indicated.

(Geological Survey of Western Australia, 1993a,b) have been released. Results of the deep crustal seismic traverse (Goleby et al., 1993; Swager et al., 1997), carried out by the Australian Geological Survey Organisation (AGSO) in 1991, have been used to generate the geological cross section on the Kalgoorlie 1:250 000 geological map.

There has been intensive exploration for both gold and nickel, particularly in the eastern part of KALGOORLIE. Company reports, including unpublished maps and exploration data, are available for examination through the GSWA WAMEX open-file system. There are also numerous studies of individual gold deposits in the region (see **ECONOMIC GEOLOGY** section).

## PHYSIOGRAPHY, CLIMATE, AND VEGETATION

KALGOORLIE lies within a broad region of generally very low relief (Fig. 1) in which greenstone belts form low, rocky ridges (usually less than 50 m above surrounding plains). The western part of KALGOORLIE comprises mainly sandplain over lateritic duricrust, scattered pavements and tors of granite, and two poorly exposed, deeply weathered greenstone belts marked by resistant banded iron-formation (BIF) ridges. The eastern part is more dissected, with regionally extensive greenstone belts forming the most prominent topographic features. The extensive areas of salt lakes in the east and northwest form part of the east-flowing Roe Palaeodrainage system (Hocking and Cockbain, 1990), while the Lake Walton system in the southwest lies to the west of a major palaeodrainage divide (the Swan–Avon Basin boundary) in a west-flowing regime (Ollier et al., 1988; Chan et al., 1992). Jaurdi Hill, northwest of Coolgardie, has the highest elevation (570 m), while the lowest elevations (less than 350 m) are found in the salt-lake systems in the southeast.

According to the regolith terrain classification of Chan et al. (1992), the western part of KALGOORLIE lies mainly within deep-weathering-dominated terrains, while the eastern part lies mainly within sediment-dominated and bedrock-dominated terrains.

The region has a semi-arid climate. Kalgoorlie–Boulder, in the southeastern part of the sheet, has an average annual rainfall of about 250 mm with an average of about 60 wet days per year. Although rainfall is fairly evenly distributed throughout the year, summer rain tends to be more episodic than winter rain. Temperatures commonly exceed 40°C in the hottest months (December–March) and there are occasional frosts in the coldest months (June–August).

KALGOORLIE lies mainly within the Coolgardie Botanical District of Beard (1990). This district marks a transition between the Roe Botanical District to the south, dominated by *Eucalypt* species, and the Austin Botanical District to the north, dominated by *Acacia* species. Over most of KALGOORLIE there is a range of woodland and shrubland assemblages including a wide variety of *Eucalypt*, *Acacia*, *Grevillea*, *Casuarina*, and *Melaleuca* species. The transition to the Austin Botanical District in the northeastern part of KALGOORLIE can be seen on the highway north of Kalgoorlie, near Goongarrie, where there is an abrupt change to mulga-dominated low woodland. Trees are typically larger and more abundant in the vicinity of greenstone belts, where soils are heavier and less depleted than they are over granite.

## NOMENCLATURE

All Archaean rocks described in these notes have been subjected to low- to medium-grade metamorphism, but for ease of description the prefix 'meta' is omitted.

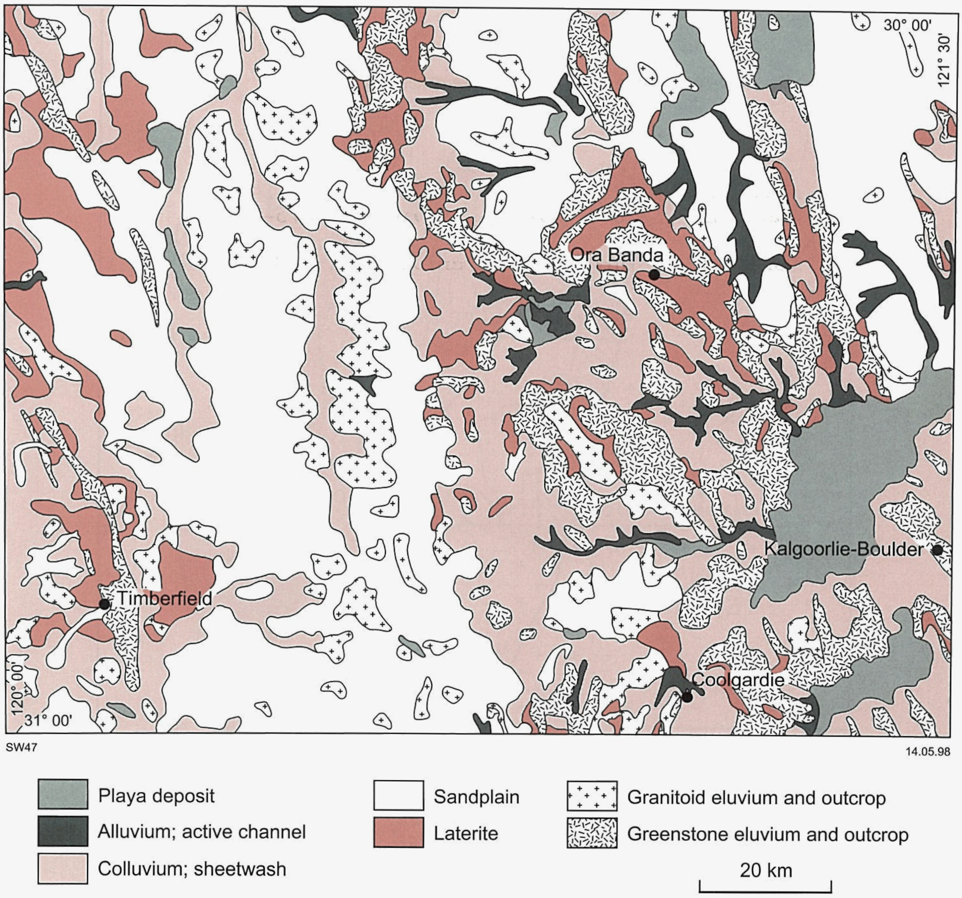


**Figure 1. Physiography and Cainozoic geology of KALGOORLIE**

# PRECAMBRIAN GEOLOGY

Gee et al. (1981) subdivided the Yilgarn Craton into the Western Gneiss Terrane and the Murchison, Southern Cross, and Eastern Goldfields Provinces. More recently, Myers (1990) and Swager et al. (1995) have proposed a number of tectono-stratigraphic terranes bounded by major shear zones (Fig. 2). The eastern half of KALGOORLIE lies mainly within the Kalgoorlie Terrane but incorporates a small part of the adjacent Gindalbie Terrane (Ahmat, 1993; Swager, 1995, 1997) in the northeast. The western third lies entirely within the Barlee Terrane (Myers, 1990; Wyche and Witt, 1994; Swager, 1995, 1997). The Kalgoorlie Terrane is separated from the adjacent Gindalbie Terrane to the east by the Mount Monger Fault and from the Barlee Terrane to the west by the Ida Fault.

U–Pb isotope studies of zircons, using Sensitive High-Resolution Ion Microprobe (SHRIMP) analyses, indicate an age of greenstone deposition of about 2.7 Ga for the Kalgoorlie Terrane. Most data come from the Kambalda and Ora Banda Domains. Some sequences in the Barlee Terrane may be significantly older (Nelson, 1997).

Swager (1989), Swager and Griffin (1990), and Swager et al. (1995) have described four phases of deformation in the Kalgoorlie Terrane. First-deformation-event ($D_1$) early

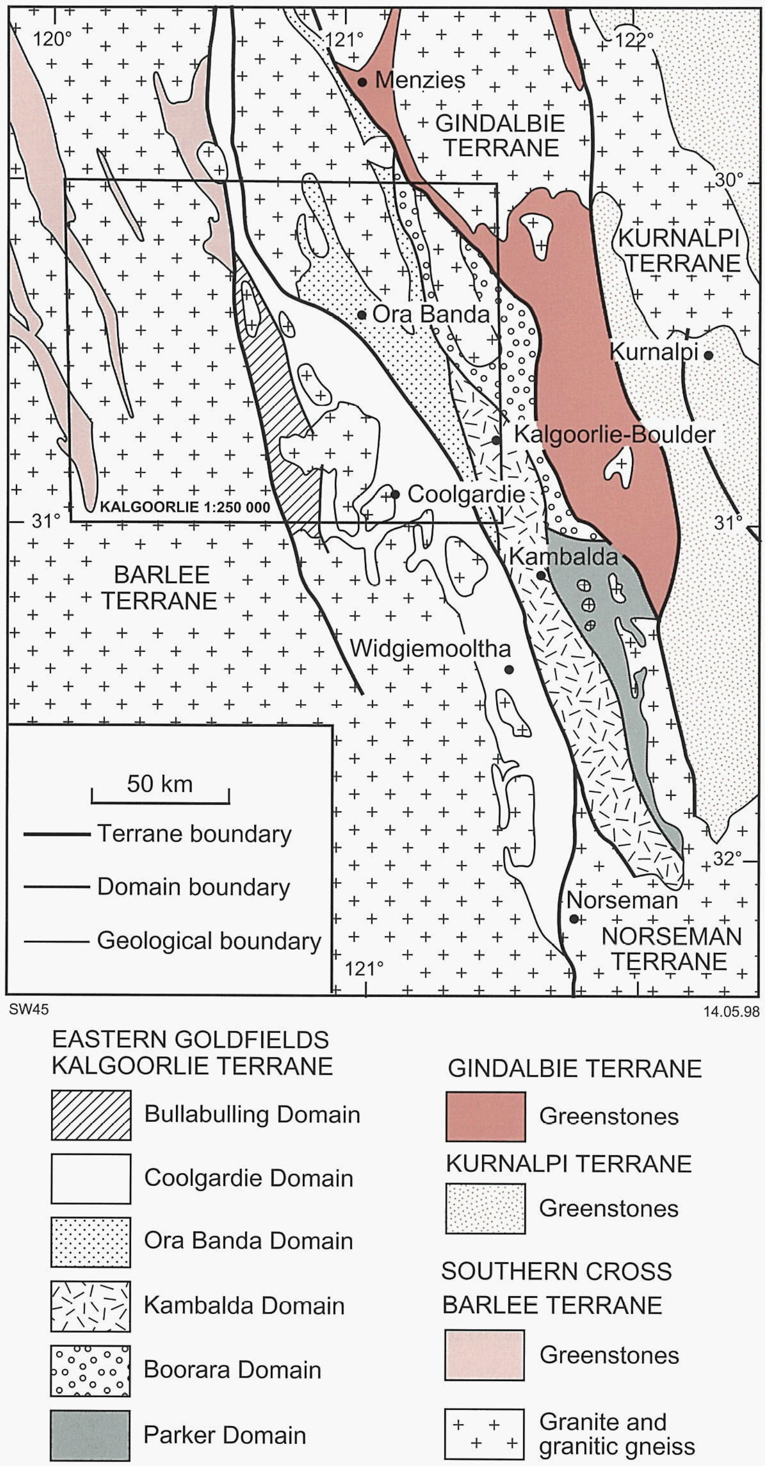


**Figure 2.** **Regional geological setting of KALGOORLIE (modified from Swager et al., 1997)**

thrusting and recumbent folding has been best documented between Kalgoorlie and Kambalda. The most readily recognizable structures are $D_2$ upright folds and $D_3$ transcurrent or transpressional faults. These features were developed in a major east–west compressional regime. Continued east–west shortening produced typically small-scale, oblique, north-trending dextral and reverse $D_4$ faults. Hammond and Nisbet (1992) and Williams and Whitaker (1993) proposed an earlier regional extensional event in the northern Eastern Goldfields based on movement directions on shear zones and metamorphic patterns and structures around granitoid domes, but evidence of this event is not readily observable on KALGOORLIE. Williams (1993) proposed a second major extensional event between $D_1$ and $D_2$ based on data generated by the 1991 AGSO deep crustal seismic traverse (Goleby et al., 1993; Swager et al., 1997). Witt and Swager (1989) described several phases of granitoid intrusion between Bardoc and Coolgardie.

