REPORT
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GOVERNMENT OF
WESTERN AUSTRALIA

MINERAL OCCURRENCES AND EXPLORATION POTENTIAL OF THE NORTH EASTERN GOLDFIELDS

by K. M. Ferguson

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

DEPARTMENT OF MINERALS AND ENERGY

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Perth 1998

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Copy editor: D. P. Reddy

REFERENCE
The recommended reference for this publication is:
FERGUSON, K. M., 1998, Mineral occurrences and exploration potential of the north Eastern Goldfields: Western Australia Geological Survey, Report 63, 40p.

National Library of Australia
Cataloguing-in-publication entry

Bibliography.
ISBN 0 7309 6599 6

1. Geology, Structural — Western Australia — Eastern Goldfields.
2. Mines and mineral resources — Western Australia — Eastern Goldfields.
3. Gold ores — Geology — Western Australia — Eastern Goldfields.
I. Geological Survey of Western Australia.
II. Title. (Series: Report (Geological Survey of Western Australia); 63).

553.409941

ISSN 0508–4741

Cover photograph:
Abandoned gold workings in quartz vein in metagabbro, 6 km north of Bandya Homestead (abandoned), Duketon.

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Mineral occurrences and exploration potential of the north Eastern Goldfields

by

K. M. Ferguson

Abstract

The north Eastern Goldfields area is defined for this study by the SIR SAMUEL, DUKETON, and WILUNA 1:250 000 map sheets. It consists of three major, structurally controlled, north-northwesterly trending, Archaean greenstone belts (Agnew–Wiluna, Yandal, and Duketon belts) separated by corridors of Archaean granite–gneiss. At the northern margin of the area Proterozoic sedimentary rocks of the Nabberu Province unconformably overlie these units. The Archaean basement is mantled by Cainozoic regolith with residual, eluvial, colluvial, and alluvial components, and a Tertiary palaeodrainage system of alluvial and playa deposits.

Economically, the most important type of mineralization in the north Eastern Goldfields is mesothermal vein and hydrothermal gold deposits. This is found in all greenstone belts and its distribution has been primarily controlled by dilational, brittle, and brittle–ductile low-strain structures marginal to, and between, regional north-northwesterly trending ductile high-strain shear zones. The regional distribution of gold mineralization also shows the dominance of mafic host rocks.

The main historical and currently operating gold-mining centres are at Wiluna, Sir Samuel, Darlot, and Duketon. More recent exploration has located major new centres in the Yandal belt at Bronzewing, Jundee–Nimary, and Mount McClure. Good potential is indicated in the Duketon belt, associated with brittle faulting in relatively small mafic to felsic intrusive bodies.

Basal lava pathways in extrusive ultramafic rocks control komatiite-associated nickel mineralization. Detailed reconstruction of flow-field morphology and stratigraphy is required to locate deposits. Most nickel mineralization discovered to date is in the Agnew–Wiluna belt.

Volcanic-hosted base-metal prospects are found in felsic volcanic rocks of the Duketon belt, but the depositional environment and chemical associations of the volcanic rocks indicate limited potential for economic mineralization.

This report is designed to summarize and support a major new dataset of mineral exploration activity and mineral occurrences in the north Eastern Goldfields area, and a 1:500 000 map of mineralization and geology.

KEYWORDS: gold, nickel, uranium, mines, deposits, mineral occurrences, exploration, production, potential, Wiluna, Duketon, Sir Samuel, greenstones.

Introduction

This regional mineral prospectivity study of the north Eastern Goldfields extracts and collates data on exploration activities and mineral occurrences from a diversity of published and unpublished sources. The data is related to the geology, after field validation where warranted, using new information from recent 1:100 000 mapping.

Information has been compiled from the following sources:

- books, journals, and industry publications and datasets;
- regional surveys, and airborne geophysical and remote-sensing datasets;
- the large dataset of open-file statutory mineral exploration reports held in the Western Australian Mineral Exploration (WAMEX) database at the Department of Minerals and Energy (DME);
- the mines and mineral deposits (MINEDEX) database of information on past and present mines and deposits in Western Australia.

Particular importance has been placed on the extraction of information from WAMEX. In the past it has been difficult for individuals or companies to comprehensively use WAMEX. A major initiative of this study is the establishment and inclusion of a spatial index to open-file mineral exploration activities (SPINDEX). For the study area the Western Australian Mineral Occurrence (WAMIN) database has been created from WAMEX and other industry and DME sources.

There are three principal components of this mineral prospectivity study: this Report, Plate 1, and a digital dataset on CD-ROM. The Report highlights a range of aspects of Plate 1 and the digital dataset, and reviews the regional geology of the area, the most important mineral occurrences, and controls on mineralization. Plate 1 presents a simplified view of the solid and regolith geology and includes a full list of mineral occurrences, indicating the commodity and mineralization style.

Appendix 1 defines the terms used in the WAMIN database and Appendix 2 describes the digital datasets. The CD-ROM contains all data used to compile the map and report, including geophysical, remote-sensing, and topographic data. The CD-ROM also includes the files necessary for viewing the data in the ArcView Geographic Information System (GIS) environment, and a self-loading version of the ArcExplorer software package modified to suit this particular dataset. Metadata statements on the geological, geophysical, and topographic datasets are included on the CD-ROM.

Location, access, and physiography

The study area is in the north Eastern Goldfields of Western Australia and is defined by the WILUNA*, SIR SAMUEL, and DUKETON 1:250 000 map sheets, between latitudes 26° and 28°S and longitudes 120° and 123°E (Fig. 1).

The major sealed road access to the area is via the Kalgoorlie–Leonora–Wiluna–Meekatharra highway, which is sealed as far north as Mount Keith (Plate 1). Good-quality, shire-maintained unsealed roads connect the major mining centres, pastoral properties, and aboriginal communities.

The north Eastern Goldfields has predominantly low relief of between 430 and 520 m AHD (Australian Height Datum). Areas underlain by greenstones form ridges, low hills, and rocky outcrops extending up to 50 m above the surrounding plains. Granitoids form high domes and tors in some areas. Breakaways typically form in duricrust over weathered granitoids and greenstones at the headwaters of palaeodrainages.

The higher areas are surrounded by areas of sandplain and dunes, and low-lying areas defined by the Tertiary palaeodrainages include sheetwash and playa deposits.

Previous work

Geological mapping of the north Eastern Goldfields at 1:250 000 scale was completed in the early 1980s and included SIR SAMUEL (Bunting and Williams, 1979), DUKETON (Bunting and Chin, 1979), and WILUNA (Elias and Bunting, 1982). A new 1:250 000 geological map of WILUNA is being compiled (Farrell, in prep.) based on the recent 1:100 000 mapping by the Geological Survey of Western Australian (GSWA) and Australian Geological Survey Organisation (AGSO).

Geological maps at 1:100 000 scale have been published for the north Eastern Goldfields by GSWA and AGSO as part of the National Geoscience Mapping Accord (NGMA). Maps published by GSWA include SIR SAMUEL (Liu, et al., 1996), DARLOT (Wyche and Westaway, 1996), DUKETON (Farrell and Langford, 1996), WILUNA (Langford and Liu, 1997), MILLROSE (Farrell and Wyche, 1997), CUNYU (Adamides et al., in prep.), DEPOT SPRINGS (Wyche and Griffin, in prep.), BANJAWARN (Farrell and Griffin, 1997), and COSMO NEWBERY (Griffin and Farrell, 1998). Maps published by AGSO include BALLIMORE (Blake, 1996), SANDALWOOD (Blake, 1995), WANGGANNOO (Lyons, 1996), TATE (Champion, 1996), URAREY (Champion and Stewart, 1996), DE LA POER (Stewart, 1996), LAKE VIOLET (Stewart, 1997a), MOUNT KEITH (Jagodzinski et al., 1997), and YEELIRRIE (Champion and Stewart, 1995). Sheet locations are shown on Plate 1.

* Capitalized names refer to standard map sheets.

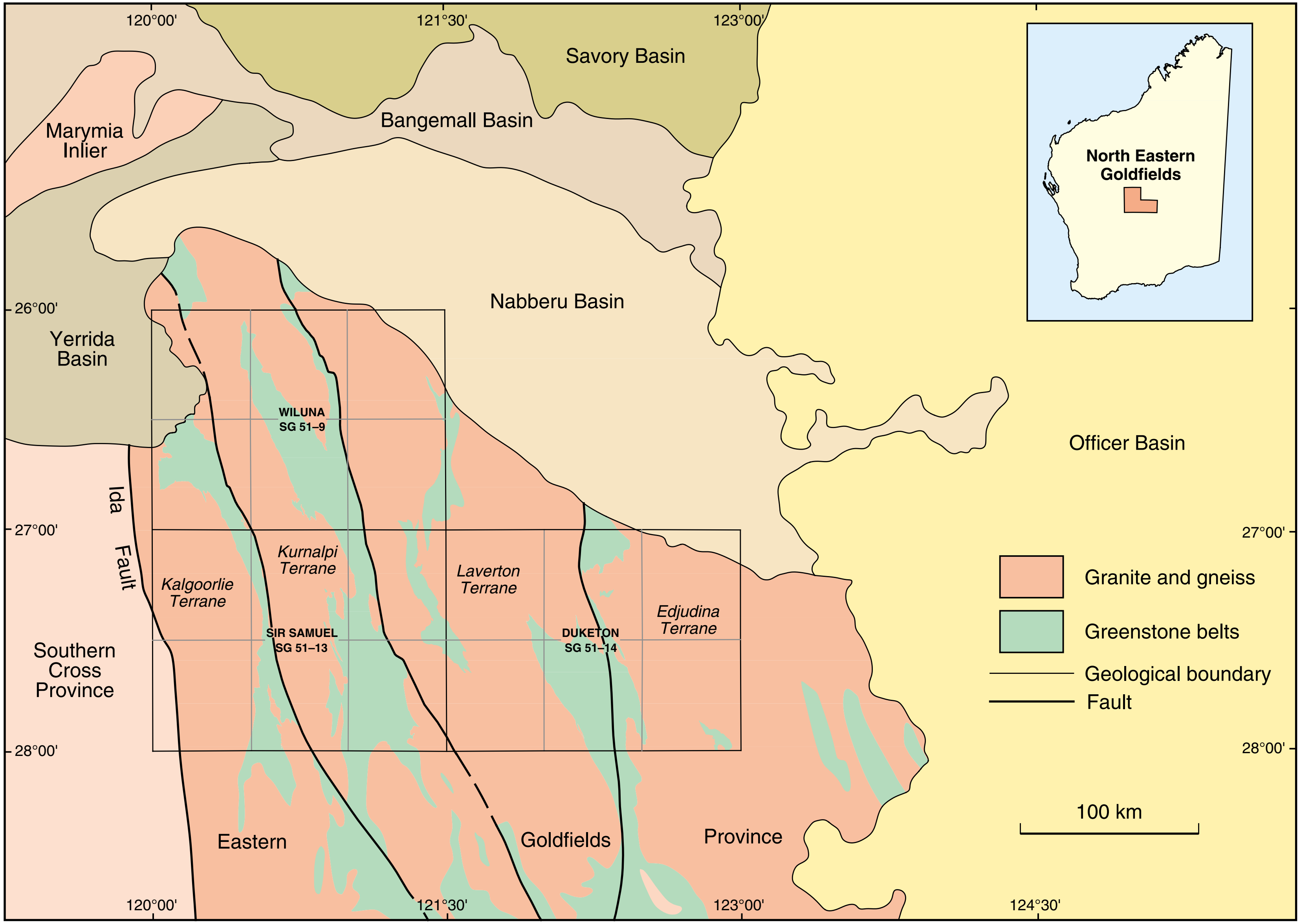

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Figure 1. Location and tectonic setting of the north Eastern Goldfields showing the relevant 1:250 000 geological maps

Earlier reconnaissance investigations and mapping in the area by GSWA and the Commonwealth Scientific and Industrial Research Organisation (CSIRO) include those by Blatchford (1899), Reed (1897), Talbot (1920, 1926), and Clarke (1925) in the Sir Samuel – Duketon area; Hobson and Miles (1950) in the Duketon area; and Sofoulis and Mabbutt (1963) in the Wiluna area.

A 1:250 000 regolith and geochemical map of SIR SAMUEL with accompanying Explanatory Notes (Kojan et al., 1996) was published as part of the regional regolith and geochemical mapping program of GSWA.

Geophysical investigations were carried out in the Wiluna gold mining area by Blazey et al. (1940) and Richardson et al. (1942). More recently, aeromagnetic, radiometric, and gravity maps were compiled by the Bureau of Mineral Resources (BMR, now AGSO). The 1:250 000 aeromagnetic map of WILUNA was interpreted by Lambourn (1972), and 1:250 000 aeromagnetic and radiometric maps of SIR SAMUEL and DUKETON were reported on by Shelley and Waller (1967).

Early GSWA mineral occurrence and resource studies in the area were carried out by Jutson (1914, 1917), Montgomery (1909, 1928), Gibson (1906a,b; 1907), Talbot (1914), and Maitland (1919). These dealt predominantly with aspects of mining and mineral resources of the Sir Samuel, Darlot, Mount Keith, and Wiluna gold mining centres.

Regional geological setting

Precambrian geology

The north Eastern Goldfields lies within the Eastern Goldfields Province of the Yilgarn Craton (Gee et al., 1981; Myers, 1997). It is part of an Archaean superterrane of north-northwesterly trending greenstone terranes in which areas of predominantly granitoid separate greenstone belts (Figs 1 and 2).

Figure 1 shows the distribution of the terranes, which is largely interpreted from recent mapping, high-quality aeromagnetic data and by extrapolation from more detailed work to the south (Myers, 1997; Swager, 1997).

The main greenstone belts within the north Eastern Goldfields terranes (Fig. 2) are dominated by thick mafic to ultramafic volcanic sequences, including tholeiitic, high-Mg, and komatiitic extrusive rocks and their intrusive equivalents. Significant portions of felsic and intermediate volcanic and subvolcanic sequences are present in the Yandal, Agnew–Wiluna, and Duketon belts. Pelitic and psammitic sedimentary sequences interbedded with chert, banded iron-formation (BIF), and shale are represented in the southern Agnew–Wiluna and Duketon belts. Dominantly monzogranitic granitoids are present both within and between the greenstone belts. These are often complexly associated with gneissic rocks and migmatite.

Proterozoic sedimentary rocks of the Yerrida and Earaheedy Basins unconformably overlie the Archaean basement along the northern margins of the study area. The Yerrida Group, northeast of Wiluna, comprises a sag-basin succession (the Windplain Subgroup) of shallow-water arenite and conglomerate, silicified evaporitic rocks, and stromatolitic carbonate rocks overlain by deeper water siltstones, shales, and carbonate rocks. The upper part of the Yerrida Group (the Mooloogool Subgroup) represents a rift-basin setting, with aphyric mafic lavas and intrusive rocks, black shale, siltstone, and carbonate rocks (Pirajno et al., 1995).