All Archaean rocks, with the possible exception of some granitoid rocks and some ?late Archaean easterly oriented dykes, have been metamorphosed — at greenschist facies in the east and greenschist and amphibolite facies in the west. Metamorphic grade is typically higher close to contacts with granitoid rocks. Most granitoid rocks were emplaced before or during regional metamorphism and have been texturally or mineralogically modified (Witt and Davy, 1997a).

## STRATIGRAPHY

### Kalgoorlie Terrane

The first edition of 1:250 000 mapping by GSWA recognized the Norseman–Wiluna Belt — a wide, linear suite of rocks within the Eastern Goldfields Province characterized by differences in lithological associations, stratigraphy, and structural style from that of greenstones in adjacent areas to the east and west (Williams, 1974).

Woodall (1965) established a stratigraphy for the Kalgoorlie–Boulder area. Subsequent detailed mapping by mining companies in the Kambalda and Kalgoorlie regions (Travis et al. 1971; Ross and Hopkins, 1975; Gresham and Loftus-Hills, 1981; Langsford, 1989) demonstrated that sequences can be correlated between the two areas. Williams (1970) proposed a regional stratigraphy, which included three volcano-sedimentary cycles. However, the cycles were subsequently reinterpreted, in terms of early recumbent folding and thrusting of greenstone sequences, by Archibald et al. (1981), Archibald (1990), and Swager and Griffin (1990). Keats (1987) and Swager et al. (1995) defined a simple, single-cycle stratigraphy for the Kalgoorlie Terrane.

The southern part of the Kalgoorlie Terrane (i.e. south of Lake Ballard near Menzies) has been subdivided into four major domains — the Ora Banda, Kambalda, Coolgardie, and Boorara Domains — and two smaller, less well-defined domains — the Bullabulling and Parker Domains (Swager et al. 1995). All but the Parker Domain are represented on KALGOORLIE (Fig. 2). Domains are separated by shear zones, which include dismembered and attenuated elements of the stratigraphy.

The generalized stratigraphy consists of a lower basalt unit, a komatiite unit, a variously developed upper basalt unit, and a unit of felsic volcanic and sedimentary rocks, all unconformably overlain locally by a unit of poorly sorted sandstone and conglomerate (Table 1). The upper basalt unit is thin or only poorly developed in the Coolgardie and Boorara Domains. Although they contain the same components, the Bullabulling and Parker Domains are not well exposed and their stratigraphies are not sufficiently well known to allow them to be directly correlated with the other domains.

**Table 1. Stratigraphy of the Kalgoorlie Terrane on KALGOORLIE**

| *Stratigraphic succession* | *Characteristic rock types* | *Ora Banda domain* | *Kambalda domain* | *Coolgardie domain* | *Boorara domain* | *Bullabulling domain* |
|---|---|---|---|---|---|---|
| Polymictic conglomerate unit | Polymictic conglomerate; coarse trough cross-beds, graded beds | Kurrawang Formation | Merougil Conglomerate (not exposed on KALGOORLIE) | Absent | Absent | Absent |
| Felsic volcanic and sedimentary unit | Rhyolite to andesite lava, tuff, volcanic breccia. Felsic volcaniclastic sedimentary rocks ranging from coarse clastic sandstone to interbedded sandstone and siltstone | **Black Flag Group**<br>Pipeline Andesite<br>Orinda Sill<br>Ora Banda Sill | **Black Flag Group**<br>Golden Mile Dolerite | **Black Flag Group**<br>Powder Sill | Felsic volcanic and sedimentary rocks | Felsic volcanic and sedimentary rocks |
| Upper basalt unit | Komatiitic and tholeiitic basalt | **Grants Patch Group**<br>Victorious Basalt<br>Bent Tree Basalt<br>Mount Pleasant Sill<br>Mount Ellis Sill | **Kalgoorlie Group**<br>Paringa Basalt<br>Williamstown Dolerite | Absent or thin and discontinuous | Absent or thin and discontinuous | No established stratigraphy |
| Komatiite unit | Thin komatiitic basalt at top. Thin komatiitic flows with minor interflow sedimentary beds overlying thicker komatiitic flows and/or massive olivine adcumulate | **Linger and Die Group**<br>Big Dick Basalt<br>Siberia Komatiite<br>Walter Williams Formation | Kapai Slate<br>Devon Consols Basalt<br>Kambalda Komatiite | Komatiite and komatiitic basalt; minor peridotite | Big Blow Chert<br>Highway Ultramafics | No established stratigraphy |
| Lower basalt unit | Tholeiitic and komatiitic basalt flows | **Pole Group**<br>Missouri Basalt<br>Wongi Basalt | Lunnon Basalt | Three Mile Sill | Scotia Basalt | No established stratigraphy |
| References | | Witt (1994), Swager et al. (1995) | Swager and Griffin (1990) | Hunter (1993) | Christie (1975), Witt (1994) | Swager et al. (1995), Wyche and Witt (1994) |

The poor exposure and probable structural thickening of many units make it difficult to estimate thicknesses of units in the Kalgoorlie Terrane.

The sequence has been intruded by a number of mafic sills. These bodies pre-date the earliest deformation of the greenstones, and some of them may be comagmatic with the mafic volcanism.

### Barlee Terrane

The Barlee Terrane includes much of what has been called the Southern Cross Province (Gee et al., 1981; Griffin, 1990). It contains a widely developed lower greenstone sequence and a more locally developed upper sequence of sedimentary rocks and felsic and intermediate igneous rocks. The lower sequence is exposed in numerous greenstone belts, which vary in stratigraphic detail but have a number of common elements including abundant chert and BIF. The lower sequence typically contains thick mafic volcanic and intrusive sequences in which rocks of tholeiitic composition constitute a much greater proportion than komatiitic varieties. Some belts have clastic sedimentary rocks and intermediate to acid volcanic and volcaniclastic rocks at various levels. A unit of quartzite and pebbly quartz sandstone is developed locally along granite–greenstone contacts. No formal stratigraphy has been proposed for this sequence.

West of KALGOORLIE, on JACKSON (Chin and Smith, 1983) and BARLEE (Walker and Blight, 1983), the main greenstone sequence is unconformably overlain by clastic sedimentary rocks of the Diemals Formation and felsic and intermediate extrusive rocks of the Marda Complex (Hallberg et al., 1976).

Only the lower sequence of the Barlee Terrane is represented on KALGOORLIE — in two greenstone belts in the western part of the sheet area and in an east-dipping sequence, west of Callion, containing BIF, chert, and shale with intercalated mafic rocks.

A poorly exposed greenstone belt extends in a south-southeasterly direction from Curara Soak in the northwest for a distance of over 50 km. It comprises banded chert and BIF with intercalated mafic and ultramafic rocks, mainly consisting of basalt, dolerite, and tremolite–chlorite schist. Away from the BIF and chert ridges, the belt is dominated by basalts, dolerites, and amphibolites of tholeiitic composition. No indications of a younging direction for this sequence have been found.

A wider and better-exposed greenstone belt extends for more than 50 km, from near Mount Walton in the central western part of KALGOORLIE, south-southeast to Mount Walter. Younging direction in this belt has not been determined. The sequence comprises, from east to west, chert, BIF, and intercalated mafic and ultramafic rocks, followed by a thick sequence of mainly tholeiitic basalt with subordinate basaltic andesite, chert, BIF, and clastic sedimentary rocks. A unit of peridotite on the western side of the belt, west of the Watt Hills, may be intrusive.

Regional aeromagnetic surveys suggest that there may be a concealed greenstone belt in the northwest between Curara Soak and Callion.

### Gindalbie Terrane

Although the Gindalbie Terrane contains a range of rock types similar to that of the Kalgoorlie Terrane, it has a more complicated stratigraphy in that it contains a calc-alkaline succession low in the sequence (Ahmat, 1993; Swager, 1995). It is represented in the northwestern part of KALGOORLIE by a small area of mafic rocks north of Ringlock Dam.

### Granitoid rocks

Granitoid rocks on KALGOORLIE vary from tonalite to syenogranite in composition, with most in the monzogranite to granodiorite range (Witt and Davy, 1997a,b). The structural subdivision used on KALGOORLIE is based on Witt and Swager (1989), who described the structural setting and geochemistry of granitoid rocks in the eastern part of the sheet area and identified three groups, based mainly on relationships with regional structures in the greenstones: pre-$D_2$ to syn-$D_2$ 'domal' granitoid rocks, post-$D_2$ to syn-$D_3$ granitoid rocks, and late tectonic granitoid rocks.

## ARCHAEAN ROCK TYPES

### Bardoc Tectonic Zone (*Atb*)

The Bardoc Tectonic Zone is a strongly deformed and interleaved package of various rock types between Paddington and Bardoc (Witt, 1994). It includes shale and acid to intermediate volcaniclastic rocks interleaved with mafic and ultramafic volcanic rocks and minor cherty interflow sedimentary rocks. Most of the interleaving results from deformation, and geological contacts and interflow sedimentary units are commonly planes of shearing. There has been extensive carbonation, particularly of mafic and ultramafic rocks. Most rock types are deeply weathered.

### Ultramafic rocks (*Au, Auk, Aup*)

Ultramafic rocks are found in all greenstone belts on KALGOORLIE but are most abundant in the Kalgoorlie Terrane, where they form a regionally extensive unit (Swager et al., 1995). This unit contains a number of components, including intervals of well-differentiated, spinifex-textured komatiite flows and lenticular and sheet-like bodies of olivine cumulates with little or no associated olivine spinifex-textured rocks. The ultramafic rocks have been assigned to various formations in different domains within the Kalgoorlie Terrane (Table 1). Hill et al. (1990) have interpreted the components as representing different facies within a regionally extensive unit that resulted from the eruption of large volumes of very hot, low viscosity lava in broad rivers and sheets across a substrate of felsic and mafic rocks.

All ultramafic rocks have been metamorphosed and many have been further altered, either by weathering or metasomatism. As magnetite is a common accessory mineral, the ultramafic rocks commonly correspond to magnetic highs on aeromagnetic maps. Morris et al. (1991) present the whole-rock geochemistry for mafic and ultramafic rocks from throughout the eastern Yilgarn Craton, and Morris (1993) describes their physical volcanology and geochemistry.

Undivided ultramafic rocks (*Au*) are mainly schistose. Varieties include tremolite(–chlorite) schist and talc–carbonate(–chlorite–tremolite) schist. Some tremolite schists contain small amounts of plagioclase and may be derived from komatiitic basalt. This basalt is typically associated with komatiite in ultramafic sequences. Undivided ultramafic rocks have been mapped mainly in the western part of the Kalgoorlie Terrane, between the Zuleika Shear and Ida Fault (Fig. 3), and are locally intercalated with chert and BIF in the west and northwest.

The term 'komatiite' here refers to ultramafic rocks with relict platy olivine spinifex textures. Arndt and Nisbet (1982) used the term more broadly to describe ultrabasic extrusive rocks with more than 18% MgO. Komatiite with relict olivine spinifex textures (*Auk*) forms thick

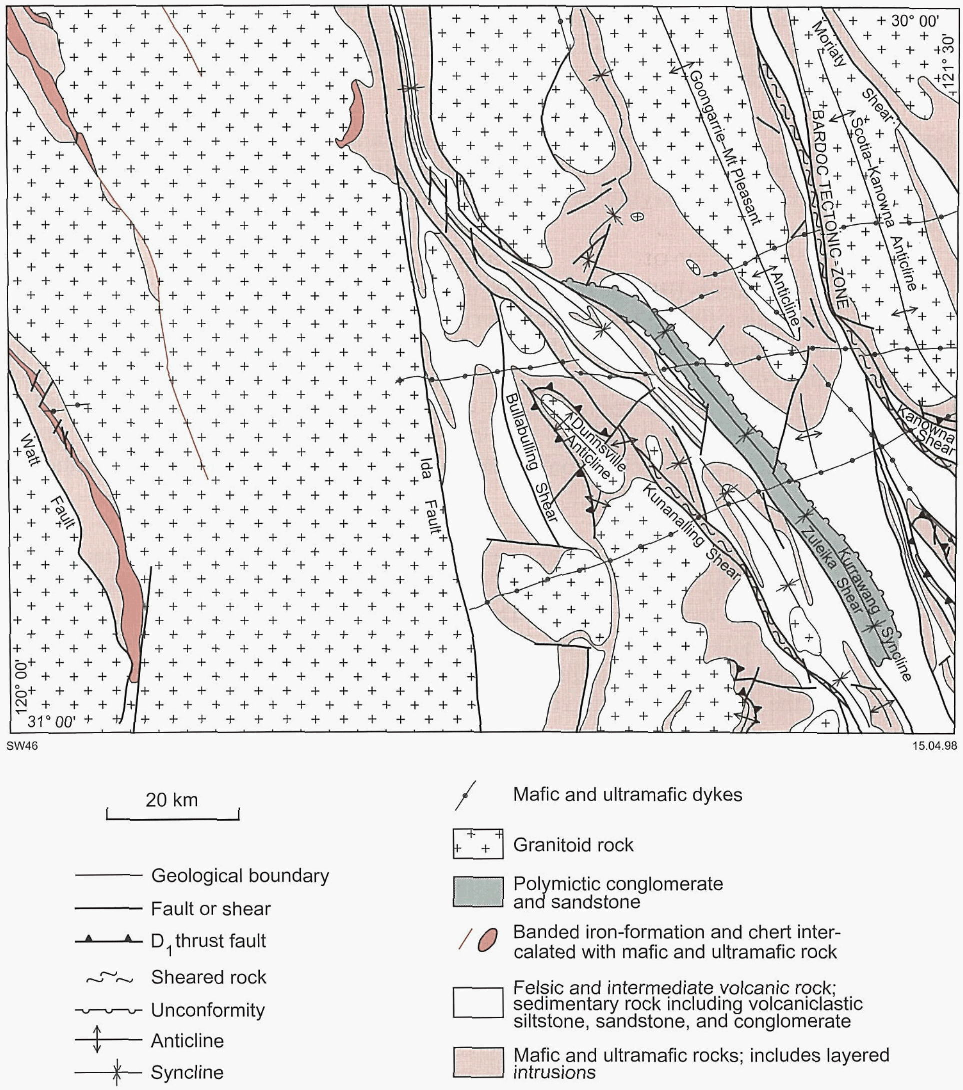


**Figure 3. Simplified geological sketch map of Kalgoorlie**

units in the eastern part of Kalgoorlie. In the Ora Banda Domain, the komatiite unit has been assigned to the Siberia Komatiite; in the Kambalda Domain, to the Kambalda Komatiite; and in the Coolgardie Domain, to the Hampton Formation (Swager et al., 1995). These rocks represent ultramafic flow units. Complete sections may contain material with relict cumulate textures, mainly orthocumulate, in the lower parts of individual peridotitic flows, and relict spinifex textures ranging from fine platy to very coarse bladed in the upper parts (Hill et al., 1990).

All komatiites have been metamorphosed, and those subjected to low-grade regional metamorphism are serpentinized. At higher metamorphic grades, tremolite is the main mineral species. Chlorite is stable over a wide range of metamorphic conditions and can be present in both serpentine- and tremolite-rich ultramafic rocks. Magnetite is a common accessory mineral. There have been episodes of profound carbonation resulting in areas of talc–carbonate alteration, such as east of Grants Patch, south of Vettersburg, and in the Hampton area east of Coolgardie.

Where komatiites are not deformed, relict igneous spinifex and cumulate textures can be preserved either by metamorphic minerals pseudomorphing igneous olivine or, at higher metamorphic grades, by having primary textures outlined by fine-grained trains of magnetite.

Peridotite (*Aup*) represents massive ultramafic units in which orthocumulate, mesocumulate, and adcumulate grains (0.1–3 cm in diameter) are pseudomorphed by serpentine. Where there has been a glassy matrix, it is altered to a fine-grained mass of tremolite, chlorite, serpentine, and magnetite. Some igneous olivine may be preserved at very low metamorphic grades. Metamorphic olivine can form in cumulates metamorphosed at amphibolite facies (Hill et al., 1990). Cumulate textures are most readily seen in the ferruginous silica caprock that commonly forms above the peridotite during the weathering process.

Preserved cumulate textures are most abundant in the Walter Williams Formation (Hill et al., 1990) — a regionally extensive unit that forms the lower part of the regional komatiite unit in the Ora Banda Domain (Table 1). The Walter Williams Formation is exposed over a wide area in the Siberia district and locally on the eastern and western limbs of the Goongarrie – Mount Pleasant Anticline. Hill et al. (1990) have interpreted the formation as representing the eruption of large volumes of komatiitic lava onto an extensive basaltic substrate.

Peridotite is present locally in the ultramafic units between Chadwin and Davyhurst and around the Dunnsville dome. Within the greenstone belt west of the Watt Hills, a large peridotite body outcrops near the western contact with granitoid rocks and contains olivine orthocumulate and mesocumulate that have been pseudomorphed by serpentine. Other lenses of peridotite with cumulate textures are associated with the basalt and BIF sequence in this greenstone belt.

### Basalt and amphibolite (*Ab, Abm, Abp, Ama*)

Mafic extrusive rocks make up a large part of the greenstone sequences. Although tholeiitic and komatiitic varieties are present, they are difficult to distinguish in the field where textures have not been preserved or are too fine grained to be easily seen in hand specimen. The whole-rock geochemistry for mafic and ultramafic rocks of the eastern Yilgarn Craton are presented by Morris et al. (1991), and their physical volcanology and geochemistry is described by Morris (1993).

Massive, fine- to medium-grained mafic rocks (*Ab*) have not been subdivided. They are mainly extrusive tholeiitic basalts but may include subordinate intercalations of komatiitic basalt. Tholeiitic basalt typically contains roughly equal amounts of calcic amphibole and plagioclase with or without accessory titanite, epidote, and opaque minerals. Quartz-filled amygdales are present locally and are characteristic of the upper part of the Missouri Basalt. Pillow structures have been reported (Petersen, 1987) but are not widely recognized, probably because the rocks are often poorly exposed. The strong deformation in some areas may also mask such structures. Local occurrences of skeletal plagioclase in discrete, thin basalt units may represent quench textures. Tholeiitic basalt may be feldspar-phyric, with fine- to medium-grained plagioclase phenocrysts, such as in the western part of the

Bullabulling Terrane and at the top of the Missouri Basalt near Wongi Hill. Coarsely plagioclase-phyric basalt has been mapped separately (see *Abp* below).

Tholeiitic basalt is present at two levels in the Ora Banda Domain sequence: the Missouri Basalt at the top of the lower basalt unit and the Bent Tree Basalt at the base of the upper basalt unit (Table 1).

Komatiitic basalt (*Abm*), also called 'high-magnesium basalt', includes basalt with relict pyroxene-spinifex textures and/or variolitic textures or rocks that have been chemically analysed with more than 10% MgO. Such rocks typically contain between 10 and 18% MgO (Cas and Wright, 1987). Grey to pale-green tremolite–actinolite is the main constituent mineral, and there may be up to about 30% plagioclase with accessory opaque oxides — typically magnetite. Chlorite may be present in areas of low-grade metamorphism. These rocks commonly contain relict pyroxene-spinifex textures in which tremolite–actinolite pseudomorphs acicular clinopyroxene. Individual pseudomorphed 'needles' can range in length from a few millimetres up to several centimetres, and clusters of pseudomorphs can assume skeletal, dendritic, arborescent, and fan-like forms.

Variolitic basalts typically consist of a fine, felted groundmass of acicular amphibole and subordinate (up to 30%) very finely recrystallized plagioclase(–chlorite), with abundant pale, spherical to ovoid cryptocrystalline varioles ranging in diameter from 1 mm to greater than 1 cm. Varioles are mineralogically similar to the groundmass in which they formed but contain a greater proportion of plagioclase. Variolitic textures are usually, but not universally, indicative of elevated MgO content.

Pillow structures are common in komatiitic basalt (e.g. in a road cutting north of the Bonnie Vale mining centre), but they are rarely well exposed in outcrop and often masked by the deformation.

Komatiitic basalt is present at two levels in the Ora Banda sequence: the Wongi Basalt at the base of the sequence and the Big Dick Basalt at the top of the komatiite unit, immediately above the Siberia Komatiite (Table 1).

Coarsely plagioclase-phyric basalt (*Abp*) is a very distinctive rock type, known locally as 'cat rock' by early prospectors because its appearance is reminiscent of the spotted coat of a native marsupial. It consists of very coarse (up to 3 cm) tabular phenocrysts of plagioclase, locally in glomeroporphyritic clusters, in a matrix of fine- to medium-grained hornblende and plagioclase. Pillow structures have been noted in openpits near Ora Banda and Grants Patch by Witt (1994), southwest of Black Flag where the basalt appears to have intruded wet volcaniclastic sediments, and south of Coolgardie (Hunter, 1993).

Coarsely plagioclase-phyric basalt forms a distinctive unit up to 2 km thick, named the Victorious Basalt (Witt, 1994), at top of the upper basalt in the Ora Banda Domain sequence. Similar basalt south of Coolgardie, named the Burbanks Formation (Hunter, 1993), is interpreted to lie within the lower basalt unit of the Kalgoorlie Terrane sequence.

Amphibolite (*Ama*) appears on the map where mafic rocks are completely recrystallized and no vestiges of primary textures or structures remain. Prismatic amphibole and fine, polygonal granoblastic plagioclase, which shows little or no twinning, are the main constituents. Clinopyroxene is present locally. Compositional variations are reflected by different proportions of plagioclase to amphibole. These rocks commonly show a well-developed metamorphic foliation. They are abundant in the western part of the Kalgoorlie Terrane and near granite contacts.

**Dolerite and gabbro (*Ao, Aog, Aogo, Aogr, Aogp, Aoge, Aogw, Aogt*)**

Medium- to coarse-grained mafic rocks (*Ao*) with relict igneous textures form layers and lenses in basalts throughout the greenstone sequences. They are similar in composition to their finer grained hosts and may represent either intrusions or coarse intervals in thick flows. Unusual gabbroic rocks in the lower part of the Siberia Komatiite northeast of Ora Banda may result from extreme fractionation of a komatiitic magma (Witt, 1994).

Coarse-grained mafic rocks (*Aog*) are clearly intrusive gabbroic sills, which intrude the sequence at various levels. They include the smaller and poorly exposed intrusions in the Kalgoorlie–Boulder area and various unnamed sills within the greenstone sequence. The Golden Mile Dolerite is a differentiated gabbroic sill (Travis et al., 1971), which is the main host to gold mineralization on the Golden Mile. It outcrops only around Kalgoorlie–Boulder, where it is associated with a number of smaller sills, such as the Williamstown Dolerite (Keats, 1987; Clout et al., 1990).