The sedimentary rocks of the Earaheedy Basin represent shallow-marine conditions following marine transgression (Bunting, 1986; Occhipinti et al., 1997).

Throughout the north Eastern Goldfields the Archaean rocks are cut by a swarm of Proterozoic mafic, microgabbro, and gabbro dykes. These have variable trends, but the predominant groups are easterly to east-southeasterly, northeasterly, and south-southeasterly trending.

Tectonic framework

The western boundary of the Eastern Goldfields (Fig. 1) is defined by the regional Ida Fault, which dips eastward to a depth of 28 km. At that depth it is a flat-lying zone of intense ductile deformation. In an earlier phase of movement, the Ida Fault partially thrust the Eastern Goldfields over the older granites and greenstones of the Southern Cross superterrane (Myers, 1997). Major north-northwesterly trending shears and faults outline the distribution of the greenstone terranes and the greenstone belts within them (Plate 1, Figs 1 and 2). The various terranes are defined as having different and distinct geological histories, primarily from work in the better exposed southern part of the Eastern Goldfields. They are interpreted (Myers, 1997) as having been brought into their present conjunctions tectonically.

Myers (1997) summarized the evolution of the Eastern Goldfields in terms of these processes. The greenstones were deposited between 2720 and 2675 Ma, with the oldest granites emplaced as sheets during the early phases of this event. The D_1 deformation event, expressed as a steeply dipping east to northeasterly trending schistosity, led to thrust stacking and recumbent folding of the greenstones and granites. During a subsequent regional east–west extensional event, clastic sedimentary basins formed in association with the extensional faults.

A regional east-northeasterly to west-southwesterly compressional event (D_2) occurred at about 2660 Ma, and was associated with peak (amphibolite facies) metamorphism and abundant intrusion of granite plutons (Fig. 3). This event is expressed as large-scale, open to tight, upright isoclinal folding and a pervasive, regionally extensive, north to northwesterly trending axial planar cleavage (S_2). Sinistral transcurrent faulting and en echelon folding (D_3) further modified this already thrust-sliced and folded sequence, and probably reactivated the

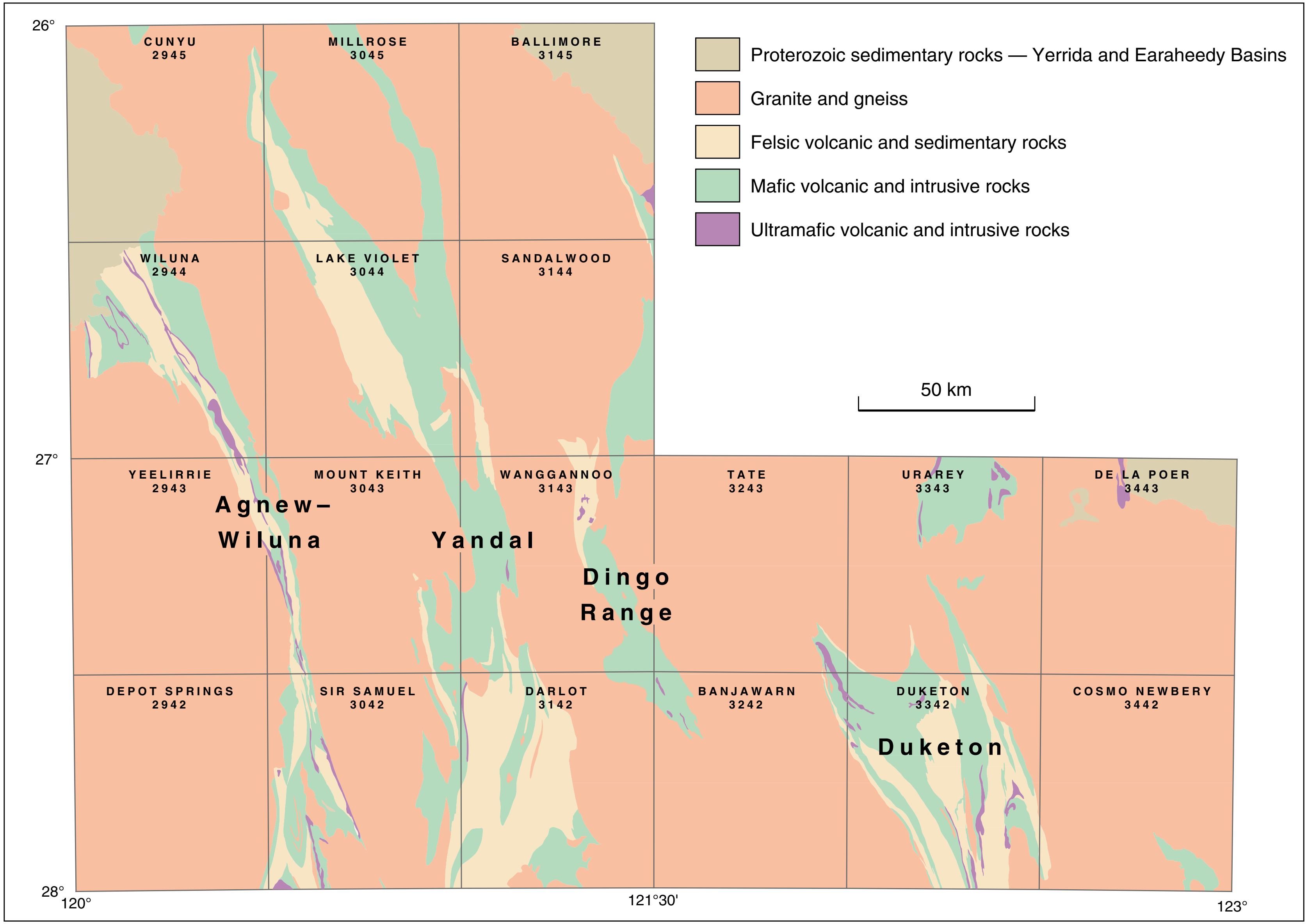

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Figure 2. Simplified geology of the north Eastern Goldfields, showing the greenstone belts and the relevant 1:100 000 geological maps

Figure 3. Wiluna South pit (Matilda), showing westerly dipping D_2 foliation

earlier thrusts. These are represented by north to northwesterly trending ductile shear and fault zones in which the movement was largely strike-slip.

Kinking and crenulation of all the structures occurred during the D_4 event and was associated with small-scale faulting and quartz veining.

Regolith

Consolidated and unconsolidated Cainozoic regolith is widespread in the north Eastern Goldfields, and is developed over the stable ancient landscape of deeply weathered Archaean and Proterozoic basement. The regolith units are predominantly of Tertiary age with a veneer of Quaternary unconsolidated deposits. This surficial cover comprises both indurated relict deposits exposed by recent erosion and a variety of younger clastic and chemical deposits (Table 1).

Archaean Craton

Greenstone belts

Stratigraphy

The recent GSWA mapping of the SIR SAMUEL (Liu et al., in prep.), WILUNA (Langford and Liu, in prep.), DARLOT (Westaway and Wyche, in prep.), and DUKETON (Langford and Farrell, in prep.) 1:100 000 map sheets has not clearly established either a greenstone stratigraphy for the north Eastern Goldfields or correlations with the better studied greenstones in the south Eastern Goldfields. Uncertainties in correlation are due to a lack of detailed structural control, high levels of alteration, deep weathering, and poor exposure.

In the Wiluna area, Liu et al. (1995) recognized a metamorphosed sequence with five units from basal basalt and gabbro (including a laterally extensive ultramafic flow) through basalt, felsic volcanic and sedimentary rocks, ultramafic rocks, and an upper unit of felsic sedimentary and volcanic rocks. Liu et al. (1995) suggested that this was a similar sequence to the Kalgoorlie Terrane. In the southern Agnew–Wiluna belt, Liu et al. (in prep.) reported a metamorphosed sequence of basal ultramafic and mafic rocks followed by felsic volcanic and sedimentary rocks, which is in turn overlain by basalt, lesser amounts of gabbro, and sedimentary rocks. They considered that the sequence of layered gabbro overlain by tholeiitic basalt in the Yakabindie area lacks local equivalents.

The stratigraphy is less clearly defined in the Duketon and Yandal belts. Langford and Farrell (in prep.) stated that only locally coherent sequences are mappable in the Duketon belt, and that their stratigraphic context is uncertain due to the lack of detailed structural control and poor exposure. Wyche and Westaway (1995) stated that greenstones in the Yandal belt have a different character to those in the Agnew–Wiluna and Duketon

Table 1. Simplified regolith scheme

Code	*Description*
Relict	Ferricrete Massive ironstone Calcrete Silcrete Silica caprock over ultramafic units Saprock
Depositional — proximal	Ironstone deposits Colluvium
Depositional — distal	Sheetwash deposits Sandplain Alluvial deposits Eolian deposits Lacustrine deposits

belts in that they have a smaller ultramafic component. They considered the Yandal greenstones to more closely resemble parts of the sequence in the Leonora–Laverton area.

Lithology

The metamorphosed ultramafic rocks (*Au*) are mainly concentrated in the Agnew–Wiluna and Duketon belts. These are typically thin, laterally extensive units that are often deeply weathered and poorly exposed. Common rock types include serpentinized peridotite with olivine cumulate textures and komatiite with platy olivine spinifex textures. These are likely to represent thick komatiite lava flows. Dunite and serpentinized dunite with relict adcumulate textures are also recognized. Talc–carbonate rocks, talc schists, talc–chlorite schists, and tremolite schists are common, but their original rock types are more difficult to ascertain. Mixed sequences of ultramafic rocks and banded iron-formation (*Au+Aci*) are also present.

Metamorphosed mafic rocks are widespread in all the greenstone belts and are divided into those that are recognizably intrusive (*Aog*) or predominantly extrusive (*Ab, Aba, Abg, Abi, Abm, Ab+As*). Metagabbro (*Aog*) is composed of amphibole after pyroxene with subordinate plagioclase and magnetite, and forms sills and various other types of intrusions in the greenstone sequences.

Metamorphosed extrusive mafic rocks include basalt (*Ab*); amphibolite (*Aba*), which is extensive in higher grade areas and represents metamorphosed basalt and gabbro; interleaved basalt and granitoid (in which basalt is dominant, *Abg*); high-Mg basalt (*Abm*); and mixed mafic and sedimentary rocks (*Ab+As*).

Metamorphosed felsic volcanic rocks (*Af*) are well represented in the Wiluna and Yandal belts, the Mount Keith area, and the central Duketon belt. They include felsic volcanic and subvolcanic rocks and volcaniclastic sedimentary rocks, often identified from small isolated exposures. They may include extremely foliated and recrystallized schists, and metamorphosed dacite, felsic tuff, and rhyolite–dacite lava. Metamorphosed andesite (*Afi*) and metamorphosed porphyritic dacite (*Afdp*) are also recognized.

Metamorphosed sedimentary rocks (*As*) are predominantly found in the Duketon belt, the central and southern parts of the Agnew–Wiluna belt, and more restricted parts of the Wiluna area and Yandal belt. Most are fine grained, strongly deformed, and deeply weathered and may include volcaniclastic rocks. Many of the sedimentary rocks, particularly in the Yandal belt, are mixed sequences of metamorphosed sedimentary and felsic rocks (*As+Af*). Chert (*Ac*) and banded iron-formation (*Aci*) are also recognized. Metaconglomerate (*Asc*) is present at the southwestern boundary of the Duketon belt and, most notably, in the Agnew–Wiluna belt as the Jones Creek Conglomerate. This conglomerate in the Kathleen Valley area and a similar unit on the western flank of the Lawlers Anticline show a variety of textures and compositions. Notably, it contains granite clasts, establishing granitoid intrusion as pre-greenstone or prior to the cessation of deposition of the greenstones.

In Plate 1 metamorphic rocks of low to medium grade have not been separated from their less metamorphosed equivalents. Higher grade metamorphic rocks have been grouped as quartzofeldspathic gneiss (*Anq*), mixed granitoid and quartzofeldspathic gniess (*Agnq*), and the relatively rare and unusual interlayered quartzofeldspathic gniess, monzonite, and metamorphosed mafic rock (*Angb*) that is found only near the northern end of the Yandal belt. The quartzofeldspathic gneiss is located in a northerly trending zone northwest of the Duketon belt, while the mixed granitoid and quartzofeldspathic gneiss unit is found on the western sides of both the Duketon and southern Agnew–Wiluna belts, and east of the northeastern limb of the Yandal belt.

Granitoids

Granitoids are present mainly between, and on the margins of, the greenstone belts. Only minor bodies are present within the belts. They are all often very poorly exposed and deeply weathered.

The large granitoid masses that lie between the greenstone belts (*Ag*) are slightly deformed in the core areas, but are strongly banded and heterogeneous towards the greenstone margins and adjacent to major shears. These large areas of granitoid are dominated by monzogranite. In the marginal areas narrow zones of intercalated greenstones are incorporated within the dominant granitoid (*Agb*), some in the form of gneissic banded amphibolites. Two bodies of granodiorite (*Agg*), marginal to and within the Yandal greenstone belt, contain elongate mafic xenoliths. The Weebo Granodiorite (*Agwe*) in the southern part of the Yandal belt may be comagmatic with these. Relatively small bodies of syenite (*Ags*) are found marginal to and within the Yandal belt. The Wandarrah Quartz Monzonite (*Agwa*), a hornblende–quartz monzonite, lies northeast of the Darlot mine on the eastern margin of the Yandal belt. Large bodies of quartz monzonite (*Agzq*) are present within the regional monzogranite, in the gneissic zones at the northern end of the Yandal belt.

Proterozoic basins

The Proterozoic sedimentary rocks of the Yerrida and Earaheedy Basins unconformably overlie Archaean basement on the northern margins of the north Eastern Goldfields. The sag- and rift-basin settings of the Yerrida Group were followed by the shallow-marine transgression of the Earaheedy Group.

Yerrida Group

The basal units of the Yerrida Group (in the Yerrida Basin), outcropping west and northwest of Wiluna, are assigned to the Juderina Formation (*ⱣYj*) and Bubble Well Member (*ⱣYjb*). They are exposed on escarpments and form prominent hills in the Finlayson Range. The Juderina Formation comprises mature quartz arenite with minor conglomerate, and the Bubble Well Member comprises chert breccia derived from stromatolitic carbonate rocks.