Although the sills intrude the greenstone sequences, they all pre-date the earliest deformation event and may be coeval with at least some of the mafic volcanism. The parent magmas are generally regarded as having had a similar petrogenetic history to compositionally equivalent volcanic rocks (Witt, 1995). They are broadly conformable with the greenstone stratigraphy but may be locally transgressive. Many of the sills show clear igneous differentiation trends and can be useful indicators of younging directions.

The larger, named sills have been labelled separately and are described below.

The Orinda Sill (*Aogo*) is the uppermost sill mapped in the Ora Banda sequence. It intrudes the Black Flag Group on the southern side of the Black Range, south of Ora Banda. It has not been studied in detail but is differentiated, with hypersthene-bearing gabbronorite in the lower part and medium-grained quartz gabbro in the upper part (Witt, 1994).

The Ora Banda Sill (*Aogr*) is a large, layered mafic and ultramafic sill (Williams and Hallberg, 1973; Witt, 1994) that extends in outcrop from southwest of Mount Carnage, southeast to Grants Patch. It intrudes the Black Flag Group and forms the prominent Black Range. Witt (1994) described six zones in the Ora Banda Sill. Zone 1 at the base is a typically poorly exposed, medium-grained, orthocumulate-textured peridotite, which can be greater than 800 m thick. This is overlain by zone 2 — a poorly exposed unit of medium-grained orthopyroxene (bronzite) adcumulate, about 150–250 m thick. Zone 3 is a 100-m thick unit of adcumulate-textured norite, and zone 4 consists of several hundred metres of gabbronorite cumulate with small, irregular patches of anorthosite. Zone 5 is similar to zone 4, but orthopyroxene is present only as inverted pigeonite and rocks contain intercumulus quartz and biotite. The uppermost part of the intrusion, zone 6, contains abundant pegmatoid segregations characterized by coarse muscovite and quartz. Gabbroic rocks towards the top of the sill have a distinctly bimodal grain-size distribution. There is a thin layer of quartz–feldspar granophyre immediately below the roof of the intrusion. The Ora Banda Sill has a Sm–Nd age of 2762 ± 32 Ma (Chauvel et al., 1985).

The Mount Pleasant Sill (*Aogp*) is a layered mafic–ultramafic sill that intrudes the Bent Tree Basalt and forms prominent outcrops over a strike length of more than 70 km, from New Mexico, along the western limb and around the hinge of the Goongarrie – Mount Pleasant Anticline, to Vettersburg on the eastern limb. Gabbroic rocks further north, near Goongarrie, may also be part of this intrusion. Witt (1994) and Witt et al. (1991) have described in detail 12 zones that can be recognized in the sill. In summary, these include a zone of melanocratic microgabbro at the base, overlain by an ultramafic layer that includes zones of olivine orthocumulate and pyroxenite. A gabbronorite layer contains

3 zones with different mineral ratios. The uppermost of these zones is characterized by mafic patches of matted tremolite–actinolite–chlorite–epidote, which are interpreted as relicts after glomeroporphyritic accumulations of orthopyroxene phenocrysts. The gabbronorite is overlain by the lower gabbro layer. The overlying granophyre layer contains ilmenite-rich quartz ferrogabbro in which quartz forms as granophyric intergrowth with albite. The top of the sill is marked by the upper gabbro layer. Kent and McDougall (1995) reported a SHRIMP U–Pb zircon age, determined by I. H. Campbell, of 2687 ± 5 Ma for the Mount Pleasant Sill.

The Mount Ellis Sill (*Aoge*) is a layered mafic sill that intrudes the lower part of the Bent Tree Basalt at or near its contact with the Big Dick Basalt. It outcrops around the hinge of the Goongarrie – Mount Pleasant Anticline, with the best exposures west of Broad Arrow at Mount Ellis. Witt (1994) described four zones in the Mount Ellis Sill. The lowermost zone, zone 1, consists of olivine gabbro and gabbronorite. Zone 2 is a gabbro with clinopyroxene phenocrysts in a finer grained, leucogabbroic groundmass; it is generally a massive rock, with local igneous layering defined by variations in grain size and the relative proportions of phenocrysts to groundmass. Zone 3 is a more melanocratic gabbro and quartz gabbro, with characteristic segregations in the form of large (up to several metres across) patches of granophyre. Zone 4, at the top of the sill, consists of porphyritic dolerite with coarse porphyroclasts of tremolite–actinolite after clinopyroxene.

The Powder Sill (*Aogw*) is a layered mafic sill that intrudes the Black Flag Group. It is exposed in a large syncline between Kundana and Kunanalling. Hunter (1993) described two main phases, which have their best development at the northern end of the exposure where the sill is thickest. The two phases comprise a lower portion of gabbro and hypersthene gabbro and an upper portion of leucocratic quartz gabbro with irregular patches of granophyre.

The Three Mile Sill (*Aogt*) is a layered mafic sill that intrudes a basalt sequence north and south of Coolgardie. It has not been studied in detail, but a section near the Sydenham gold mine shows distinct igneous layering from pyroxenite at the base, up through gabbro, to porphyritic leucogabbro (locally glomeroporphyritic) with coarse clinopyroxene phenocrysts. This unit is overlain by gabbro, then quartz gabbro, followed by a thin unit of more-mafic gabbro at the top.

## Intermediate rocks (*Aiv*)

Intermediate volcanic and volcaniclastic rocks (*Aiv*) are observed mainly in the felsic volcanic and sedimentary unit of the Kalgoorlie Terrane sequence, although analyses have demonstrated the presence of calc-alkalic andesite in the Victorious Basalt in the Ora Banda Domain (Morris, 1993) and within the basalt sequence in the upper part of the western greenstone belt north of Mount Walter.

The most extensive exposures of intermediate rocks are west of White Flag Lake (Morris, in prep.), where they form the uppermost part of the Black Flag Group (Table 1) immediately beneath the unconformably overlying Kurrawang Formation in the Kurrawang Syncline. They include a range of volcanic and volcaniclastic rocks; the most abundant rock type is a coarse volcaniclastic conglomerate with angular to subrounded, pebble- to boulder-sized clasts, mainly of porphyry, with fine- to coarse-grained plagioclase and hornblende phenocrysts and quartz-filled amygdales, in a very fine, siliceous matrix. The matrix has a similar composition to the clasts. There are local, clast-free beds, pyritic in places, which may represent either lava or sedimentary lenses. Coarser fractions in thin- to medium-bedded units are compositionally similar to the clasts. Some bedded units contain graded bedding and possible cross-beds. Rare outcrops of lava include porphyritic plagioclase–hornblende andesite and jointed hornblende dacite. Hunter (1993) described thin beds of lapilli tuff, crystal tuff, and very fine grained ash deposits in this area.

Intermediate rock that outcrops west of Grants Patch between the Ora Banda and Orinda Sills has been assigned to the Pipeline Andesite Member of the Black Flag Group by Witt (1994). It consists of blocky andesite fragments up to 30 cm, but typically less than 2 cm, in length. It is similar in character to intermediate rocks in the Kurrawang Syncline described above and may be a stratigraphic equivalent. It has a U–Pb zircon age of 2704 ± 8 Ma (Pidgeon, 1986).

Small outcrops of feldspar-phyric andesite outcrop locally within felsic volcanic and volcaniclastic sequences in the Coolgardie and Bullabulling Domains.

### Felsic rocks (*Afv*, *Afs*)

Felsic volcanic and volcaniclastic rocks (*Afv*) are widespread on KALGOORLIE but not well exposed. They form much of the upper part of the felsic volcanic and sedimentary unit (Black Flag Group — Table 1) of the Kalgoorlie Terrane sequence. Low in the sequence the unit also includes felsic schists, which are probably derived from felsic volcaniclastic rocks.

Morris (in prep.) has documented the lithology, volcanology, and geochemistry of the felsic rocks in the Kalgoorlie Terrane and adjacent areas to the east and north. He described the felsic rocks of the Black Flag Group as a dacite–rhyolite association comprising dacite and rhyolite lavas with associated breccia, volcaniclastic sandstone, and carbonaceous shale. Dacite and rhyolite were extruded as subaqueous lava lobes, with dacite dominating over rhyolite. Most lava lobes are less than 10 m thick.

Hunter (1993) described dacite to rhyodacite porphyry, crystal and lapilli tuffs, volcaniclastic conglomerate, and a variety of clastic sedimentary rocks from KALGOORLIE. It is often difficult to decide whether rocks are primary pyroclastic deposits or whether they represent epiclastic sediments. The conglomerate contains subangular clasts of the porphyry, up to 50 cm in diameter, in a matrix of similar composition. Clastic sedimentary rocks range from shale to pebbly sandstone and conglomerate and commonly contain sedimentary structures such as graded bedding, flame structures, and load casts. Cross-beds and ripples are rare. Some shale and chert units may represent fine ash-fall deposits.

Gibson–Honman Rock, 12 km southwest of Kalgoorlie, is a good example of felsic lava with associated volcaniclastic breccia (Morris, in prep.). Lava lobes, 3–4 m in diameter, consist of porphyritic dacite or rhyolite with scattered phenocrysts of alkali feldspar and plagioclase up to 3 mm in diameter in a cryptocrystalline groundmass, with minor amounts of hornblende contained locally. The breccia contains clasts of the lava in a matrix of similar composition. Elongate rafts and lenses of shale or slate may represent sedimentary interbeds and/or substrate ripped up by the lava during eruption.

Morris (in prep.) also describes rhyolite and rhyolite breccia from a locality about 10 km north of Kalgoorlie near Gidgi Lake, where they contain fine (1 mm) quartz and feldspar phenocrysts in a glassy matrix with locally developed globular, possibly spherulitic, features. The rhyolites are associated with sedimentary rocks including shale, cross-bedded sandstone, and volcaniclastic sandstone breccia.

Felsic rocks are commonly deformed to produce quartz–feldspar–mica schists that may contain andalusite (Hunter, 1993). There are outcrops of strongly deformed, coarsely porphyroclastic felsic rock within the Missouri Basalt (the lower basalt unit in the Ora Banda Domain sequence) at Chadwin Well, Black Rabbit Dam, and in thin units further north in the Kurrawang Syncline. The felsic rock consists of large (up to 1.5 cm) porphyroclasts, mainly of plagioclase, in a fine-grained, quartz–feldspar–biotite matrix. Wyche and Witt (1994) suggested that the felsic rock may be either: 1) an intrusive feldspar porphyry that is comagmatic with felsic volcanic rocks of the Black Flag Group or a later granitoid intrusion; or 2) a sedimentary rock within the basalt, derived from a volcanic or granitoid source. A SHRIMP U–Pb zircon age of 2658 ± 6 Ma (Nelson, 1995) indicates that these rocks are younger than the stratigraphically overlying komatiite unit, suggesting that they probably represent metamorphosed intrusive porphyry.

Layered felsic rocks (*Afs*), interpreted from seismic and gravity data (Goleby et al., 1993), are shown only in the map cross-section. They may represent felsic gneisses and deformed granitoid rocks.

### Sedimentary rocks (*As, Ac, Aci, Ash, Akc, Aks*)

In the Kalgoorlie Terrane, sedimentary rocks are most abundant in the upper part of the sequence: the Black Flag Group and the unconformably overlying Kurrawang Formation (Table 1). Sedimentary rocks in the poorly exposed Bullabulling Domain, west of the Bullabulling Shear in the western part of the Kalgoorlie Terrane, are probably equivalent to the Black Flag Group of the other domains but are too poorly exposed to be placed into a readily definable stratigraphy. Thin interflow sedimentary units are, in places, intercalated with mafic and ultramafic volcanic rocks.