Small areas of the terriginous, sedimentary Johnson Cairn Formation (*ⱣYc*) and Thaduna Formation (*ⱣYt*) are located in the northwestern corner of the study area. They are overlain by aphyric tholeiitic lavas and microgabbro sills of the Killara Formation (*ⱣYk*), which formed in a rift basin. The Bartle Member (*ⱣYkc*) of the Killarra Formation contains complexly intermixed chert, cherty evaporitic units, and silicified pyroclastic material. Black shales, siltstones, and carbonate rocks of the overlying Maraloou Formation (*ⱣYm*) form small outcrops, west-northwest of Wiluna.

Earaheedy Group

Shallow-marine units of the Earaheedy Group (in the Earaheedy Basin) are principally represented by the basal Yelma Formation (*ⱣEy*), comprising quartz arenite and shale with a few lenses of stromatolitic carbonate towards the top, and the Frere Formation (*ⱣEf*), comprising iron-formation with siltstone and chert interbeds. The overlying Windidda Formation (*ⱣEwi*) and Wandiwarra Formation (*ⱣEwa*) include stromatolitic carbonate rocks, sandstone, marine shale, and minor conglomerate.

Unassigned outliers of quartz arenite and shale (*Ᵽs*) at Mount Wilkinson Well and Mount Lawrence Well may belong to the Yelma Formation of the Earaheedy Group.

Proterozoic dykes

The Archaean granite–greenstones and the Proterozoic basins are cut by easterly to southeasterly trending mafic dykes (*Ᵽdy*). These dolerite and basalt dykes are prominent linear features on aeromagnetic images.

Permian geology

Outliers of the Officer Basin, comprising Permian conglomerate, sandstone, and mudstone (*Ᵽs*), form small isolated patches throughout the north Eastern Goldfields. The largest of these is in the eastern part of the area, northeast of the Duketon belt.

Cainozoic geology

The Cainozoic regolith, which mantles the Archaean and Proterozoic geology of the north Eastern Goldfields, formed predominantly in the Tertiary, but includes a veneer of Quaternary cover. Table 1 groups the main relict and depositional types of regolith.

Residual duricrust and related chemical deposits are the oldest units, and are mainly preserved as low hills and breakaways. Proximal slope-transported regolith often forms a thin veneer over the duricrust.

More-distal deposits are related to the extensive Tertiary palaeodrainage system, which forms a dendritic pattern indicating a flow direction to the southeast, towards the Eucla Basin. One exception is in the northeastern part of the Duketon area where palaeo-drainage was westward, towards the Indian Ocean. The system contains extensive playa deposits and the margins grade into basin and dune topography. Quaternary alluvial deposits occupy the fluvial channels and currently active floodplains, and grade downstream into lacustrine sediments in playa deposits. Small non-saline claypans have formed on the margins of the playa deposits and in some of the larger palaeodrainage systems.

Table 2 lists the regolith codes for the north Eastern Goldfields, which are included in the digital dataset accompanying this report. The Tertiary lithologies that are essentially relict have developed on weathered rock and include ferruginous duricrust (*Czl*), massive ironstone ridges and cappings (*Czli*), silcrete (*Czz*), and silica caprock developed over ultramafic rocks (*Czu*).

Proximal depositional units include degraded ferruginous duricrust and massive ironstone rubble (*Czf*), areas of granite rubble over deeply weathered granitoid (*Czg*), quartz-vein rubble and debris (*Czcq*), and colluvial deposits of gravel and sand as sheetwash and talus (*Czc*).

More-distal colluvial deposits of clay and fine sand form extensive sheetwash fans (*Cza*). Extensive sandplains (*Czs*) are dominated by unconsolidated quartz-rich sand and overlie granitoids. Quaternary alluvial deposits in active fluvial channels and floodplains (*Qa*) and in small claypans (*Qac*) may be part of the active system. Playa lakes in the major palaeodrainage valleys contain deposits of saline and gypsiferous evaporites and clay and sand (*Czp*). Sand, silt, clay, and gypsum form stabilized dunes in and around playa lakes (*Czd*), and ephemeral lake and dune deposits have formed in drainage basins adjacent to the lakes (*Czb*). Calcrete

Table 2. Regolith codes for the north Eastern Goldfields

Code	*Description*
Qa	Alluvium — clay, silt, sand, and gravel in channels and flood plains
Qac	Clay and silt in claypans
Cza	Sheetwash deposits — clay, silt, and sand in extensive fans; commonly ferruginous
Czb	Ephemeral lake and dune deposits — clay, silt, and sand in drainage basins adjacent to playa lakes
Czc	Colluvium — silt, sand, and rock debris in slope deposits and proximal sheetwash; includes ironstone fragments
Czcq	Quartz-vein rubble and debris
Czd	Dune deposits — sand, silt, clay, and gypsum in stabilized dunes adjacent to playa lakes
Czf	Ferruginous rubble — degraded lateritic duricrust and ferruginous debris
Czg	Sand over granitoid — quartzofeldspathic sand
Czk	Calcrete
Czl	Laterite — lateritic duricrust
Czli	Massive ironstone as ridge and capping
Czp	Playa deposits — saline and gypsiferous evaporites, clay, and sand in playa lakes
Czs	Sandplain deposits — unconsolidated sand, and minor silt and clay; includes low, vegetated dunes
Czu	Silica caprock over ultramafic rock
Czz	Silcrete
Regolith as shown in Plate 1	
D	Depositional (Qa, Qac, Cza, Czb, Czc, Czcq, Czd, Czk, Czp, Czs)
R	Relict (Czf, Czl, Czu, Czz)
E	Exposed (Outcrop + Czli, Czg)

(*Czk*) has formed within the alluvial-channel sediments and at margins of lakes.

Plate 1 shows a simplified regolith scheme, as it is principally designed to illustrate the geological distribution of mineral occurrences. The classification of regolith materials uses a modification of the CSIRO RED scheme (Smith et al., 1992) in which three broad groups are differentiated: relict, exposed, and depositional. The relict and depositional regolith types in Plate 1 are indicated by a pattern overlay on the solid geology. The exposed regolith type includes outcrop and relict massive ironstone and residual sand over granitoid, and is left clear. Table 2 includes the code for the three regimes.

Exploration and mining

Gold

Mineral exploration in the north Eastern Goldfields commenced in the 1890s following the discovery of gold in the Kalgoorlie–Coolgardie area. Since then exploration has been dominantly for gold. Mesothermal vein and hydrothermal gold deposits proximal to major zones of faulting and shearing are present within and at the margins of the greenstone belts. These gold deposits formed between 2.64 and 2.63 Ma in brittle–ductile structures, predominantly in mafic volcanic rocks (with high Fe:(Fe+Mg) values and metamorphosed to greenschist facies), dolerites, or BIF (Solomon and Groves, 1994; Yeats and McNaughton, 1997). Volumetrically less-significant mineralizing events occurred at about 2.66 Ma and after 2.63 Ma. Major gold-mining centres in the north Eastern Goldfields are at Wiluna, the Kathleen Valley – Sir Samuel area, and Darlot. More recent discoveries have drawn attention to the potential of the Yandal and Duketon belts (Plate 1).

The major gold-mining centres at Wiluna, Kathleen Valley, Sir Samuel, Lawlers, Darlot, and Duketon were discovered and began production between 1896 and 1900 (Appendix 3). Continuity and levels of production from these areas fluctuated, with peak production in 1903 declining to low levels by the 1920s, followed by a resurgence in the 1930s. A further decline occurred in the 1960s.

The 1980s and 1990s have seen a steady return to high levels of production and exploration with redevelopment in old centres such as Wiluna, Bellevue in the Sir Samuel area, the Darlot area (including British King), and Bills Find and Corboys in the Yandal Belt (Appendix 4). New centres have been discovered and developed at Mount McClure, Bronzewing, Jundee–Nimary, and Gourdis in the Yandal belt, and at Baneygo, Russell Find, and Christmas Well (Fig. 4) in the Duketon belt. Present resources are tabulated in Appendix 5.

Residual gold is present in laterite, which overlies most gold occurrences and deposits in the area. In the old, relatively shallow workings throughout the area a significant proportion of the gold has come from this material. Some of the recent discoveries (such as those at Mount McClure, Bronzewing, and Gourdis) have a significant laterite-hosted resource that is mined by open-pit methods.

Nickel

Nickel sulfide mineralization is also a major part of the known and potential mineral resources of the north Eastern Goldfields. Nickel sulfide deposits of this type

Figure 4. Christmas Well pit at Duketon

are associated with large flows of high-temperature, high-Mg komatiitic lava (Hill et al., 1990; Hill et al., 1996). High-grade deposits form as adcumulates at the basal contacts of lava pathways. Larger, lower grade adcumulations of disseminated sulfides are centrally located in olivine-rich bodies within very large lava pathways (Barnes et al., 1997).

Examination of the WAMEX database indicates that modern exploration in the north Eastern Goldfields began in the mid-1960s. The initial focus was on nickel–copper mineralization in the Mount Keith, Yakabindie, Wiluna, and Duketon areas by Timor Oil, Tenneco Australia, Western Mining Corporation, Amax Exploration, Cominco Exploration, Kennecott Exploration, and CRA Exploration.

The nickel boom in the 1960s, triggered by the discovery of high-grade nickel sulfide at Kambalda, led to the discovery of a number of deposits in the Mount Keith – Perseverance belt (Fig. 5). The Perseverance (Agnew) deposit was discovered in 1971 and production began in 1976. Other mines have been developed as part of the Rockys Reward and Mount Keith projects, and further deposits have been discovered in the Honeymoon Well and Yakabindie areas. A laterite resource has been identified in the Wiluna area in the north-northwesterly extension of the ultramafic rocks that host the Honeymoon Well and Mount Keith deposits.

Up to 1997, nickel production in the north Eastern Goldfields was 71 586 t (1978–86) and 246 396 t (1989–97) from Leinster, and 66 908 t (1994–97) from Mount Keith. Resources are presented in Appendix 5.

Base metals

Following the discovery of the major Teutonic Bore deposit in the Leonora area in 1974, the felsic volcanic and metamorphosed sedimentary rocks of the north Eastern Goldfields were explored for volcanic-hosted base-metal sulfides. Exploration also began in the Duketon–Erlistoun area and at Bronzewing in the Yandal belt. There was detailed exploration in the Mason Hill – Fisher Well area and at Swanson Hill in the Duketon belt by Esso Exploration, Golconda Exploration, CEC Exploration, and Western Mining Corporation. The Mason Hill and Tuff Hill prospects were outlined in metamorphosed felsic volcanic and sedimentary rocks by percussion and diamond drilling. Gossans were identified at Tuff Hill in rhyolite breccias and in over 500 m strike length of tuffs using transient electromagnetic (TEM) surveys and percussion drilling

Small vein-type copper deposits with associated gold and silver have been worked at Kathleen Valley, but copper production has been relatively limited.

Uranium

Calcrete-hosted uranium is present in the extensive Tertiary palaeodrainage system of the region. Carnotite,

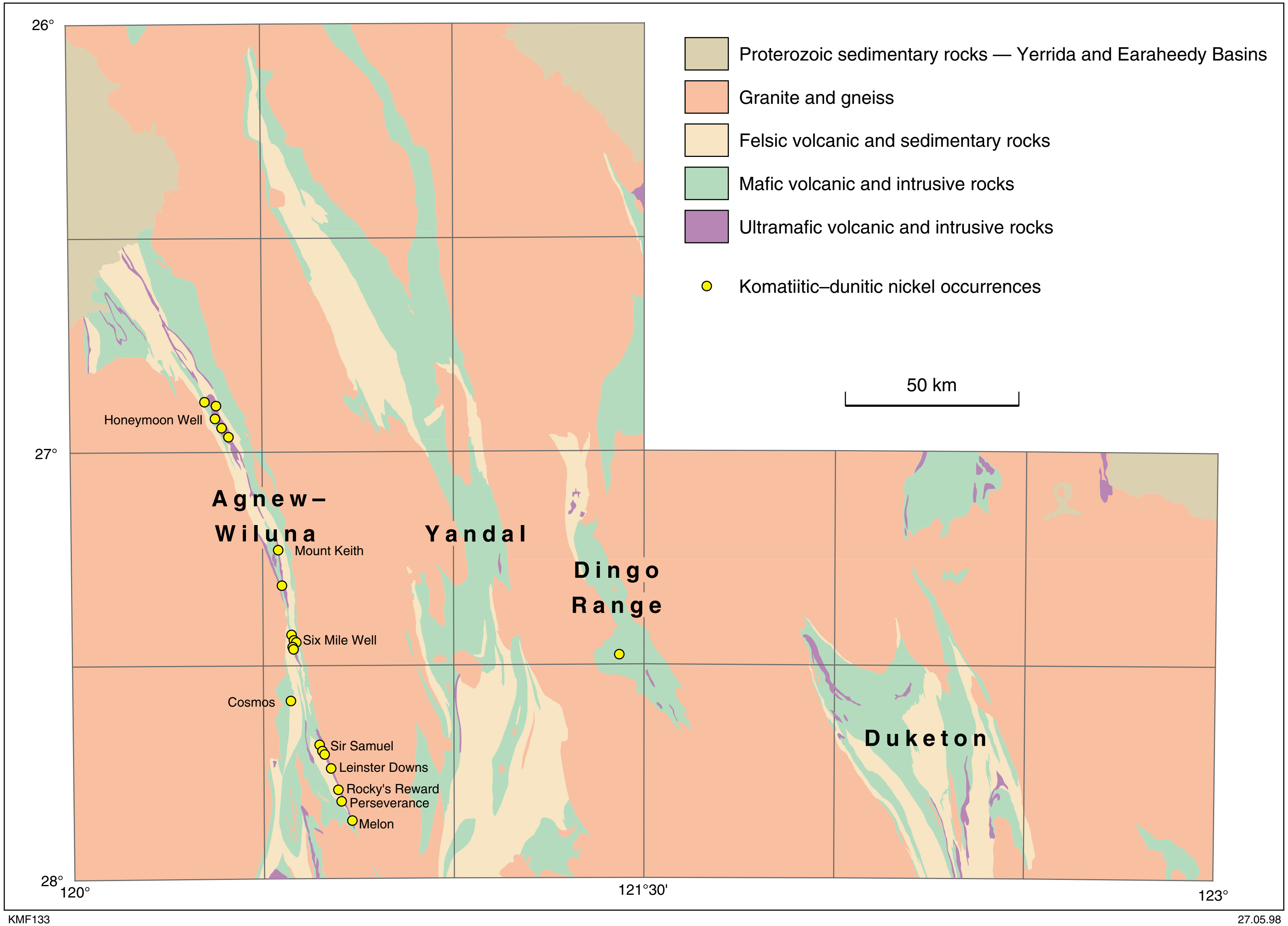


Figure 5. Orthomagmatic mafic and ultramafic mineralization — komatiitic to dunitic nickel occurrences

derived from leaching of uranium by ground and surface water from granitoid within the drainage catchment, is present in irregular coatings or fillings in the calcrete and in clays within playa lakes.

In the early 1970s exploration for uranium, for nuclear energy development, was stimulated in the area by the discovery of a uranium resource in calcrete within the Tertiary palaeodrainage at Yeelirrie. Subsequently, other deposits and occurrences were located at Abercromby Well, Lake Way, and Lake Maitland.

Mineralization

The 628 mineral occurrences on Plate 1 are grouped by commodity (colour) and mineralization style (symbol), as explained in Appendix 1. In the following sections the occurrences are grouped by mineralization style and then by commodity, in order of importance.

Orthomagmatic mafic and ultramafic mineralization

Komatiitic or dunitic

The work of Hill et al. (1988), Hill et al. (1990), and Hill et al. (1996) established that all the komatiite- and dunite-associated nickel deposits in the Eastern Goldfields are extrusive in origin, and can be subdivided into two types.

In the first type, the komatiite flows are thin (20–100 m). Massive sulfides (2–15% nickel) with olivine–sulfide cumulates (about 2.5% nickel) formed at the base of lava-flow channels in komatiite flow fields. The Perseverance – Rocky's Reward (1506–1510)* and Cliffs – Mount Keith (1619–1621) deposits are of this type.

In the second type, disseminated sulfides are present in the central zones of large bodies of olivine cumulate that occupy subvolcanic lava feeder zones. They range from olivine–sulfide orthocumulate to olivine–sulfide adcumulate, with grades averaging 0.6% nickel (reaching a maximum of 1.5% nickel). They include the deposits at Mount Keith (1619, 1621), Six Mile Well (1624), and Honeymoon Well (1515, 1524–1526).

Perseverance

The Agnew–Wiluna greenstone belt is one of the richest komatiite-hosted nickel sulfide provinces in the world, with reserves of about 190 Mt at 0.94% nickel (Libby et al., 1993).

The Perseverance nickel deposit (1507, 1508) conforms to the type 1 deposit style of Hill et al. (1996). It occupies the stratigraphic base of a 2.5 km-wide, 400 m-thick komatiitic lava-flow channel, which formed through thermal erosion of floor rocks of olivine adcumulate and mesocumulate. This body is an isolated subchannel within the more extensive channel-complex base. The channel complex is itself weakly mineralized, reflecting changing conditions and processes during active channel flow, and conforming to the type 2 deposit style of Hill et al. (1996) and Libby et al. (1993).

The mineralization at Perseverance and Rocky's Reward (1509, 1510) has been imbricated and folded during shearing at the base of the complex, and is within the zone of influence of the major Perseverance Fault. At Rocky's Reward the mineralized ultramafic unit is in complexly folded tectonic slices derived from a thicker ultramafic body (Libby et al., 1993).

Honeymoon Well

At Honeymoon Well (1515, 1524–1526), as at Mount Keith (1619, 1621), the nickel deposits are within a large lava pathway now occupied by olivine mesocumulate–adcumulate dunite. In this area the ultramafic sequence is anomalously thick (up to 3 km thick) due to duplication by faulting. Gole et al. (1996) recognized two ultramafic horizons in the complex. The lower horizon is characterized by a high degree of lateral lithological variation due to turbulent and episodic flow. This horizon hosts all the Honeymoon Well nickel deposits.

All the Honeymoon Well nickel deposits, with the exception of the Wedgetail deposit (1524), contain disseminated sulfides in olivine-rich cumulates and conform to the type 2 deposit style of Hill et al. (1996). The Hannibals deposit (1525) is on the western contact of the Honeymoon Well ultramafic complex (Gole et al., 1996). This deposit lies within a westerly younging, fault-bounded sequence dominated by olivine mesocumulates with minor olivine adcumulates and olivine orthocumulates. The mineralized sequence is repeated in western and eastern overlapping fault blocks along a low-angle fault. A subhorizontal, high nickel-grade core is present in the western block.

The mineralization is disseminated, with maximum nickel grades of 2.4%. The mineralized zones form igneous stratigraphic horizons that become thin and interdigitate with barren ultramafic rocks at the margins. About 30% of the deposit contains low-grade (300–2000 ppm) copper.

Vein and hydrothermal mineralization

Undivided

Mesothermal vein and hydrothermal gold mineralization falls within this style group (Appendix 1). It is the principal economic target in the northern part of the Eastern Goldfields.

The principal areas of gold prospecting and mining in the 1890s and early 1900s were within the greenstone belts, focusing in the Wiluna, Darlot, Sir Samuel,

* The number in parentheses following a deposit name is the unique WAMIN Deposit Number for that deposit, as used in Plate 1.

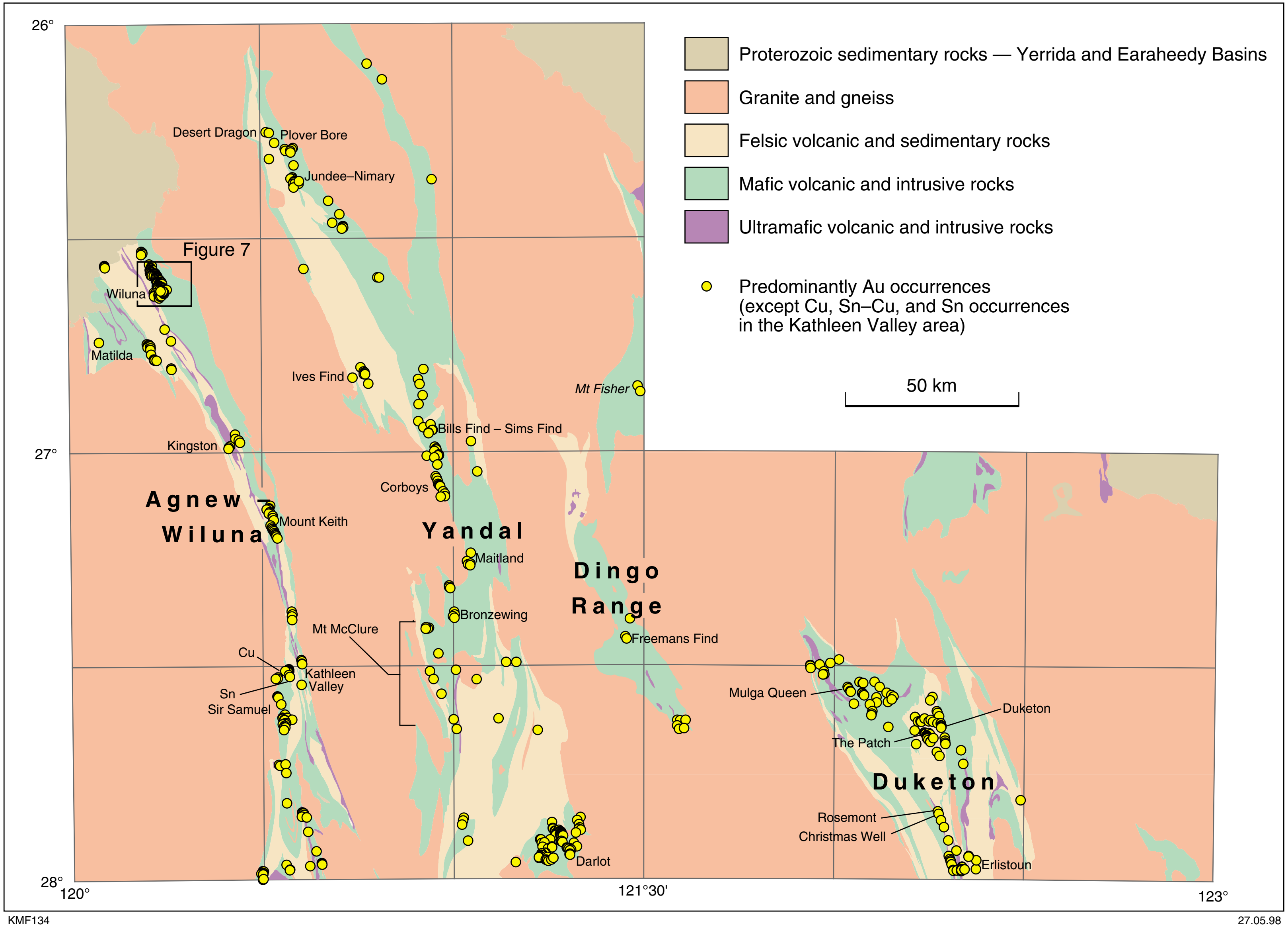


Figure 6. Vein and hydrothermal mineralization — predominantly gold occurrences

Kathleen Valley, Erlistoun, and Duketon centres. Since the advent of modern mineral exploration techniques in the 1950s and 60s, exploration for gold, nickel, and base metals has extended to all the greenstone belts. There have been significant discoveries in the less well-exposed Yandal belt and continuing development, including significant new discoveries, in the areas of historical development (Fig. 6).

A model or profile for this type of mineralization is now fairly well established (Solomon and Groves, 1994; Hodgson, 1993). Gold is associated with major structural breaks in stable cratonic terranes within fault and joint systems produced by regional compression or transpression, including major listric reverse faults and second- and third-order splays (Ash and Aldrick, 1996). High-strain regions, which show a high density of such anostomosing deformation zones, are associated with focused fluid flow.

The most favourable greenstone host rocks (basalt, gabbro, dolerite, and BIF) have high Fe:(Fe+Mg) values, are of middle to upper greenschist facies, and lie within the brittle–ductile transition zone, having formed at depths between 6 and 12 km. The vein and hydrothermal deposits may also be present in komatiites, intermediate to felsic volcanic and intrusive rocks, and sedimentary rocks. They are metamorphosed, with metasomatic addition of SiO_2, K_2O, CO_2, H_2O, S, and Au. Gold is usually associated with relatively low accumulations of As, Ag, W, Sb, Te, B, Cu, Pb, Zn, and Mo. Fluid sources may be metamorphic or magmatic, or a combination of the two.

Comparisons with more modern tectonic settings suggest that deposits may have been related to the closure of volcanic arc – marginal basin complexes in convergent margin environments (Solomon and Groves, 1994).

Wiluna mining centre

The main operating, high-production gold deposits (Fig. 7) at the Wiluna mining centre are at Wiluna, Happy Jack, Bulletin, and Moonlight (1008–1010, 1030, 1031, 1068, 1079, 1093, 1095, 1096, 1125–1128, 1131, 1132, 1135, 1140, 1514, 1532, 1533, 1535–1538, 2766). They are controlled by the north-northeasterly trending Wiluna strike-slip fault system (maximum dextral displacement of 1350 m) and hosted by low-grade mafic and ultramafic lavas. Hydrothermal breccias, cataclastic zones, tectonites, shear veins, and ladder veins in the fault zone indicate mostly brittle failure. Open-space filling textures suggest high-level low temperatures and pressures (Hagemann, 1997).

There are two types of gold mineralization in the Wiluna area (Fig. 7). The first type takes the form of visible gold in quartz-vein systems that are mainly conformable with the local sequence, and may in part be controlled by north-northwesterly trending faults. The second, more economically important mineralization is present as fine, more disseminated gold in lode systems in north to north-northeasterly trending cross-cutting shear zones (McGoldrick, 1990). Although the intensity of mineralization in the shear lodes is often unrelated to host lithology, there appears to be a favourable association where the shears cut tholeiitic lavas. Furthermore, during deformation competency contrasts between some units produced open spaces favourable for ore formation. In the shear-lode zones a combination of mineralized shear stockwork and disseminated ore between the shears produced orebodies up to 20 m thick. Primary ore consists of minute inclusions of gold in arsenopyrite and stibnite. The alteration assemblage is quartz–carbonate–pyrite–arsenopyrite–stibnite.

Bronzewing

At Bronzewing (1203–1206, 1574–1575, 2591, 2607, 2703) the orebodies take two forms: the first has complexly mineralized pipe-like stockwork vein arrays, and the second comprises narrower shear zones. Both are hosted by heterogeneously deformed tholeiitic basalt in a 500 m-wide, northerly trending structural corridor within a northerly striking mafic and ultramafic lithological package (Dugdale, 1997).

In the Discovery ore zone the mineralized tholeiites lie between a hangingwall granitoid intrusion and footwall ultramafic rocks. The northerly plunging ore zone is controlled by a conjugate set of north-north-westerly trending sinistral and northeasterly trending dextral deformation zones. The structural control is similar in the Central ore zone, but the zone plunges to the south-southeast. Both deposits are complexly mineralized pipe-like vein arrays. The four generations of veins are petrographically and structurally distinct, and suggest mixing of early, partially seawater-derived fluids and later gold-bearing fluids (Dugdale, 1997).

The stylistically different Western ore zone (Hickman, in prep.) lies about 200 m west of the Central zone and dips beneath it. The Western zone is a shear zone of laminated quartz and carbonate veining (up to 5 m wide and striking at about 20°) that may connect with the Old Bronzewing workings to the north, which were discovered in 1908 (Montgomery, 1909).

The pipe-like stockwork Central and Discovery ore zones may lie in 'pressure shadows' between northerly trending shear zones of the type seen in the Western zone (Hickman, in prep.).

Jundee–Nimary

In the northern part of the western arm of the Yandal greenstone belt (1541–1552, 2749), a system of closely spaced multiple lodes was explored by a number of companies following the discovery of mineralization by panning methods in 1988–89. Great Central Mines and Eagle Mining are presently mining some of these bodies, in adjoining tenements.