On KALGOORLIE, the Barlee Terrane contains abundant chert and BIF within the greenstone sequence. There are also outcrops of clastic sedimentary rocks, although the nature and proportion of these rock types is difficult to determine due to the deep weathering and extensive regolith cover.

Undivided sedimentary rocks (*As*) include shale, siltstone, chert, sandstone, pebbly sandstone, and conglomerate. They are most commonly shown in association with the felsic volcanic and sedimentary upper part of the Kalgoorlie Terrane sequence and may contain a significant felsic volcaniclastic component. However, the poor exposure and deep weathering makes it difficult to determine protoliths in most instances. Sedimentary structures are typically obscured by deformation and weathering, but graded bedding and cross-bedding are preserved locally. Clastic sedimentary rocks in the west, south of Mount Walton, are very deeply weathered and lateritized but may include shale and sandstone.

Chert (*Ac*) and BIF (*Aci*) outcrop in the west between Mount Walter and the Yendilberin Hills and in the greenstone belt that extends southeast from Curara Soak, where they are the main ridge-forming units. The iron content of these rocks is highly variable, and they range in character from very thinly bedded to laminated, pale to dark-grey banded chert; to grey, pink, and red ferruginous banded chert; to highly magnetic, red and black, magnetite-bearing BIF. The more cherty and more ferruginous varieties have been subdivided into chert and BIF on the map according to their appearance in outcrop. Bedding is commonly disrupted by kinks and minor folds. Local tight intrafolial folds may be products of a very early deformation event.

Some chert within the sedimentary sequences in the Kalgoorlie Terrane may represent silicified shale or mudstone units. Banded iron-formation has not been recorded in outcrop east of the Ida Fault on KALGOORLIE but is present as clasts in the conglomerates of the Kurrawang Formation.

Interflow sedimentary rocks (*Ash*), mainly shale, are found in most of the mafic volcanic sequences. They are commonly deformed to thin slate horizons or silicified to chert.

The Kurrawang Formation is a sandstone and conglomerate formation that outcrops sporadically for over 80 km along the northern side of the Zuleika Shear, southeast from the Carnage district to White Lake. It rests unconformably at the top of the Kalgoorlie Terrane sequence in the Ora Banda Domain and occupies the core of the Kurrawang Syncline. The formation may be up to 2000 m thick in places. Hunter (1993) has subdivided the Kurrawang Formation into a lower unit of polymictic conglomerate and an upper unit of sandstone.

The lower part of the Kurrawang Formation (*Akc*) consists of cobble conglomerate, sandy pebble conglomerate, and pebbly sandstone (Hunter, 1993). It is about 750 m thick near White Lake in the south but thins to the north. The conglomerate is poorly sorted, matrix supported, and medium to thick bedded. It contains well-rounded, commonly stretched clasts, which may be up to 25 cm long but typically range between 5 and 10 cm in length. There is a wide range of clast types, the most common being felsic and intermediate rocks derived from the Black Flag Group. However, there are also clasts of BIF; chert and quartzite; and, less commonly, basalt, amphibolite, and ultramafic rock. The matrix consists of medium- to coarse-grained, poorly sorted, lithic sandstone. Banded iron-formation clasts are restricted to an extensive horizon, about 30 m thick, that has a problematic provenance, as BIF is not known in the Kalgoorlie Terrane sequence; the nearest outcrops of BIF are those in the greenstone belts of the Barlee Terrane to the west.

The upper part of the Kurrawang Formation (*Aks*) consists of medium- to coarse-grained, locally pebbly lithic sandstone. Cross-bedding and graded bedding are common, and there is a general upward-fining trend.

### Quartz and/or feldspar porphyry (*Ap*)

Libby (1978a) has described in detail the textures and mineralogies of a suite of porphyritic felsic rocks from the Eastern Goldfields region.

Felsic porphyry, which is considered to be mainly intrusive, is found at several levels in the Ora Banda Domain sequence. Several varieties of felsic porphyry within mafic rocks of the Ora Banda sequence have been described by Witt (1994). Quartz–feldspar(–biotite) porphyry is the most abundant and typically contains 5–10% phenocrysts (typically less than 2 mm but up to 5 mm across) of quartz and feldspar (dominantly plagioclase), with up to about 5% biotite in a microcrystalline groundmass. Glomeroporphyritic textures are common. A large body of quartz–feldspar porphyry has been emplaced near the top of the Big Dick Basalt, northwest of Mount Pleasant. This body is itself intruded by the Liberty Granodiorite. Porphyry containing abundant phenocrysts up to about 2.5 mm in length, of approximately equal amounts of hornblende and plagioclase in a microcrystalline groundmass, lies mainly within the Siberia Komatiite and is particularly abundant on the eastern limb of the Goongarrie – Mount Pleasant Anticline between Canegrass and Vettersburg. Albite-rich, quartz-poor porphyry is also found mainly within the Siberia Komatiite. Witt (1992) described how this rock might be a product of sodium metasomatism of the closely associated hornblende–plagioclase porphyry. An unusual biotite–quartz–feldspar porphyry with abundant greenstone xenoliths lies within the ultramafic sequence northeast of Grants Patch (Witt, 1994).

Felsic porphyry intrusions within the Black Flag Group in the southeastern part of KALGOORLIE typically contain phenocrysts of quartz and sodic feldspar that may be up to

**Table 2. Pre-$D_2$ to syn-$D_2$ granitoid rocks on KALGOORLIE**

| *Name* | *Map symbol* | *Grain size (mm)* | *Texture* | *Mafic minerals* |
|---|---|---|---|---|
| Granitoid rock, undivided | *Agd* | – | – | – |
| Bora Monzogranite | *Agbo* | 0.5–3 | Equigranular | Biotite |
| Cawse Monzogranite | *Agca* | 0.4–10 | Seriate to porphyritic | Biotite |
| Crowbar Granodiorite | *Agcb* | 1–7 | Equigranular | Biotite, hornblende |
| Credo Granodiorite | *Agcr* | 0.1–4 | Seriate to porphyritic | Biotite |
| Dunnsville Granodiorite | *Agdn* | 0.5–6 | Seriate to porphyritic | Biotite, hornblende |
| Goongarrie Monzogranite | *Aggo* | 0.4–10 | Seriate to porphyritic | Biotite |
| Nine Mile Monzogranite | *Agnm* | 1–4 | K-feldspar phenocrysts aligned to regional foliation | Biotite, hornblende |

1.5 cm in length, but usually much less, in a microcrystalline quartzofeldspathic matrix, with common fine biotite and local fine tourmaline (Hunter, 1993). Alkali-feldspar porphyry, which lacks quartz phenocrysts, outcrops south of the Great Eastern Highway in the Binduli area, about 10 km southwest of Kalgoorlie.

Northwest of Davyhurst, and extending north onto RIVERINA (Wyche, 1996), there are numerous thin units (typically less than 2 m thick) of feldspar and quartz–feldspar porphyry with phenocrysts (up to 5 mm but typically less than 2 mm in length) of quartz and sodic plagioclase in a fine quartzofeldspathic matrix with subordinate sericite and fine biotite. They lie within a tholeiitic basalt sequence that has been metamorphosed at upper greenschist to lower amphibolite facies and moderately to strongly deformed. Some of the porphyry units clearly pre-date the regional deformation. They are typically concordant with structural trends and may represent tuff bands within the basalt or high-level intrusive rock associated with nearby granitoid rocks.

## Granitoid rocks (*Ag*)

Granitoid rocks are a major component of the Yilgarn Craton. They are, for the most part, poorly exposed and typically deeply weathered. It has long been assumed that granitoid or gneissic rocks form a sialic basement to the greenstone sequences in the Eastern Goldfields (Gee et al., 1981). However, despite numerous records of xenocrystic zircons within greenstone sequences in the Eastern Goldfields, suggesting the existence of an older continental crust (Campbell and Hill, 1988), no sialic basement to the greenstones in this region has yet been identified.

Outcropping granitoid rocks in the Eastern Goldfields range in composition from tonalite to syenogranite, with those in the monzogranite to granodiorite range being the most abundant (Tables 2, 3, and 4). Most varieties contain either biotite or biotite and hornblende as their mafic components.

Various classifications have been proposed for the granitoid rocks of the Eastern Goldfields region. An early scheme subdivided them into 'internal granites', or those emplaced within greenstone belts, and 'external granites', or those emplaced between greenstone belts (Sofoulis, 1963).

Libby (1978b) carried out a broad-ranging petrographic study of granitoid rocks in the Eastern Goldfields Province and eastern part of the Southern Cross Province. He found

Table 3. Post-$D_2$ to syn-$D_3$ granitoid rocks on KALGOORLIE

| *Name* | *Map symbol* | *Grain size (mm)* | *Texture* | *Mafic minerals* |
|---|---|---|---|---|
| Bali Monzogranite | *Agbl* | 3–7 | Porphyritic | Biotite |
| Calooli Monzogranite | *Agcl* | medium–coarse | Equigranular | Biotite |
| Rowles Lagoon Monzogranite | *Agro* | 1–6 | Sparsely porphyritic | Biotite |
| Silt Dam Monzogranite | *Agst* | 2–6 | Equigranular | Biotite |
| Two Gum Monzogranite | *Agtg* | 0.5–7 | Porphyritic | Biotite, hornblende |

that textural and compositional trends follow broad tectonic trends and, in particular, that granitoid rocks in what is now called the Barlee Terrane appear to be richer in K-feldspar than those east of the Ida Fault.

Witt and Swager (1989) described the structural setting and geochemistry of granitoid rocks in the eastern part of KALGOORLIE. They identified three groups, based mainly on relationships with regional structures in the greenstones: those intruded early, during the regional shortening (pre-$D_2$ to syn-$D_2$); those intruded late, during the regional shortening (post-$D_2$ to syn-$D_3$); and those that post-date the major deformation (late tectonic). This scheme forms the basis of the subdivision used on the geological map (Tables 2, 3, and 4).

The recently acquired SHRIMP U–Pb zircon geochronological data from the Kalgoorlie–Boulder area do not always support the classification of the granitoid rocks based on field observations, suggesting the need for further investigation of field relationships. The Crowbar Granodiorite, interpreted as pre-$D_2$ to syn-$D_2$, has a U–Pb zircon age of 2657 ± 5 Ma; post-$D_2$ to syn-$D_3$ biotite monzogranite from near Chadwin Well has a U–Pb zircon age of 2660 ± 3 Ma; and biotite syenogranite from northwest of Siberia, interpreted as late tectonic, has a U–Pb zircon age of 2673 ± 3 Ma (Nelson, 1995). Other U–Pb zircon geochronological data on granitoid rocks interpreted as late tectonic include an age of 2602 ± 11 Ma for the Mungari Monzogranite, 2680 ± 5 Ma for the Bonnie Vale Tonalite (Hill et al., 1992), and c. 2650 Ma for the Liberty Granodiorite (Kent and McDougall, 1995).

In a review of trace-element data from the Southern Cross – Kalgoorlie region, Wyborn (1993) subdivided the more mafic granitoid rocks of the eastern Yilgarn Craton into four broad groups: early banded gneiss and migmatite, mafic tonalite to granite (as formally defined), granodiorite to granite, and monzogranite to granite. The first three groups are Y depleted and Sr non-depleted, whereas the last group is Y non-depleted and Sr depleted. Wyborn (1993) found that all the granitoid rocks were derived by partial melting of the lower crust and appear to have had a significant crustal prehistory. More recently, the granitoid rocks in the Kalgoorlie region have been classified into a series of pre-folding and post-folding supersuites on the basis of their structural setting, U–Pb zircon ages, and geochemical character (Witt and Davy, 1997a,b)

The 1991 AGSO deep crustal seismic traverse (Drummond et al., 1993) passed across the Dunnsville Granodiorite and the granitoid body that occupies the core of the Scotia–Kanowna Anticline. The seismic data suggest that these intrusions are steep-sided, flat-lying bodies or sheets underlain by supracrustal rocks. The granitoid rocks in the Goongarrie – Mount Pleasant Anticline do not appear on the seismic image, although the traverse passed quite close to the southern end of their known outcrop. Goleby et al. (1993) and Swager et al. (1997) interpret the granitoid rocks as flat, tabular bodies of relatively limited areal extent.

**Table 4. Late-tectonic granitoid rocks on KALGOORLIE**

| *Name* | *Map symbol* | *Grain size (mm)* | *Texture* | *Mafic minerals* |
|---|---|---|---|---|
| Granitoid rock, undivided | *Agl* | – | – | – |
| Fair Adelaide Syenogranite | *Agad* | 3–4 | Equigranular | Biotite |
| Bonnie Vale Tonalite | *Agbv* | 1–5 | Equigranular | Biotite |
| Doyle Dam Granodiorite | *Agdd* | 0.5–5 | Equigranular | Biotite, hornblende |
| Karramindie Monzogranite | *Agka* | fine–medium | Equigranular | Biotite |
| Kintore Tonalite | *Agkn* | medium | Equigranular | Biotite |
| Liberty Granodiorite | *Aglb* | 0.5–5 | Equigranular | Biotite, hornblende |
| Mungari Monzogranite | *Agmu* | 1–3 | Equigranular | Biotite |
| Lone Hand Monzogranite | *Agon* | ?medium | Equigranular | Biotite |

### Minor intrusions (*p*, *q*)

Veins and dykes of quartz (*q*) and pegmatite (*p*) are present throughout the greenstone sequences but are most abundant near granite–greenstone contacts. Several prominent quartz veins (e.g. at Mount Walter in the southwest and west of Wongi Hill in the central north) are probably related to faulting at granite–greenstone contacts.

## MAFIC AND ULTRAMAFIC DYKES (*Edy*)

Dykes (*Edy*) that cut across both the granitoid and greenstone rocks in the Eastern Goldfields are part of a widespread suite of mafic and ultramafic dykes within the Yilgarn Craton. They rarely outcrop and are identified mainly from aeromagnetic maps as linear features that show both normal and reversed polarities of magnetization. Most have an approximately easterly trend. There are commonly small offsets and some dykes with a markedly different orientation. One such dyke on KALGOORLIE is the Parkeston Dyke, which extends northwest from Kalgoorlie, cuts across greenstones in the Goongarrie – Mount Pleasant Anticline, and may be contiguous with a northwest-trending dyke, identified on aeromagnetic maps, northwest of Wongi Hill.

Some dykes can be traced for several hundred kilometres on aeromagnetic maps. However, they are rarely greater than a hundred metres wide and commonly much less. They are typically steep dipping and have sharp contacts, indicating minimal contact effects with enclosing country rocks. Dykes consist mainly of gabbro or dolerite with or without olivine, with some orthopyroxene-bearing varieties (Hallberg, 1987; Hunter, 1993).

According to Hallberg (1987) the dykes were probably emplaced in tensional fractures between 2400 and 2000 Ma when the northern and southern margins of the craton were still active. However, recent SHRIMP U–Pb zircon geochronological data from a granophyric phase within an east-trending dyke, about 3 km north of Mount Vetters Homestead, give an age of crystallization of 2661 ± 3 Ma, indicating that at least some of these dykes may be late Archaean in age.

# STRUCTURE

Swager (1989) and Swager and Griffin (1990) have described four phases of deformation in the Kalgoorlie Terrane (Table 5). More recently, some authors have proposed more complex deformation histories involving extensional events early in the deformation history. Swager (1997) presents a summary of the various models.

**Table 5. Regional deformation history of KALGOORLIE**

| *Event* | *Regional deformation history* | *Examples on KALGOORLIE* |
|---|---|---|
| $D_1$ | regional shortening; thrust stacking and recumbent folding | Dunnsville dome (Martyn, 1987; Swager, 1990); repeated mafic–ultramafic sequences near Coolgardie |
| $D_2$ | formation of syntectonic clastic basins pre- to syn-$D_2$ regional shortening; north- to northwest-striking upright folds | Kurrawang Formation, Kurrawang Syncline, Goongarrie – Mount Pleasant Anticline, Scotia–Kanowna Anticline |
| $D_3$ | continued east-northeast–west-southwest shortening; north- to northwest-striking transcurrent faults; transpression | Kunanalling Shear; Zuleika Shear |
| $D_4$ | oblique north- and northeast-striking faults; dextral | Northeast-trending structures on the Golden Mile |

The $D_1$ recumbent folding and thrusting event is best documented between Kalgoorlie and Kambalda (Swager and Griffin, 1990); however, Swager (1990) has described a possible $D_1$ thrust that has been subsequently folded around the northern end of the Dunnsville dome during $D_2$. Repetition of mafic–ultramafic sequences around Coolgardie indicates the possibility of a regionally extensive thrust sheet. The direction of movement of $D_1$ is equivocal, but the present-day orientation of the structures suggests that it was a north–south shortening event.

The second deformation event ($D_2$) was an east-northeast–west-southwest shortening event that produced northwest-trending, region-wide upright folding. It is represented on KALGOORLIE by large-scale features such as the Kurrawang Syncline and the granitoid-cored Goongarrie – Mount Pleasant and Scotia–Kanowna Anticlines. Regional shortening continued during $D_3$ and is represented by north- to northwest-trending transcurrent or transpressional faults such as the Kunanalling Shear and the Boulder Fault. Associated en echelon $F_3$ folds suggest a sinistral sense of movement on these structures. The major shear zones that form the domain and terrane boundaries (Figs 2 and 3) may be long-lived features with complex histories that probably include a significant component of $D_3$ movement (Swager et al., 1995).

Domain boundary faults are typically large-scale structures characterized by wide zones of shearing, resulting in the disruption and attenuation of the greenstone succession. They are commonly associated with widespread carbonate alteration. Major pre-existing structures cannot be traced across these faults and their complex histories do not allow the determination of the total amount of movement. However, the similarity between greenstone geology on either side of some structures (e.g. the Zuleika Shear) precludes the possibility of craton-scale displacements (Swager et al., 1995).

North- to northeast-trending lineaments and faults, in places marked by quartz veins that cut across granite–greenstone contacts, may be related to $D_4$. These structures are readily apparent on total-magnetic-intensity images derived from detailed aeromagnetic data, and have been assigned to $D_4$ in the Golden Mile area around Kalgoorlie–Boulder, where they typically show some dextral movement (Keats, 1987; Swager, 1989).

The Kalgoorlie Terrane is separated from the Barlee Terrane to the west by the Ida Fault and the Gindalbie Terrane to the east by the Moriaty Shear – Mount Monger Fault system. The Ida Fault is clearly identified on aeromagnetic images but is difficult to locate on the ground due to lack of outcrop. Total displacement on interterrane faults cannot be determined but may be very large (Swager et al., 1995).

A number of the major boundary structures on KALGOORLIE, including the Ida Fault, Bullabulling Shear, and Bardoc Tectonic Zone, were imaged by the 1991 AGSO seismic traverse (Drummond et al., 1993; Goleby et al., 1993; Swager et al., 1997). The Ida Fault is a shallow, east-dipping structure that can be traced for up to 30 km into the lower crust, and its last movement appears to be extensional. The Bullabulling Shear appears as a splay on the Ida Fault, and the Bardoc Tectonic Zone appears as a complex west-dipping structure. The seismic profile also shows that the greenstone sequence is only up to about 7 km thick and has a sharp contact with underlying sialic crust. This contact has been interpreted as a basal detachment surface. The crust is two-layered, with the upper layer about 10–12 km deep. It is deeper beneath the greenstones, where it appears to step down to the east on the Ida Fault. The crust–mantle boundary (the Moho) is interpreted to be about 33 km deep in the Barlee Terrane in the western part of KALGOORLIE, and to dip shallowly to the east beneath the greenstones. These data suggest that there may have been multiple extensional episodes, but it is not clear whether the last extensional movement on the Ida Fault post-dates $D_4$.

The axis of the Kurrawang Syncline has been displaced by a series of northeasterly to east-northeasterly trending faults in the vicinity of Siberia. Witt and Swager (1989) have interpreted these structures as accommodation faults resulting from the forceful emplacement of post-$D_2$ to syn-$D_3$ granitoid rocks immediately to the west. A similar mechanism has been invoked for the emplacement of the Silt Dam Monzogranite in the central-southern part of KALGOORLIE.

West of the Ida Fault, in the Barlee Terrane, the two exposed greenstone belts appear to form narrow, fault-bounded keels within sialic crust. The AGSO seismic traverse (Goleby et al., 1993) shows a shallowly east-dipping structure, interpreted as a fault, beneath the Watt Hills, with some shallowly west-dipping, possibly complementary structures to the east of the greenstone belt. The greenstone belts are disrupted by numerous late, northerly to north-northeasterly trending dextral faults, which may be related to a north-northeasterly trending magnetic lineament that appears to offset a concealed greenstone belt in the northwestern part of KALGOORLIE (Fig. 3). These faults may be equivalent to $D_4$ structures in the Kalgoorlie Terrane.

## METAMORPHISM

Binns et al. (1976) presented a regional overview of metamorphic patterns in the eastern Yilgarn Craton, and Ahmat (1986) subsequently described metamorphism and metamorphic patterns in the Southern Cross Province.

Metamorphic conditions in the region ranged from very low grade (prehnite–pumpellyite) in areas east of KALGOORLIE, well away from greenstone margins, to moderate and high-grade areas (middle to upper amphibolite facies) around greenstone margins and along the eastern side of the Ida Fault. Temperature has played a greater role than pressure in metamorphism. This is indicated by the widespread occurrence of andalusite and the subordinate occurrence of garnet in the higher grade metapelitic rocks east of the Ida Fault. Most rocks are recrystallized, but primary igneous textures are commonly preserved.

Binns et al. (1976) described two contrasting styles of regional metamorphism for the Yilgarn Craton: static style in areas of very low- to medium-grade metamorphism, where primary structures and textures have been preserved in spite of metamorphic recrystallization and mineralogical reconstitution; and dynamic style in higher grade areas where there has been relatively intense deformation and original structures and textures have been largely destroyed. Static-style areas typically occupy the central, low-strain parts of greenstone belts, whereas dynamic-style areas are typically the higher grade, higher strain areas along granite–greenstone contacts. In areas of highest metamorphic grade, rocks are completely recrystallized. Mafic rocks are characterized by dark-green hornblende and may contain garnet and metamorphic clinopyroxene. Ultramafic rocks may contain metamorphic olivine. Peak metamorphic temperatures probably occurred late during $D_2$–$D_3$ regional shortening, contemporaneous with syn-$D_3$ granitoid emplacement (Swager et al., 1995). Where recognized, contact metamorphic effects are typically restricted to relatively thin aureoles around granitoid rocks emplaced during the regional metamorphic event (Witt, 1994; Swager et al., 1995).

Most rocks show evidence of retrograde alteration, typically as saussuritization of plagioclase and chloritization of hornblende in metabasites, serpentinization and talc–carbonate alteration of ultramafic rocks, and sericitization and chloritization of metapelites. There has been extensive carbonation and hydration along and adjacent to major fault systems. Carbonation may have begun soon after volcanism in long-lived structures and continued during regional deformation and metamorphism (Swager et al., 1995). Witt (1992) described sodium metasomatism of intrusive porphyries that appears to have taken place late during the regional deformation and may coincide with the gold mineralization event. Some of the alteration in the Kalgoorlie–Kambalda area may be attributed to hydrothermal sea-floor alteration early in the depositional history of the greenstone sequence (Barley and Groves, 1989).