The main rock types are basalt, dolerite, and gabbro intruded by felsic porphyry. Relatively thin interbeds of sedimentary units become more numerous up dip to the west. Stewart (1997b) suggested that the lower basaltic and upper felsic volcanic and sedimentary sequences

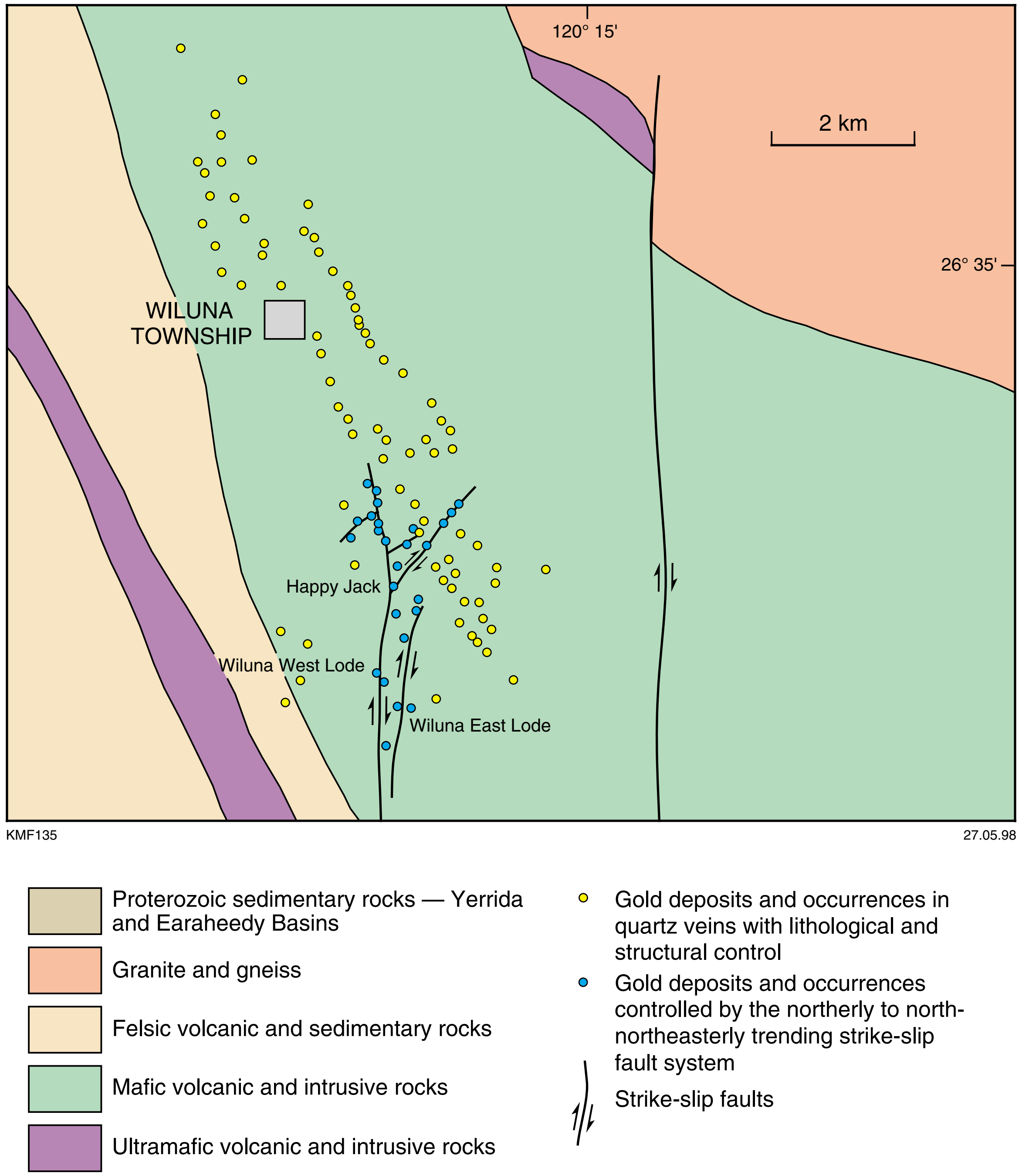


Figure 7. Vein and hydrothermal gold occurrences in the Wiluna area

of the Yandal succession are folded in a north-northwesterly trending D_2 synform. The Jundee–Nimary deposits appear to straddle the boundary between the lower and upper units. Hickman (in prep.) suggested that mineralization is associated with brittle-style deformation along northerly and northwesterly striking zones with low-angle southerly and southwesterly dips, and shows little lithological control. The orebodies are quartz–carbonate stockworks, and associated alteration includes silicification, carbonation, chloritization, and sulfidation. No major shear zones, which might have provided a conduit for mineralizing fluids, have been located nearby.

Bills Find

The Bills Find mine (1198) in the Yandal greenstone belt mainly produced gold in 1993–94. It is located in sulfidic quartz veins and veinlets within sheared banded pelitic and semipelitic metamorphosed sedimentary rocks, which lie between hangingwall felsic volcanic and intrusive rocks and footwall sedimentary rocks intruded by felsite and microgranite. The ore zone dips to the northwest and the shear zone trends northeast. The pelitic sedimentary rocks are sulfidic and carbonaceous, and ore zone alteration includes silicification, biotite alteration, sericitization, and sulfidation. Granitoids lie nearby to the west and southeast.

The deposit may be the result of a combination of structural (northeasterly trending shear adjacent to a major northwesterly trending fluid conduit) and chemical (carbonaceous pelitic sedimentary rocks) controls (Hickman, in prep.).

Mount McClure

The Mount McClure deposits (1468–1474, 2589, 2655, 2828, 2871, 2902) form an elongate group extending over about 15 km in mafic, ultramafic, and felsic volcaniclastic and epiclastic rocks. They are in part parallel to the north-northwesterly trending, sheared, granite–greenstone western margin of the Yandal belt.

The southern group from Success to Mount McClure South follows a linear, north-northwesterly trending anomalous zone, which is probably a major shear, and lies within a different part of the sequence from the northern deposits at Cockburn–Lotus. The Success–Parmelia–Challenger group lies in strongly sheared, easterly younging, mafic–felsic tuff and graphitic tuff with associated chert. The tabular orebodies dip 50° to the east. At Success the host metamorphosed sedimentary rocks dip 60° to the east. Further south, at Dragon, mineralization is hosted in ultramafic rocks in a sequence that dips 50° to the east, parallel to foliation (Harris, J., 1994, pers. comm.).

The mineralization at Lotus is in two parallel shears in a dolerite, within a complex, northerly striking, steeply westerly dipping but easterly younging sequence of metamorphosed felsic and ultramafic rocks, dolerite, basalt, basaltic to felsic tuffs, and sedimentary rocks. The shears and dolerite dip steeply to the east. An easterly trending sinistral fault with a displacement of 100 m has been located north of Calista (Harris, J., 1994, pers. comm.). The mineralization at Calista (1469) is controlled by a basalt–ultramafic contact, which is anomalous over a 3 km zone (Maxey, 1997).

Darlot mining centre

In the Darlot mining centre (1051–1062, 1064, 1066, 1067, 1071, 1074, 1075, 1109–1111, 1219, 1221, 1223–1225, 1227, 1228, 1231, 1233, 1234, 1237, 1276, 1278, 1280–1283, 1285, 1287, 1292, 1293, 1295, 1306, 1307, 1310–1313, 1341–1351, 1361, 1366–1368, 1626, 1960–1963, 2185, 2633) the lithological package includes metamorphosed dolerite and basalt intercalated with felsic volcanic and sedimentary units. These have been folded and thrust-faulted with a north-northwesterly trend. Later easterly and east-northeasterly trending faults cut the main fabric and are intruded by mafic–ultramafic bodies.

The main Darlot mine, which began operating in 1988, incorporated old workings such as Zangbar, Monte Christo, Filbandint, and Africander. The main Darlot lode shear is centred on a 1–3 m-wide laminated quartz vein trending northwesterly to north-northwesterly and dipping to the northeast at a relatively shallow angle (30–45°). The host rock is pyritic, silicified, carbonated, and chloritized basalt and dolerite. Mineable gold is also present in brecciated and quartz–carbonate-veined rocks of various compositions (Hickman, in prep.). Another similar northwesterly striking line of workings that lies 500 m to the northwest may be an extension of the Darlot line of lode. The St George workings lie about 1.5 km east of the Darlot line on a large, irregular quartz vein striking at 350° and dipping 45° to the west.

Centenary

The major 1996 gold discovery at Centenary (1628), about 1.2 km east of the Darlot pit, is locally more than 100 m thick, extends at least 1000 m to the north and south at depths between 150 and 500 m, and is open to the north, south, and west. The mineralized body includes intersections of up to 135 m at 4.4 g/t gold, and has an inferred resource estimated at 2.1 million ounces (8.4 Mt at 7.7 g/t).

The mineralization is associated with multiple, thin, shallow-dipping quartz veinlets with associated pyrite alteration in a northeasterly dipping sequence of basalts and felsic volcano-sedimentary rocks intruded by dolerite, in which it is best developed, (Bucknell, 1997). It lies within a north-northwesterly striking thrust fault that dips to the southwest by 30°. The fault cross-cuts the host sequence and appears to represent back-thrusting to the easterly dipping Darlot thrust fault. The mineralized body lies above the easterly extension of the Darlot fault-lode, which dips at about 20° to the east in this area. It is not known if the Centenary deposit continues beneath the Darlot fault, but recent results seem to suggest that parallel footwall and hangingwall mineralized zones lie above and below Centenary, above the Darlot fault (Bucknell, 1997).

Bellevue

At Bellevue, in the Mount Keith – Perseverance belt, gold mineralization (1416–1429, 1458, 1479–1482, 2643) is located in two northerly trending shear zones dipping 65° to the west in an east-facing mafic volcanic sequence, east of the Miranda Fault. The lodes consist of mylonitic sheared basalt and quartz breccia zones (Brotherton and Wilson, 1990). Quartz breccia ore shoots are present in dilational zones. Mineralization is associated with the intersection of structural planes and is present in both quartz breccias and mylonitized basalt.

Stratiform sedimentary and volcanic mineralization

Volcanic-hosted sulfide

Tuff Hill

Exploration by Carpentaria Exploration and Esso Australia located disseminated sulfides at Tuff Hill (767)

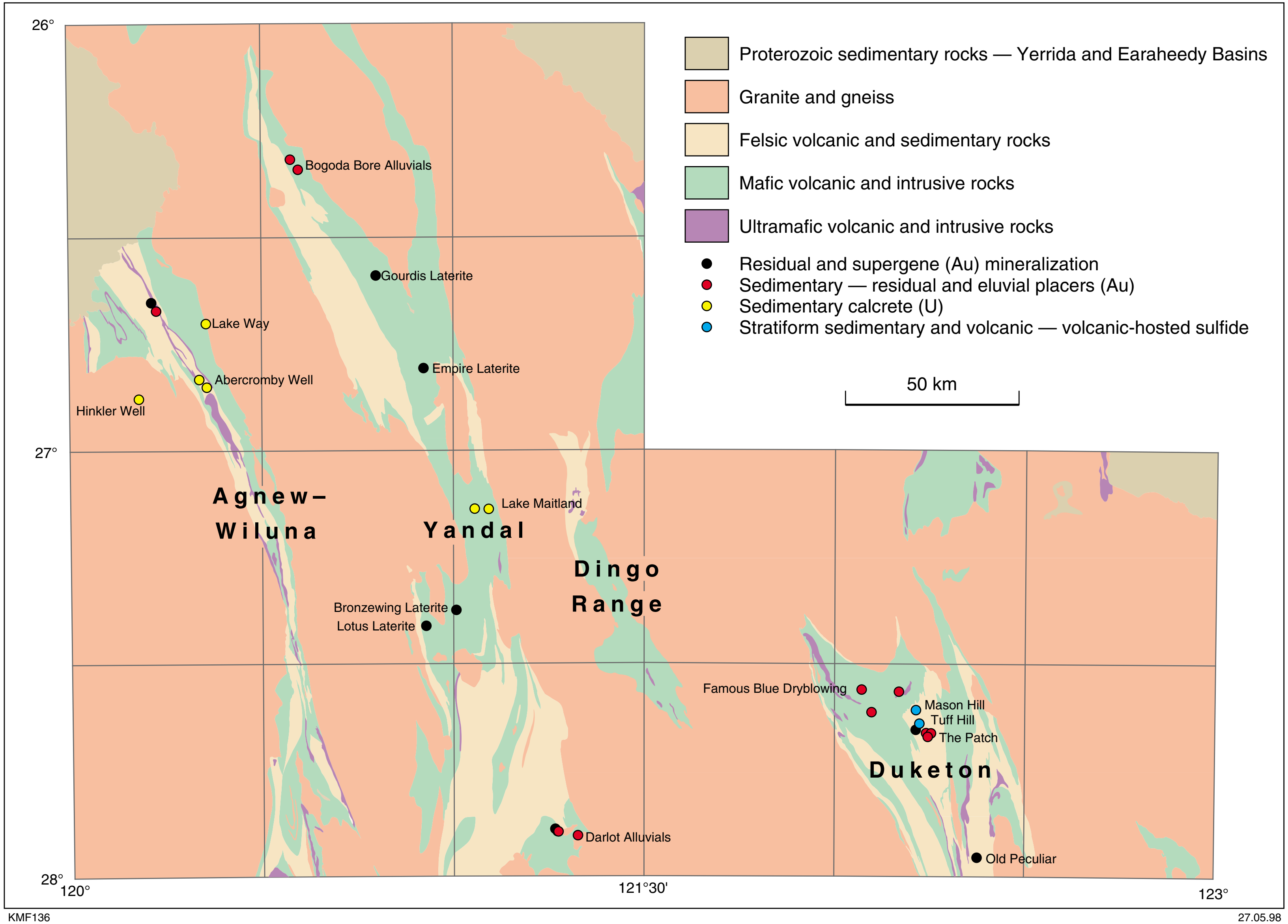


Figure 8. **Residual and supergene (gold) mineralization, sedimentary — residual and eluvial placers (gold), sedimentary calcrete (uranium), and stratiform sedimentary and volcanic mineral occurrences**

in quartz–sericite schist, interpreted as representing rhyolite tuff and minor breccia (possibly altered mafic tuff). The deposit is in the central-northern part of the Duketon greenstone belt in felsic volcanic and sedimentary rocks (Fig. 8) that form a north-northwesterly trending wedge between mafic and ultramafic rocks and banded iron-formation. Gossans extend about 500 m in a north–south direction along strike, and dip at about 60° to the west. Following successful target definition using TEM, percussion drilling intersected zinc-rich disseminated and massive sulfides in fragmental rocks. Diamond drilling intersected narrow zones (up to 0.3 m thick) of massive sulfides (mainly sphalerite with some pyrite, chalcopyrite, and galena), mostly in veins. The best intersection in the massive sulfides was 0.8 m at 2.9% zinc, 1.3% lead, 0.26% copper, and 70 g/t silver. A deeper intersection gave 0.1 m at 4.7% copper, 2.7% lead, 0.6% zinc, and 325 g/t silver. Mineralization is associated with sericite, silica, carbonate, and chlorite alteration.

Mason Hill

At Mason Hill (766), anomalous lead and zinc values were first located by Carpentaria Exploration in faulted rhyolite–andesite flows, tuff, and breccia with some chert, mafic rocks, and sedimentary rocks (Fig. 8). Gossans identified during exploration were also enriched in cobalt, bismuth, and gold. Percussion drilling indicated significant mineralization over a strike length of 400 m in rhyolite breccia, with intersections of up to 3 m at 4% zinc, 1% lead, and 0.2% copper. A maximum of 5.5 g/t of gold was recorded. Follow-up diamond drilling intersected narrow, high-grade zones of crudely layered sphalerite–galena–pyrite with minor chalcopyrite and tennantite in rhyolite breccia. A typical intersection was 0.3 m at 9.3% zinc, 1.6% lead, 0.07% copper, and 57 g/t silver. Fine stringer mineralization with quartz, chlorite veining, and remobilized galena and sphalerite may indicate remobilization associated with faulting, rather than feeder zones. There is sericite, silica, and tourmaline alteration.