## CAINOZOIC GEOLOGY

Ollier et al. (1988) and Chan et al. (1992) have discussed the regolith and landscape evolution in the Kalgoorlie region.

There are no Palaeozoic or Mesozoic rocks on KALGOORLIE. However, Cainozoic deposits in the region include early Tertiary sediments within channels of the Roe Palaeodrainage system (Commander et al., 1992). Palaeochannels are up to 60 m deep, but Tertiary sediments do not outcrop and are only known from borehole data. They comprise a lower unit (the Middle to early Late Eocene Wollubar Sandstone) of quartz sand with subordinate conglomerate, clay, carbonaceous silt, and lignite, and an upper unit of clay with subordinate sandy clay (the Perkolilli Shale).

All rocks on KALGOORLIE, including the Tertiary sediments, have been affected by weathering in situ — particularly silicification, ferruginization, and calcification (Commander et al., 1992).

Cainozoic units have been differentiated mainly by photo-interpretation (Fig. 1). Playa-lake deposits (*Czts*) are characterized by evaporites interbedded with clay and sand. Rowles Lagoon differs from most of the lacustrine deposits in the region in that it contains fresh water and is surrounded by more heavily vegetated, swampy ground.

Dunes adjacent to playas (*Cztd*) are eolian deposits of sand, silt, and gypsum derived from dried-out lakes.

Colluvium (*Czc*) consists of gravel, sand, and silt, including locally abundant white vein-quartz scree, which has been deposited as sheetwash or talus at the base of slopes.

Quartzofeldspathic sand (*Czg*), which has formed in situ over areas of granitoid rock, is widespread in the western part of KALGOORLIE.

Sandplain deposits (*Czs*) consist of sheets and dunes of yellow non-calcareous sand. There has been some debate as to how much of the sand formed in situ (Ollier et al., 1988), but the presence of dunes in the northern and western parts of KALGOORLIE suggests that it contains a significant proportion of reworked material. Sandplains commonly form thin veneers over laterite.

Laterite and its reworked products (*Czl*) are widespread and obscure the greenstone geology over much of KALGOORLIE. Laterite forms a hard ferricrete crust, which is locally reworked to gravel. The crust can range in thickness from a few centimetres up to about 10 m. Complete weathering profiles can be over 100 m thick (Ollier et al., 1988). This unit includes areas of caprock over ultramafic rocks in the Siberia district. The caprock hosts lateritic nickel deposits.

Quaternary alluvium (*Qa*) consisting of clay, silt, sand, and gravel occupies active stream channels.

## ECONOMIC GEOLOGY

The Eastern Goldfields region is a mineralized province of world significance. The Kalgoorlie–Boulder district, which includes the Mount Charlotte mine and the Fimiston pit (the Superpit) on the Golden Mile, has produced over 1400 t of gold since the discovery of gold at Kalgoorlie in 1893. The Eastern Goldfields is also a major nickel-producing region.

### GOLD

The gold deposits of the Kalgoorlie region are widely documented. Ho et al. (1990) describes the nature and setting of gold deposits in the Yilgarn Craton in a volume that includes summary descriptions of some of the larger deposits on KALGOORLIE. Witt (1993a,b) describes lithological and structural controls on gold mineralization between Menzies and Kambalda, and Witt (1993c,d,e) describes all of the mines between Menzies and Kambalda with any significant gold production (i.e. generally taken to be greater than 5 kg). These descriptions include mines between Siberia and Grants Patch as well those between Goongarrie and Kalgoorlie–Boulder. Descriptions of larger deposits throughout the region, including Goongarrie, Davyhurst, Grants Patch, Sand King, Eureka, Bardoc, Ora Banda, Paddington, Lady Bountiful, Lady Bountiful Extended, the Kalgoorlie goldfield, and Mount Percy, can be found in Hughes (1990). Gebre-Mariam et al. (1993) describes gold and silver mineralization at Racetrack, and Cassidy and Bennett (1993) describes the Lady Bountiful deposit. Kent and McDougall (1995) discusses constraints on the timing of gold mineralization. Hughes (1990) includes descriptions of the Bayleys (Bayleys Reward), Three Mile Hill, Greenfields, and Tindals deposits in the Coolgardie district. Knight et al. (1993) contains further descriptions of deposits and discusses controls on mineralization in the Coolgardie district.

In general, gold mineralization in the Eastern Goldfields region is thought to be late, relative to the regional metamorphic and deformational history (Witt, 1991, 1993a; Witt et al., 1997). Structure is the single most important control on gold mineralization and, although broadly related to the craton-scale structures, most major deposits are associated with smaller-scale features adjacent to or near these structures. These may include quartz-vein-dominated systems, fault and shear-bounded quartz-vein systems, quartz-vein and breccia systems, and brittle–ductile shear zones. Gold may be found within most greenstone varieties, but deposits are more common in mafic intrusive and extrusive rocks (Witt, 1993a). Deposits in granitoid rocks are rare — an example on KALGOORLIE is the Lady Bountiful deposit in the Liberty Granodiorite. Deposits in the eastern part of KALGOORLIE are in relatively low grade (greenschist facies) rocks, while many of those in the central part between Coolgardie and Davyhurst are found in higher grade (amphibolite facies) rocks. Although some deposits contain free gold in quartz veins, much of the mineralization is associated with extensive wallrock alteration. This alteration is characterized by pervasive carbonation with associated potassium metasomatism, silicification, and hydration (Ho et al., 1990; Witt, 1991; Witt et al., 1997).

There is wide variation in structural styles between individual deposits. The largest deposits in the region are those of the Kalgoorlie goldfield. Mineralization on the Golden Mile, at the southern end of the field, in the Fimiston pit, is found in areas of alteration associated with shear zones in a layered coarse-grained mafic rock (Golden Mile Dolerite). The Mount Charlotte deposit, at the northern end of the field, lies in alteration haloes around quartz stockworks in the same host (Clout et al., 1990).

Historical gold production is difficult to estimate as records are often incomplete and there has been much reworking of the same ground. All of the authors noted above provide some production data. Witt (1993a,b,c,d,e) gives detailed estimates of the production and size of deposits over much of the eastern part of KALGOORLIE up until 1989. Data for DAVYHURST and DUNNSVILLE can be found in Wyche and Witt (1994) and Swager (1990) respectively. Early production on leases from all Western Australian goldfields was compiled and presented in Western Australian Department of Mines (1954). The deposits in the Kalgoorlie district, including the Golden Mile, Mount Charlotte, and Mount Percy (with a combined historical production of more than 1400 t), constitute a resource that is at least an order of magnitude larger than any other known deposit or group of deposits in the region.

Gold production in the Eastern Goldfields has waxed and waned over the past 100 years in response to developments in the wider economy (Blainey, 1993). However, with the gold boom of the 1980s and the development of technology for efficient and cheap mining of large low-grade deposits, many old mines were reopened and some new discoveries were brought into production. In the period between 1982 and 1995, records of the Department of Minerals and Energy show that gold production from all mines on KALGOORLIE, including the total production on the Golden Mile, increased from about 7.733 t in 1982 to about 44.026 t in 1996. Silver has been produced as a by-product of some gold-mining operations, such as the Sand King mine (Wyche and Witt, 1994).

## NICKEL–COBALT

The major nickel resource on KALGOORLIE is the Cawse lateritic nickel–cobalt deposit, which overlies ultramafic rocks on the western limb of the Goongarrie – Mount Pleasant Anticline. The resource stretches over a strike length of almost 20 km. At its northwestern end it includes three previously identified deposits — SM7, Linger and Die, and Gulch — which overlie massive adcumulates of the Walter Williams Formation. The SM7 deposit was used as a source of siliceous flux in the Kalgoorlie nickel smelter, and the Linger and Die deposit was mined as a high-grade cobalt ore (Marston, 1984; Elias et al., 1981). The Cawse deposit contained an estimated resource of 193 Mt at 0.70% nickel and 0.04% cobalt at June 1996. About 80% of the resource is associated with limonitic clays in the upper part of the weathering profile and the remainder with nontronitic clays and talc zones associated with bedrock structures (Resource Information Unit, 1997).

The only significant production of nickel sulfides on KALGOORLIE has come from the Scotia mine in the northeast. This mine produced 14 628 t of nickel in ores and concentrates between 1968 and 1977. Average head grades were 2.17% nickel and 0.15% copper. The nickel sulfide mineralization is hosted by a lenticular peridotite body at the base of a komatiite unit within a sequence containing amphibolite and metasedimentary rocks (Marston, 1984). The deposit has been described by Christie (1975), Page and Schmulian (1981), Stolz and Nesbitt (1981), and Marston (1984).

A number of smaller nickel prospects have been identified in the Scotia area. Some lie within an ultramafic sequence on the eastern side of the Scotia–Kanowna Anticline, about 18 km east of Scotia. The Bardoc nickel prospect, just southwest of the Mount Vetters Homestead, is within a southern extension of the ultramafic unit that hosts the mineralization at Scotia (Marston, 1984).

## COPPER

A small amount of copper has been produced from shale in the hangingwall of the Mount Pleasant Sill at Mount Pleasant. Similar occurrences have been noted in the Lady Bountiful and Goongarrie areas (Marston, 1979).

## TUNGSTEN

Small parcels of wolframite have been mined from quartz and pegmatite veins in the Ora Banda district. Scheelite is present in a number of gold mines at Kalgoorlie–Boulder, Coolgardie, and Davyhurst, and there has been some small production from the Tindals (2641.01 kg $WO_3$) and Leslie Norma (1944.5 kg $WO_3$) mines at Coolgardie and the Golden Pole (12 337.5 kg $WO_3$) mine at Davyhurst (Baxter, 1978).

## SILVER, LEAD, AND ZINC

Some gold mines produce silver as a by-product, and many contain small amounts of galena and sphalerite, but there are no known ore-grade deposits of these minerals on KALGOORLIE (Blockley, 1971; Ferguson, in prep.).

## IRON

The two greenstone belts in the western part of KALGOORLIE contain BIF interbedded with grey banded chert within a mainly mafic sequence. The BIF lies in thin (typically less than 2 m) layers and lenses within the more abundant chert and, from visual inspection, appears to have a relatively low iron content.

## GEMSTONES

Small deposits of moss agate, opaline silica, and chrysoprase associated with ultramafic rocks have been worked locally, for example in the Coolgardie and Ora Banda districts, but no production has been recorded.

## WATER

The water resources of the Kalgoorlie region are described in Commander et al. (1992). The most reliable water supplies are those obtained from Tertiary palaeochannels of the Roe Palaeodrainage system. This water is saline, ranging from about 30 g/L total dissolved solids (TDS) in the upper reaches of palaeochannels in the west, to about 200 g/L TDS near the salt lakes in the east. Some water has been obtained from weathered and fractured bedrock.

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# Appendix

## Gazetteer of localities

| *Locality* | *AMG (E)* | *AMG (N)* | *Locality* | *AMG (E)* | *AMG (N)* |
|---|---|---|---|---|---|
| Bardoc (mining centre) | 334000 | 6643500 | Kurrawang (mission) | 340100 | 6587900 |
| Bayleys Reward (mine) | 326100 | 6575000 | Lady Bountiful (mine) | 327500 | 6624000 |
| Binduli (mining centre) | 346400 | 6590400 | Lake Walton | 216000 | 6575000 |
| Black Flag (mining centre) | 331000 | 6617000 | Mount Burges Homestead | 319800 | 6585200 |
| Black Rabbit Dam | 296800 | 6641000 | Mount Carnage | 303300 | 6639500 |
| Black Range | 310000 | 6637000 | Mount Charlotte (mine) | 354400 | 6597500 |
| Bonnie Vale (mining centre) | 325000 | 6585000 | Mount Percy (mine) | 354100 | 6599400 |
| Broad Arrow (mining centre) | 339500 | 6629900 | Mount Walter | 231400 | 6575400 |
| Bullabulling (mining centre) | 299000 | 6571000 | Mount Walton | 216400 | 6619700 |
| Callion (mining locality) | 266800 | 6665000 | Mount Vetters Homestead | 336400 | 6641500 |
| Canegrass (mining centre) | 324000 | 6662000 | Mungari Homestead | 336600 | 6584400 |
| Carbine (mining centre) | 299000 | 6626000 | New Mexico (mine) | 303500 | 6645100 |
| Chadwin (mining centre) | 286000 | 6641000 | Ora Banda (mining centre) | 314000 | 6638000 |
| Chadwin Well | 287500 | 6641400 | Paddington (mining centre) | 340800 | 6625600 |
| Coolgardie | 323000 | 6575000 | Racetrack (mine) | 330800 | 6618100 |
| Credo Homestead | 291400 | 6627500 | Ringlock Dam | 353800 | 6659200 |
| Curara Soak | 218400 | 6674700 | Rowles Lagoon | 294000 | 6631000 |
| Davyhurst (mining centre) | 272000 | 6672000 | Sand King (mine) | 303200 | 6655300 |
| Eureka (mine) | 332100 | 6643600 | Scotia (mine) | 333800 | 6657700 |
| Fimiston Pit | 356000 | 6595000 | Siberia (mining centre) | 303000 | 6652000 |
| Gibson–Honman Rock | 349600 | 6586600 | Sydenham (mine) | 324000 | 6580200 |
| Gidji Lake | 346000 | 6614000 | Three Mile Hill (mining locality) | 325000 | 6578000 |
| Golden Pole (mine) | 271500 | 6674400 | Timberfield | 228700 | 6587300 |
| Goongarrie (mining centre) | 323000 | 6674000 | Tindals (mining locality) | 325000 | 6571000 |
| Grants Patch (mining centre) | 318000 | 6630000 | Vettersburg (mining locality) | 331500 | 6649500 |
| Greenfields (mine) | 328000 | 6576400 | Watt Hills | 221000 | 6611000 |
| Hampton (mining locality) | 332000 | 6572000 | White Flag Lake | 333000 | 6608000 |
| Jaurdi Hill | 302200 | 6604000 | White Lake | 348000 | 6583000 |
| Kalgoorlie–Boulder | 354000 | 6597000 | Wongi Hill | 302500 | 6663800 |
| Kunanalling (mining centre) | 315000 | 6605000 | Yendilberin Hills | 215000 | 6622000 |
| Kundana (mining centre) | 330000 | 6602000 | | | |

# KALGOORLIE

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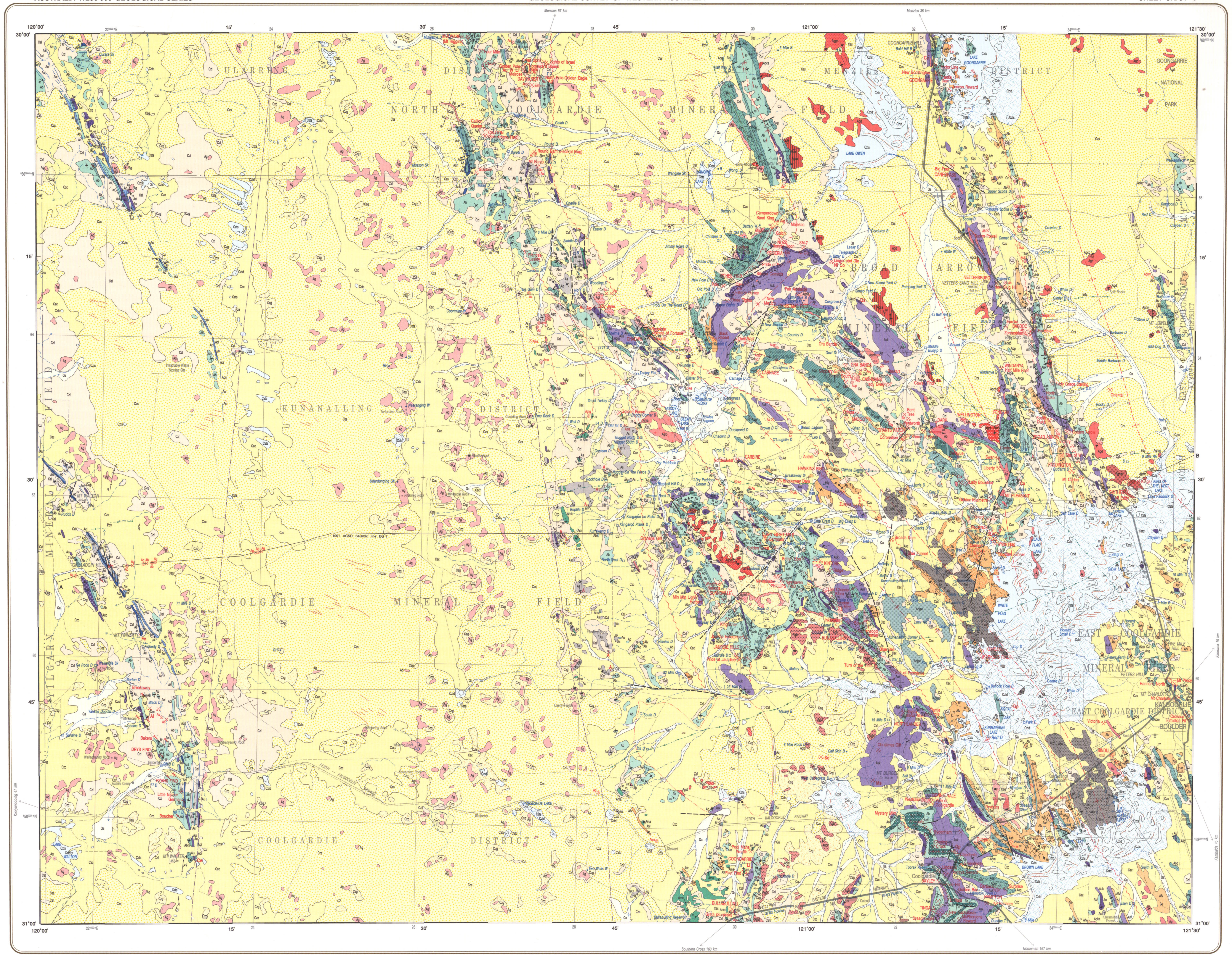

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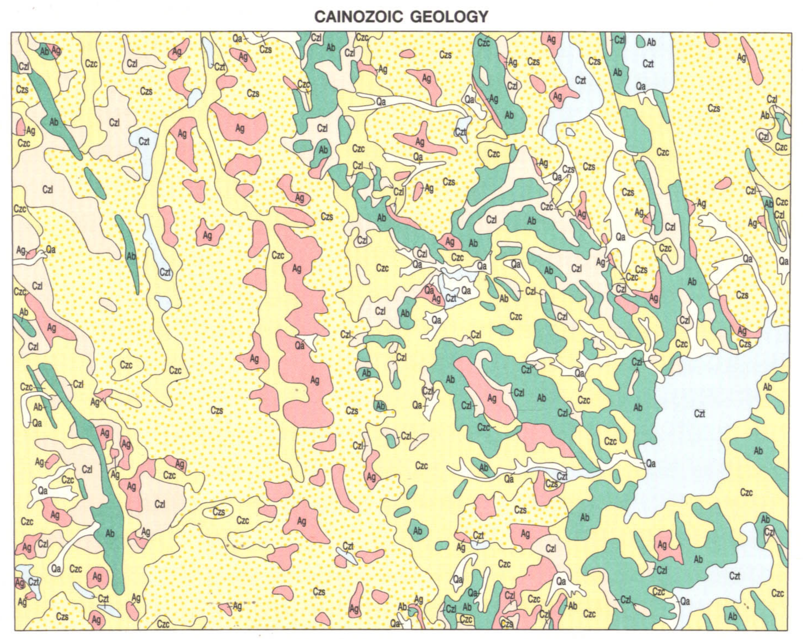

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## DIAGRAMMATIC SECTION A–B*

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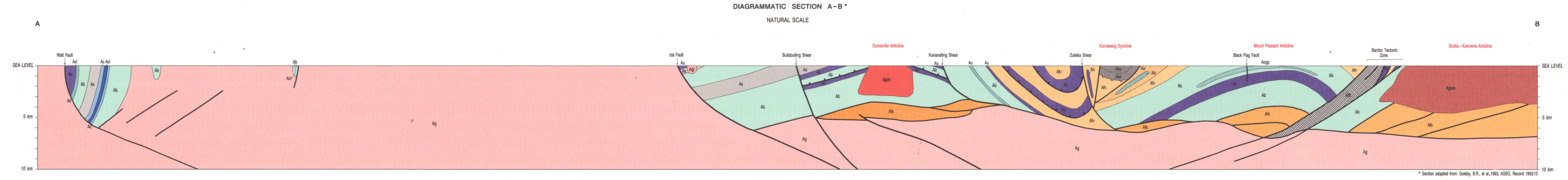
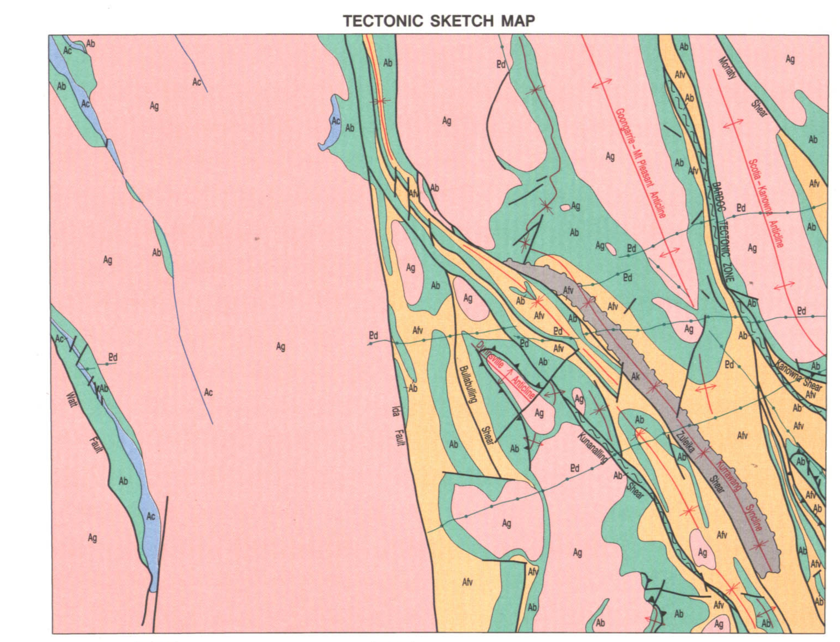


Unconformity — Thrust fault

## TECTONIC SKETCH MAP



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DIRECTOR, GEOLOGICAL SURVEY
OF WESTERN AUSTRALIA

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Metres — Kilometres

TRANSVERSE MERCATOR PROJECTION

ZONE 51 AUSTRALIAN MAP GRID

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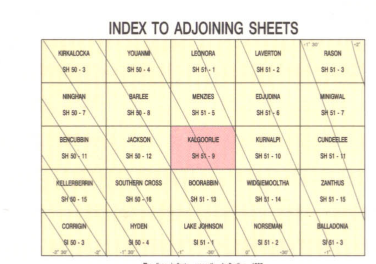

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