A third Carpentaria Exploration prospect was identified at Fisher Well during exploration in the southerly extension of the sequence seen at Tuff Hill and Mason Hill, in rhyolitic and andesitic ash-tuff, agglomerate, and breccia. Chert horizons are absent, indicating no significant periods of quiescence. Percussion drilling, following up rotary air blast (RAB) drilling, encountered disseminated and vein pyrite with sphalerite, subordinate galena, and minor chalcopyrite in the coarser tuffs and agglomerates of three volcanic cycles. There is chlorite, sericite, silica, and tourmaline alteration. Grades of mineralization are comparably low (24 m at 0.4% zinc, 16 m at 0.43% zinc, and 0.3 m at 2.5% zinc). A diamond drillhole intersected 5.3 m at 1.2% zinc in brecciated, altered tuffs.

Sedimentary mineralization

Calcrete

Calcrete-hosted uranium deposits (Fig. 8) were discovered in the north Eastern Goldfields during the 1970s within the Tertiary palaeodrainage system, following the 1970 discovery of Yeelirrie to the west of the study area.

In the Wiluna area, drainages running from the north and west into Lake Way contain uranium prospects (1497) on the northern margin of the lake. These have formed at the junctions of the palaeodrainage and the lake. Carnotite forms coatings on bedding planes and broken calcrete blocks in clay and gravel. Four areas of high-grade mineralization have been delineated within a low-grade halo. A measured resource of 3.77 Mt of ore at 0.98 kg/t (3695 t U_3O_8) has been estimated.

Further south at Abercromby Well (1645) a second, easterly trending drainage enters the lake. A calcrete-hosted uranium prospect in a 6 km-wide calcrete delta has drill intersections of 1.65 m at 2228 ppm U_3O_8 and 1.75 m at 2331 ppm U_3O_8 from carnotite in the calcrete and in calcareous grits. In this drainage, another prospect has been outlined at Hinkler Well (1527), 15 km upstream from Abercromby Well. Mineralization forms irregular coatings and fillings in the calcrete, with widespread small, low-grade pockets. The highest surface-sample assay was 2300 ppm U_3O_8, and the highest drill-sample assay was 930 ppm U_3O_8.

Residual to eluvial placers

In many of the old gold workings in the north Eastern Goldfields a significant proportion of the mined gold came from material eroded from the ore deposit, either directly from outcrop or from the laterite capping the deposit. The material may be adjacent to the source deposit or extend in an extensive eluvial or alluvial mantle or fringe.

Examples are seen at The Patch (783, 786, 789), Famous Blue (2206), and Ten Mile Bore (904), about 5 km southeast of Famous Blue (Fig. 8). Extensive alluvial deposits in the Darlot mining centre (1290, 1598, 2840) were worked at the turn of the century by up to 600 dryblowers. More recent assessment of these alluvials by Ferrovanadium Corporation indicates that they are in well-defined stream channels in a sedimentary sequence up to 25 m thick. Recent, unconsolidated river gravels and flood plain deposits overlie lithified and semi-lithified ferruginous river gravels. Lithification of the older sediments has progressed to intense lateritization in places. Gold is present in both the lithified and younger sediments. Ferrovanadium Corporation estimated a grade of about 0.9 g/m^3 gold.

Residual and supergene mineralization

Many, if not most, of the hydrothermal gold deposits in the study area are lateritized at the surface to some extent. In many of the old workings development did not go far beyond the laterite ore. In some cases the laterite ore was a significant resource in itself and has been mined.

At Bronzewing (2606; Fig. 8), as in many other prospects and mines, the laterite ore led to the discovery of the underlying deposit. At Bronzewing the laterite ore contributed 500 000 t of ore averaging 1.5 to 2.0 g/t gold. Gold is present in the lower channel-fill and conglomerate breccia, which seems to be a proximal scree-like deposit overlying basaltic saprolite, and is also present in the overlying silty alluvial laterite. The overall thickness ranges from 8 to 60 m on a west-northwesterly dipping palaeoslope (Hickman, in prep.). At Monte Christo (1230) mining of the extended Darlot pit included a laterite resource of 135 000 t at 1.35 g/ t gold.

An example of old workings with a relatively thin mineralized laterite capping (770) is present about 3 km west-northwest of The Patch, west of Duketon. In an adit at the southern end of the line of workings, pisolite can be seen in cracks and openings within the upper parts of the solid rock, clearly having formed in situ and forming the bulk of the mined material.

The Gourdis mine (1554) accesses both laterite-hosted and primary mineralization.

Mineralization controls and potential

Orthomagmatic mafic and ultramafic mineralization

The distribution of nickel sulfide deposits in ultramafic igneous rocks in the north Eastern Goldfields is intimately associated with the volcanogenic setting of the host rocks and the process of segregation of the sulfides (Hill et al., 1996).

In type 1 deposits the basal accumulation of massive and matrix sulfide ores forms at the base of episodic, preferred lava pathways in komatiitic flow fields. These deposits are found in relatively narrow olivine cumulate and adcumulate lenses. In Type 2 deposits the lava flows are present as olivine adcumulate lenses with disseminated sulfide ore in broader, more continuous sheet flows within erosional pathways.

Locating such deposits requires fairly detailed reconstruction of the flow-field stratigraphy and morphology from mapping and drilling, in an environment affected by complex structural reworking of the original volcanic deposits and the effects of deep weathering.

Vein and hydrothermal mineralization

Gold

There is general acceptance that the distribution of mesothermal gold deposits in an Archaean craton setting is repeated on a crustal scale, and is principally controlled by a combination of structural features. First-order regional, linear, high-strain, ductile shear zones focus the flow of metamorphic and igneous fluids; second-, third-, or fourth-order brittle–ductile structures create a lower strain dilational environment in which mineralization can accumulate. The regional shear zones show abundant evidence of fluid flux, including quartz veining and hydrothermal alteration, but little or limited mineralization. Within the structurally favourable second-order or higher zones, gold deposition was controlled by fluid–wallrock reactions, such as the sulfidation of iron-rich hosts. Thus basalt, dolerite, and banded iron-formation are most commonly associated with mineralization.

In general, as can be seen in Plate 1 and Figure 6, the regional distribution of gold occurrences in the north Eastern Goldfields conforms to this structural–lithological pattern. The distribution of old workings, mines, deposits, and occurrences in the Wiluna and Matilda areas demonstrates this pattern on a smaller scale. In the Wiluna area, for example, the mafic-dominated eastern part of the sequence is weakly mineralized in strike-parallel, north-northwesterly trending quartz veins, and strongly mineralized in lodes in northerly striking complex dilational structures (Fig. 7). The western part of the sequence, however, is characterized by felsic–intermediate volcanic rocks and sedimentary rocks, and is relatively unmineralized. Where mineralization is present in this western area, in Wiluna Mines' Regent and Red Lady prospects (1522–1523), it is associated with north-northeasterly trending strike-slip faults where they intersect dolerite and ultramafic units within the dominantly felsic sequence.

In the Matilda area (1516–1521), west of the major Perseverance Fault, the mineralization is also in predominantly mafic units dominated by high-Mg basalts and chlorite schists (Morgan and El-Raghy, 1990; Hagemann, 1997). It is close to a contact with an eastern zone of felsic tuff, and controlled by northerly to north-northeasterly trending strike-slip faults marginal to the Perseverance Fault. Mineralization occupies zones of intense shearing, stockwork veining, and sericitic alteration (Morgan and El-Raghy, 1990).

The second style of mineralization seen at Wiluna is hosted in quartz veins and is subparallel to lithology (Fig. 7). It is seen in the line of old workings extending north-northwest along the Black Swan – Caledonian trend (966, 982). This style tends to produce thin limited concentrations of mineralization. Other groups of occurrences and workings on this trend appear to line up either on lithological boundaries or on faults and shears. In the Mount Keith group (1252–53, 1255, 1259–61, 1264–65, 1267–68, 1296–1303, 1596–1597, 1620), for example, two sets of old workings are associated with north-northwesterly trending shears. There has been no recent development here, so potential in this narrow zone is presumably limited.

The Corboys group of workings (1185–90, 1192, 1194–96) also follows the north-northwesterly regional trend, within a shear zone that follows the granite–greenstone contact on the western margin of the Yandal belt. Only the Tuscana mine (1195) is totally within granite. As with the northern group of old workings at Wiluna, the mineralization here seems to be mainly related to quartz veining. Although northerly trending dextral faults have been noted, these do not seem to have resulted in large-scale dilational fractures, and there is only limited ore fluid – wallrock interaction (Hickman, in prep.). These features may explain why examination of the area in the 1980s and early 1990s failed to locate mineable targets.

Other mineralized zones in the Yandal belt, such as Jundee–Nimary and Bronzewing, emphasize the importance of structural factors over lithological controls. However, in some cases, such as Gourdis (1553–1556), major structural fluid conduits are either missing or have not been recognized. In other cases, such as at Wiluna Mines' Desert Dragon prospect (2845), lithological controls appear to be critical. At this prospect a mineralized zone up to 1.5 km long lies entirely within a porphyritic felsic intrusion that is also prospective at other locations along strike (Wiluna Mines Ltd, 1996).

The mineralization at Darlot, in the Yandal belt, has been described in the context of at least two sets of quartz-veined shear and fault lodes with relatively shallow dips and strikes. One of these, the Darlot line, coincides with the regional north-northwesterly trend, whereas in the major Centenary deposit the controlling structures are at least second order, with a westerly rather than easterly dip.

The Duketon belt is divided structurally into fault-bounded eastern, central, western, and northern domains. The major north-northwesterly trending shear zones that form the boundaries of these domains also appear to control the distribution of mineralization.

The Christmas Well – Mulga Queen Fault is closely associated with a line of workings at its southern end, extending from Sydney Mint (755) to the Rosemont prospect (1642) and including the Baneygo (752) and Christmas Well (759) pits, which operated during 1988–93. Mineralization at Christmas Well pit (Fig. 4) is present in shoots within a carbonate–sericite-altered granophyre (Harris et al., 1997). At Rosemont the mineralization is in quartz veins in an altered quartz diorite. This may suggest that movement along, or reactivation of, the shear zone has opened dilational structures within the relatively competent (brittle) intrusive rocks. In the Baneygo pit the workings suggest that mineralization was concentrated at the intersection of two vein trends.

At the northern end of the major structure at Mulga Queen (859, 861–863; Figs 9 and 10), the main potential seems to be on a parallel shear in the Famous Blue group of workings (866–868, 870; Figs 11 and 12). Here the more strongly mineralized quartz veins seem to occupy dilational riedel faults between the main northwesterly trending structures. A second mineralization type has recently been located in pyrite stringers within a highly altered diorite host at Famous Blue (Maxey, 1997). Mineralization at Hootanui (1579–1582) is also hosted in quartz stockwork in felsic porphyry. These occurrences are similar to the Rosemont mineralization and suggest a sub-type of felsic intrusive-hosted mineralization in the Duketon belt.

Other areas of historical mining in the Duketon belt, such as at Duketon (831–833, 835, 837–839, 841, 844, 849, 852–855) and The Patch (771, 766–777, 779, 782, 784–785, 787–788, 790–791), seem to be relatively narrow and limited, and are based on quartz lodes in north-northwesterly to northwesterly trending fault shears.

In summary, mesothermal gold mineralization in the north Eastern Goldfields is spatially related to major north-northwesterly trending shear zones, which acted as conduits for mineralizing fluids. Whilst these structures often have some mineralization located within them, the main potential appears to be in second- to fourth-order structures. These offer complex dilational pathways for mineralizing fluids, and structurally and lithologically controlled sites for focused fluid access and precipitation of ore-grade bodies. The regional distribution of occurrences shows the dominance of mafic hosts within this structural framework. Recent exploration trends suggest that relatively small-scale felsic and mafic intrusive bodies within the greenstone belts may be important in providing the right type of competency contrast to produce brittle–dilational host environments for larger, high-grade deposits, such as Centenary, Mount McClure, and Rosemont.

Base metals and tin

Minor copper mineralization (1397, 1400–1401, 1403–1408) in pyrite–chalcopyrite–quartz veins, commonly in association with gold and silver, is found in mafic hosts spatially related to north-northwesterly trending shear zones in the Kathleen Valley Gabbro and Mount Goode Basalt, in the Kathleen Valley area of the Agnew–Wiluna belt (Bunting and Williams, 1979; Fig. 6). A total of 424 t of copper was mined in this area between 1909 and 1967.

A small occurrence of tin (1489), in the form of a cassiterite-bearing lepidolite–albite pegmatite, 3 km south-southwest of the Kathleen Valley townsite, was worked between 1945 and 1953 (Bunting and Williams, 1979; Fig. 6).

Stratiform sedimentary and volcanic mineralization

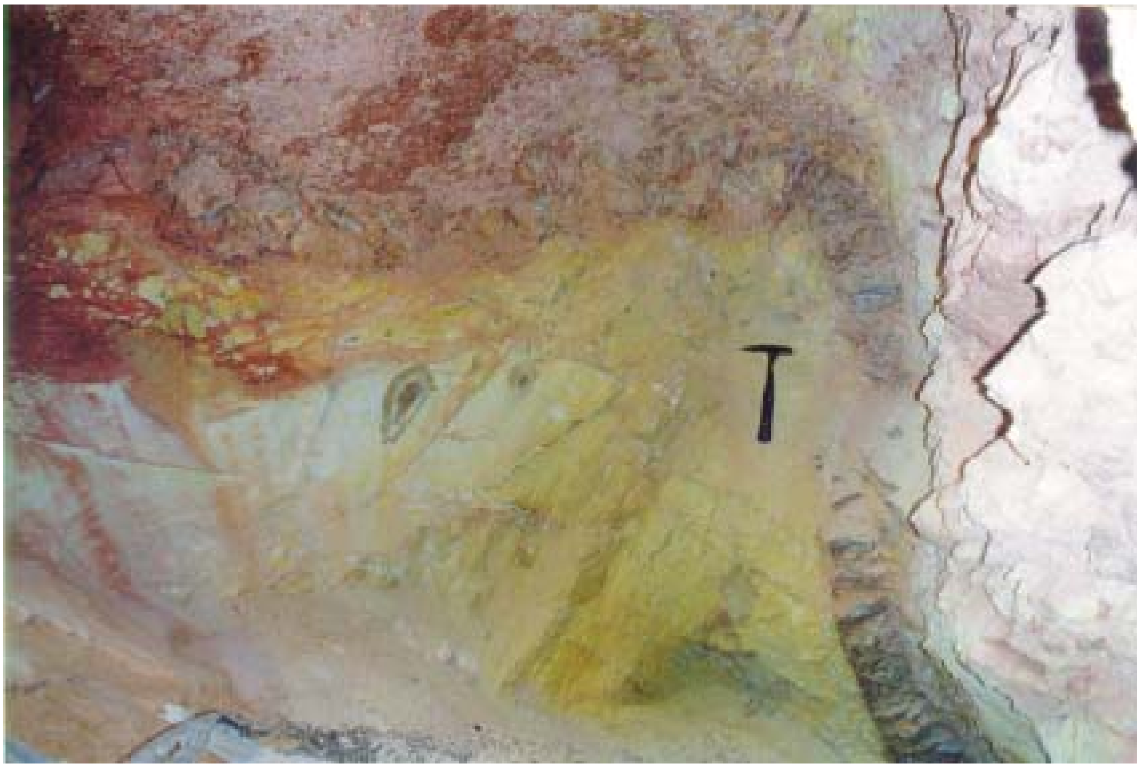
The potential for volcanogenic base-metal mineralization in the north Eastern Goldfields depends primarily on the presence and distribution of deep-water felsic volcano-sedimentary suites in the greenstone belts. Felsic rocks are present in the Agnew–Wiluna, Yandal, and Duketon greenstone belts. Targeted exploration in the 1970s failed to locate major deposits, but results from the Duketon belt suggest that potential exists for mineralization.

Most of the felsic volcanic rocks in the north Eastern Goldfields, including the Spring Well complex in the Darlot area and the Duketon belt felsic rocks, belong to the andesite-dominated calc-alkaline association recognized by Hallberg and Giles (1986) and discussed by Hallberg et al. (1993). They indicated that this association is not of the large-ion lithophile element-

KMF 139 30.04.98

Figure 9. Line of old workings on westerly dipping fault or shear, looking south, at Mulga Queen

Figure 10. Historical mining of westerly dipping quartz vein in lateritized mafic sequence at Mulga Queen



KMF 142 18.05.98

Figure 11. Famous Blue pit with quartz vein dipping towards camera

KMF 143 18.05.98

Figure 12. Folded and mineralized quartz vein at Famous Blue pit

enriched type rhyolite and dacite suite associated with volcanic-hosted base-metal mineralization at Teutonic Bore. They also considered the calc-alkaline suite to have been deposited in a subaerial to subaqueous, rather than deep-water, environment. Cas (1992) has indicated that a deep-water origin is an important element in the base-metal potential of felsic volcanic suites.

Witt et al. (1996) suggested that the bimodal volcanism of the Kalgoorlie and Gindalbie Terranes in the Eastern Goldfields had characteristics in common with mineralized felsic rocks of the Superior Province in Canada. However, they concluded that the Kalgoorlie Terrane felsic units and dacites and rhyolites of the Black Flag Group had steep rare-earth element patterns, which are not ideal for volcanic-hosted massive sulfide mineralization. Witt et al. (1996) included the Agnew–Wiluna belt in their Kalgoorlie Terrane.

These characteristics would suggest rather low potential for volcanic-hosted massive sulfide in the area, and may explain the limited nature of the Duketon prospects and the lack of exploration success elsewhere.

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Appendix 1

Mineral occurrence definitions

The Geological Survey of Western Australia's (GSWA's) Western Australian Mineral Occurrence (WAMIN) database contains geoscience attribute information on mineral occurrences in Western Australia. The database includes textual and numeric information on the location of occurrences, accuracy of the locations, commodities, mineralization classification, resource tonnage, estimated grade, mineralogy of ore, gangue mineralogy, details of host rocks, and both published and unpublished references.

The WAMIN database uses a number of authority tables to constrain the essential elements of a mineral occurrence, including the operating status, commodity group, and style of mineralization. In addition, there are parameters that dictate whether the presence of a mineral or analysed element is sufficiently high to rank occurrence status; this report only deals with mineral occurrences. Other attributes were culled from reports provided by mineral exploration companies or from authoritative references.

Those elements of the database that were used to create the mineral occurrences symbols and tabular information displayed in Plate 1 are:

- operating status and occurrence name (occurrence number style);
- position and spatial accuracy (symbol position);
- commodity group (symbol colour);
- mineralization style (symbol shape);
- determination limits;
- source and reliability of the data.

The elements of the database used for the symbols in Plate 1 are operating status, commodity group, and mineralization style. These parameters have been also defined for the mineral prospectivity enhancement studies for southwestern Western Australia, north Eastern Goldfields, and the Bangemall Basin. The definitions presented here will be used in future prospectivity studies.

Operating status

The database includes mineralization sites ranging from small but mineralogically significant mineral occurrences to operating mines. The classification takes into account all deposits and mines with established resources in the Department of Minerals and Energy (DME) mines and mineral deposits information database (MINEDEX; Townsend et al., 1996). All occurrences in the WAMIN database are assigned a unique, system-generated number. The style of this number (bold, italicized, and so on) is used as the coding to indicate operating status, both on Plate 1 and in the accompanying table. The system used in Plate 1 is:

- mineral occurrence — any economic mineral exceeding an agreed concentration and size found in bedrock or regolith (italic numbers, e.g. *2906*);
- prospect — any working or exploration activity that has found subeconomic mineral occurrences, and from which there is no recorded production (italic numbers, e.g. *84*);
- mineral deposit — economic mineral for which there is an established resource figure (Plain numbers, e.g. 314);
- abandoned mine — workings that are no longer operating or are not on a care-and-maintenance basis, and for which there is recorded production, or where field evidence suggests that the workings were for more than prospecting purposes (bold, italic, sans serif numbers, e.g. ***263***);
- operating mine — workings that are operating, including on a care-and-maintenance basis, or that are in development leading to production. (bold, sans serif numbers, e.g. **1457**).

The name of an occurrence and any synonyms that may have been used are derived from the published literature and from company reports. As some occurrences will not have been named in the past, these appear without names in the WAMIN database; no attempt has been made to provide names where none is currently recognized. Where a name appears in the MINEDEX database (Appendix 5), that is used where possible, although there may be differences because MINEDEX reports on production and resources, whereas WAMIN notes individual occurrences.

Commodity group

The WAMIN database includes a broad grouping based on potential or typical end-use of the principal commodities comprising a mineral occurrence. The commodity group as given in Table 1.1 determines the colours of the mineral occurrence symbols in Plate 1.

The commodity groupings are based on those published by the Mining Journal Ltd (1997), and are modified as shown in Table 1.2 to suit the range of minerals and end-uses for Western Australian mineral output.

Table 1.1. WAMIN authority table for commodity groups

Commodity group	*Typical commodities*	*Symbol colour*
Precious mineral	Diamond, semi-precious gemstones	white
Precious metal	Ag, Au, PGE	yellow
Steel-industry metal	Co, Cr, Mn, Mo, Nb, Ni, V, W	orange-yellow
Speciality metal	Li, REE, Sn, Ta, Ti, Zr	green
Base metal	Cu, Pb, Zn	red
Iron	Fe	blue
Aluminium	Al (bauxite)	orange
Energy mineral	Coal, U	black
Industrial mineral	Asbestos, barite, kaolin, talc	dark green
Construction material	Clay, dimension stone, limestone	blue

Mineralization style

There are a number of detailed schemes for dividing mineral occurrences into groups representing the style of mineralization. The most widely used scheme is probably that of Cox and Singer (1986). The application of this scheme in Western Australia would necessitate modifications to an already complex scheme, along the lines of those adopted by the Geological Survey of British Columbia (Lefebure and Ray, 1995; Lefebure and Hoy, 1996). Representing the style of mineralization on a map cannot be simply and effectively achieved if the scheme adopted is too complex.

GSWA has adopted the principles of ore-deposit classification from Evans (1987). This scheme works on the premise that 'If a classification is to be of any value it must be capable of including all known ore

Table 1.2. Modifications made to the Mining Journal Ltd (1997) commodity classification

Commodity group (Mining Journal Ltd, 1997)	*Commodities*	*Changes made for WAMIN commodity group*
Precious metals and minerals	Au, Ag, PGE, diamonds, other gemstones	Diamond and other gemstones in precious minerals group. Au, Ag and PGE in precious metals group
Steel-industry metals	Iron ore, steel, ferro-alloys, Ni, Co, Mn, Cr, Mo, W, Nb, V	Fe in iron group
Speciality metals	Ti, Mg, Be, REE, Zr, Hf, Li, Ta, Rh, Bi, In, Cd, Sb, Hg	Sn added from major metals
Major metals	Cu, Al, Zn, Pb, Sn	Cu, Pb, and Zn into the base-metals group Al (bauxite) into aluminium group Sn in speciality metals
Energy minerals	Coal, U	No change
Industrial minerals	Asbestos, sillimanite minerals, phosphate rock, salt, gypsum, soda ash, potash, boron, sulfur, graphite, barite, fluorspar, vermiculite, perlite, magnesite/ magnesia, industrial diamonds, kaolin	No change

Table 1.3. WAMIN authority table for mineralization styles and groups

Mineralization style	*Typical commodities*	*Group symbol[(a)]*
Kimberlite and lamproite intrusions	Diamond	☆
Carbonatite and alkaline igneous intrusions	Nb, Zr, REE, P	
Orthomagmatic mafic and ultramafic — undivided	PGE, Cr, V, Ni, Cu	✚
Orthomagmatic mafic and ultramafic — komatiitic or dunitic	Ni, Cu, Co, PGE	
Pegmatitic	Ta, Li, Sn, Nb	⬡
Greisen	Sn	
Skarn	W	
Disseminated and stockwork in plutonic intrusions	Cu, Mo	
Vein and hydrothermal — undivided	Au, Ni, Cu, Pb, Zn, U, Sn, F	◇
Vein and hydrothermal — unconformity	U	
Stratiform sedimentary and volcanic — volcanic-hosted sulfide	Zn, Cu, Pb, Ag, Au	△
Stratiform sedimentary and volcanic — volcanic oxide	Fe, P, Cu	
Stratiform sedimentary and volcanic — undivided	Pb, Zn, Cu, Ag, Au, Fe	
Stratiform sedimentary and volcanic — sedimentary-hosted sulfide	Pb, Zn, Cu, Ag	
Stratabound — undivided	Pb, Ba, Cu, Au	□
Stratabound — carbonate-hosted	Zn, Pb, Ag, Cd	
Stratabound — sandstone-hosted U	U	
Sedimentary — undivided	Mn	
Sedimentary — banded iron-formation	Fe	
Sedimentary — residual to eluvial placers	Au, Sn, Ti, Zr, REE, diamond	
Sedimentary — alluvial to beach placers	Ti, Zr, REE, diamond, Au, Sn	
Sedimentary — calcrete	U, V	○
Sedimentary — basin	Coal	
Residual and supergene	Al, Au, Fe, Ni, Co, V	▭
Undivided	Various	▽

NOTE: (a) The white symbol colour used in this table does not indicate the commodity group in Table 1.1

deposits so that it will provide a framework and a terminology for discussion and so be of use to the mining geologist, the prospector and the exploration geologist'. The system here is based on an environment – rock association classification, with elements of genesis and morphology where they serve to make the system simpler and easier to apply and understand (Table 1.3).

To fully symbolize all the mineralization-style groups would result in a system that is too complex. As the full details of the classification are preserved in the underlying WAMIN database, the chosen symbology has been reduced to nine shapes.

Mineral occurrence determination limits

The lower cut-off limit for a mineral occurrence is more reliably based on exploration company information from WAMEX. Minimum intersections in drillholes or trenches for a number of commodities are presented in Table 1.4.

Professional judgement is used if shorter intercepts at higher grade (or vice versa) are involved. Any diamonds or gemstones, including diamondiferous kimberlites, would be classified as mineral occurrences.

Table 1.4. Minimum intersections for mineral occurrences in drillholes or trenches

Element	*Intersection length (m)*	*Grade*
Hard rock and lateritic deposits		
Gold	>5	>1 ppm
Silver	>10	>1 ppm
Platinum	>0.5	>1 ppm
Lead	>5	>0.5%
Zinc	>5	>2%
Copper	>5	>0.5%
Nickel	>5	>0.5%
Cobalt	>5	>0.1%
Chromium	>0.2	>5% Cr_2O_3
Tin	>5	>0.02%
Iron	>5	>40% Fe
Manganese	>5	>25%
Uranium	>5	>1000 ppm U
Diamonds	na	any diamonds
Tantalum	>5	>200 ppm
Tungsten	>5	>1000 ppm (0.1%)
Placer deposits		
Gold	na	>300 mg/m^3 in bulk sample
Diamonds	na	any diamonds
Heavy minerals	>5	>2% ilmenite

NOTE: na: not applicable

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Appendix 2

Description of digital datasets

There are three principal components of this study: this Report, Plate 1, and a CD-ROM containing digital datasets for use with database or Geographic Information System (GIS) software. The CD-ROM includes all the data used to compile Plate 1 and the Report, as well as files of exploration and mining activity, and geophysical, remote-sensing, and topographic data. The CD-ROM also includes the files necessary for viewing the data in the ArcView GIS environment, and a self-loading version of the ArcExplorer software package modified to suit this particular dataset.

Solid geology and regolith

The solid geology and regolith incorporates an interpretation of the study area, based on a recent 1:100 000 compilation of Geological Survey of Western Australia (GSWA) mapping and Landsat TM interpretation. The full details of the solid geology and regolith are on the CD-ROM. The regolith shown on Plate 1 is a simplified version of the digital dataset on the CD-ROM, and uses two overprints to distinguish relict and depositional regimes. The CD-ROM also includes a large number of solid-geology and regolith units smaller than 250 000 m^2 in area that were omitted from Plate 1 for simplicity.

Mineral occurrences (WAMIN)

The Western Australian Mineral Occurrence (WAMIN) dataset as used in this Report and on Plate 1 is described in Appendix 1. The dataset on the CD-ROM includes textual and numeric information on:

- location of the occurrences (AMG coordinates, latitude and longitude, geological province, location method, and accuracy);
- commodities and commodity group;
- mineralization classification and morphology;
- order of magnitude of resource tonnage and estimated grade;
- mineralogy of ore and gangue;
- details of host rocks;
- published and unpublished references.

WAMEX

All relevant open-file mineral exploration company reports held in the Department of Minerals and Energy's (DME's) Western Australian Mineral Exploration (WAMEX) database were used for this study. Information extracted from these reports was used to analyse the historical trends in exploration activity and target commodities.

MINEDEX

The DME's mines and mineral deposits information (MINEDEX) database has current information on all mines, process plants, and deposits, excluding petroleum and gas, in Western Australia. Mineral resources included in MINEDEX should conform to the JORC (1996) code to be included in the database. The database contains information relevant to WAMIN under the following general headings:

- commodity group and minerals;
- corporate ownership and percentage holding;
- site type and stage of development;
- location data (a centroid) including map, shire, mining district and centre;
- current mineral resource estimates;
- mineralization type;
- tectonic unit;
- tenement details.

All relevant resource information is in MINEDEX and WAMIN uses the unique MINEDEX site number as a cross-reference for this information. WAMIN may contain pre-resource global estimates, which do not conform to the JORC (1996) code, but are included in MINEDEX.

TENGRAPH

The TENGRAPH database is compiled from DME's electronic tenement-graphics system and shows the position of mining tenements relative to other land information. It provides information on the type and status of the tenement and the name(s) and address(es) of the tenement holders. It should be borne in mind that the tenement situation is constantly changing, and that current tenement plans should be consulted before making any landuse-based decisions or applying for tenements.

SPINDEX

A GIS-based spatial activity index (SPINDEX) to historical open-file mineral exploration in the study area has been assembled (Ferguson, 1995). The index contains spatial and textual information defining the location of exploration activity in the area. For the north Eastern Goldfields, SPINDEX was compiled between 1994 and 1997, and contains information on types of mineral exploration activity such as statistics relating to:

- report numbers;
- sample types and numbers;
- elements assayed;
- metres of drilling and number of holes;
- scales of presentation of the data.

Positional data were taken from hard-copy maps at various scales and company reports. The data were located from coordinate and geographical information, transferred on to 1:50 000-scale maps and then digitized. Table 2.1 lists the activity types.

The activity data are linked to more general data concerning the individual exploration projects (commonly defined in WAMEX by accession A-numbers). This information includes the company or companies involved in the project, the commodities explored for, the timing of the project, and a summary (annotation) of the project, including exploration concept, activities, and a synopsis of results.

Table 2.1. Exploration activity types

Activity	*Description*
ACH	Airborne geochemistry
AEM	Airborne electromagnetic surveys
AGRA	Airborne gravity surveys
AMAG	Airborne magnetic surveys
ARAD	Airborne radiometric surveys
DIAM	Diamond drilling
EM	Electromagnetic surveys (includes TEM, SIROTEM)
GEOL	Geological mapping
GEOP	Other geophysical surveys (includes IP, resistivity)
GRAV	Gravity surveys
HYDR	Groundwater surveys
LSAT	Landsat TM data
MAG	Magnetic surveys
NGRD	Non-gridded geochemical surveys (includes chip, channel, dump, and gossan)
RAB	RAB drilling (includes other shallow geochemical drilling, such as auger)
RAD	Radiometric surveys (includes downhole logging)
RC	RC drilling
REGO	Regolith surveys (includes laterite, pisolite, and ironstone)
RES	Resistivity
ROT	Rotary drilling (predominantly percussion drilling)
SEIS	Seismic surveys
SOIL	Soil surveys
SSED	Stream-sediment surveys

Geophysics

The aeromagnetic data for the area are presented in the form of a digital colour total magnetic intensity (TMI) image. The data used to create the image were flown by the Australian Geological Survey Organisation (AGSO) at a line spacing of 1500 m, and gridded to a cell size of 800 m. More detailed surveys have been undertaken in recent years, but these data are part of a commercial, multi-client survey, and can only be obtained from World Geoscience Corporation.

Measurements of the background radiation using an airborne crystal usually took place concurrently with the AGSO aeromagnetic surveys over the area. A colour digital image shows the comparative K–Th–U ratios as red–green–blue (RGB). The data are relatively disparate in nature, as variations in the crystal size and flying height were not tightly constrained over the area.

A regional gravity survey by AGSO, at a station spacing of 11 km, is presented in the digital dataset as an image showing the Bouguer anomaly, gridded to a cell size of 5 km.

Landsat

Landsat TM imagery has been acquired for all the 1:250 000 map sheets covered by the north Eastern Goldfields (Plate 1). The raw data are available commercially through the Remote Sensing Services section of the Western Australian Department of Land Administration. Images that preserve the original 25 m pixel size are included in the digital package, but these cannot be reverse-engineered back to any bands or band ratios of the original 6-band dataset.

Both image datasets comprise a patchwork of 1:250 000 map tiles. The simplest of the two uses a decorrelation stretch of the first principal component of bands 1, 2, 3, 4, 5, and 7, written out as an 8-bit dataset that can be viewed as a monochrome image. The second, more complex image can be viewed in colour, and was created using a decorrelation stretch of bands 4, 5, and 7.

Roads and culture

Selected roads are given as a single dataset, and range from sealed highways to unsealed roads. The digital data in this file were captured by digitizing from Landsat imagery.

Place names for the area are given in a separate file, and include towns and major hills. More comprehensive topographical and cultural data, including drainage, can be obtained from the Australian Land Information Group (AUSLIG). Currently, GSWA is completing an initiative that will see the area covered by a fully revised dataset of topography, drainage, and cultural features based on high-resolution satellite imagery.

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Appendix 3

Historical gold production in the north Eastern Goldfields

Mine centre	*Mine group*	*Period*	*Ore (tonnes)*	*Au mined (kg)*	*Au alluvial & dollied (kg)*	*Total gold production*
Corboys	Corboys	1925–1949	5 027.25	90.32	–	90.32
Corboys	Toscana	1925–1950	1 964.94	69.32	0.20	69.52
Corboys	Waratah	1926–1946	2 740.19	73.00	–	73.00
Corboys	Other		313.95	4.24	–	4.24
Total			**10 046.33**	**236.88**	**0.20**	**237.08**
Leinster	Leinster	1900–1936	13 278.10	831.11	–	831.11
Leinster	Other	1898–1909	67.05	2.70	–	2.70
Total			**13 345.15**	**833.81**	**–**	**833.81**
Bronzewing	Bronzewing	1909–1911	136.65	2.57	–	2.57
Bronzewing	Hawk	1909–1910	74.17	2.03	–	2.03
Bronzewing	Malbie	1909–1911	264.67	5.29	–	5.29
Bronzewing	Lucky	1952–1953	189.46	5.89	–	5.89
Total			**664.95**	**15.78**	**–**	**15.78**
Kingston	Enterprise	1901–1904	3 791.71	102.19	0.93	103.12
Kingston	Pomme D'Or	1934–1989	18 367.93	123.87	–	123.87
Kingston	Other		35.56	0.23	–	0.23
Total			**22 195.20**	**226.29**	**0.93**	**227.22**
Kathleen	Hidalgo	1899–1962	2 558.80	31.56	0.14	31.70
Kathleen	Pascoe leases	1898–1936	638.30	11.19	–	11.19
Kathleen	Yellow Aster	1900–1936	77 032.87	1 451.26	0.51	1 451.77
Kathleen	Beth Hend	1903–1988	1 504.46	23.38	0.19	23.57
Kathleen	Main Roads	1988–1993	84 068.00	260.98	0.54	261.52
Kathleen	Other		6 462.58	91.70	22.97	114.67
Total			**172 265.01**	**1 870.07**	**24.35**	**1 894.42**
Sir Samuel	Bellevue Ltd	1897–1968	255 235.96	4 099.19	0.70	4 099.89
Sir Samuel	Isidore	1900–1928	2 238.81	54.62	10.83	65.45
Sir Samuel	Dreamland	1910–1912	825.50	16.5	–	16.50
Sir Samuel	Vanguard	1898–1947	16 228.57	164.95	–	164.95
Sir Samuel	Westralia	1899–1954	3 997.45	46.79	0.06	46.85
Sir Samuel	Bellevue (QM & spa)	1986–1993	1 422 314.00	16 290.46	–	16 290.46
Sir Samuel	Other	1899–1937	8 665.28	166.59	4.57	171.16
Total			**1 709 505.57**	**20 839.1**	**16.16**	**20 855.26**
New England	Glennis	1899–1936	1 929.38	33.46	–	33.46
New England	Lowlans	1911–1939	1 389.89	23.90	–	23.90
New England	Other		789.43	6.94	–	6.94
Total			**4 108.70**	**64.30**	**–**	**64.30**
Coles Find	Black Adder	1920–1954	4 430.00	85.86	–	85.86
Coles Find	Matilda	1989?–1993	2 507 355.00	5 179.70	–	5 179.70
Coles Find	Other		5 500.00	46.85	0.65	47.50
Total			**2 517 285.00**	**5 312.41**	**0.65**	**5 313.06**
Collavilla	May Queen	1910	36.58	0.78	–	0.78
Collavilla	May Queen Reward	1912	1 505.71	14.65	–	14.65
Collavilla	Golden Fleece	1931	61.47	0.51	–	0.51
Total			**1 603.76**	**15.94**	**–**	**15.94**
Simms Find	Simms Find	1933–1947	852.42	33.57	2.99	36.56
Lawlers	Glasgow Lass	1898–1911	9 450.93	240.65	1.64	242.29
Lawlers	Vivien G.M. Co.	1901–1941	215 758.96	2 418.24	2.99	2 421.27
Lawlers	Vivien Gem	1905–1926	4 291.84	98.80	2.69	101.49
Lawlers	Brilliant	1902–1910	12 674.09	273.85		273.85
Lawlers	Dobra Serica	1905–1911	1 242.06	34.69	0.03	34.72
Total			**243 417.88**	**3 066.23**	**7.35**	**3 073.62**

Appendix 3 (continued)

Mine centre	*Mine group*	*Period*	*Ore (tonnes)*	*Au mined (kg)*	*Au alluvial & dollied (kg)*	*Total gold production*
Bills Find	Bills Find	1935–1937	391.00	9.23	1.37	10.60
Bills Find	Bills Find	1993	74 112.00	128.11	–	128.11
Total			**74 503.00**	**137.34**	**1.37**	**138.71**
Wiluna	Black Swan	1898–1940	217 144.41	2 376.40	–	2 376.40
Wiluna	Brothers	1898–1911	3 603.75	91.95	–	91.95
Wiluna	Bulletin	1904–1925	13 480.80	134.30	–	134.30
Wiluna	Caledonia	1910–1935	2 857.91	69.65	–	69.65
Wiluna	Coolgardy Brilliant	1897–1905	21 734.78	230.47	–	230.47
Wiluna	Derwent	1898–1910	796.39	27.77	–	27.77
Wiluna	Essex	1897–1950	4 466.84	63.53	–	63.53
Wiluna	Florence No. 3	1898–1935	9 642.35	114.89	–	114.89
Wiluna	Golden Age Con. Ltd.	1901–1904	43 201.34	614.32	–	614.32
Wiluna	Golden Age Lakeway	1897–1913	25 496.01	409.45	1.24	410.69
Wiluna	Golden Bracelet	1902–1916	1 717.55	62.16	–	62.16
Wiluna	Happy Jack	1909–1916	4 018.79	41.97	–	41.97
Wiluna	Just in Time	1897–1922	1 845.31	41.26	14.92	56.28
Wiluna	Lakeway G.F. Ltd.	1900–1906	8 374.89	247.60	–	247.60
Wiluna	Monarch of the East	1898–1935	15 497.81	334.19	1.11	335.30
Wiluna	Moonlight	1908–1985	907 589.07	6 936.26	–	6 936.26
Wiluna	Try Again	1901–1912	2 911.09	72.65	0.07	72.72
Wiluna	Western Alluvials	1984–1988	976 279.00	5 949.63	–	5 949.63
Wiluna	Wiluna G.M. Ltd.	1910–1995	7 810 190.70	45 666.02	–	45 666.02
Wiluna	Wiluna/Wiluna G.M.	1989–1993	5 051 515.00	14 213.05	–	14 213.05
Wiluna	Wiluna Dumps	1989–1993	–	127.85	–	127.85
Wiluna	Brilliant	1923–1950	10 008.37	121.88	–	121.88
Wiluna	Jubilee	1935–1950	24 618.19	246.22	–	246.22
Wiluna	Squib	1906–1927	347 478.92	4 153.09	–	4 153.09
Wiluna	Other		6 985.05	1 489.98	1.54	1 491.52
Total			**15 611 454.32**	**83 836.54**	**18.88**	**83 855.42**
Darlot	Pride of Darlot	1898–1906	498.09	12.70	–	12.70
Darlot	Ballangarry	1898–1946	7 388.35	98.14	–	98.14
Darlot	British King	1898–1985	19 512.96	387.46	–	387.46
Darlot	St George	1897–1936	926.59	248.84	102.18	351.02
Darlot	Amazon	1898–1913	4 026.92	200.89	0.36	201.25
Darlot	King of the Hills	1898–1914	2 378.71	61.63	7.80	69.43
Darlot	Zangbar Leases	1902–1983	44 001.51	430.44	0.47	430.91
Darlot	New Discovery	1919–1973	2 323.51	26.71	–	26.71
Darlot	Waikato	1898–1906	4 452.11	163.03	0.29	163.32
Darlot	Morning Light	1898–1903	317.50	14.34	–	14.34
Darlot	The Dragon	1946–1952	954.02	17.19	–	17.19
Darlot	Darlot/Sundowner	1989–1993	1 891 088.00	8 745.02	–	8 745.02
Darlot	Amazon	1898–1913	3 912.11	195.50	–	195.50
Darlot	Other		16 427.90	273.10	68.96	342.06
Total			**1 998 208.28**	**10 874.99**	**180.06**	**11055.05**
Duketon	The Patch	1905–1937	432.23	26.30	–	26.30
Duketon	Connemara	1897–1921	378.46	8.33	–	8.33
Duketon	The Patch	1913–1937	473.86	28.67	–	28.67
Duketon	Golden Spinifex/Lauriston	1901–1915	3 731.76	89.84	–	89.84
Duketon	Duketon North	1903–1906	1 256.28	32.13	–	32.13
Duketon	Duketon South	1901–1906	682.75	21.74	–	21.74
Duketon	Mulga Queen	1904–1945	12 895.07	316.72	–	316.72
Duketon	Mount Maiden	1903–1910	1 872.01	46.02	–	46.02
Duketon	Famous	1904–1910	677.67	17.19	–	17.19
Duketon	Famous Blue	1904–1940	10 402.81	147.64	–	147.64
Duketon	Hootanui	1904–1910	622.29	68.15	–	68.15
Duketon	Other		171.20	4.62	–	4.62
Total			**33 596.39**	**807.35**	**–**	**807.35**
Erlistoun	Baneygo	1898–1927	3 674.36	126.12	–	126.12
Erlistoun	Mistake	1891–1935	4 141.98	105.03	–	105.03
Total			**7 816.34**	**231.15**	**–**	**231.15**

SOURCE: Department of Minerals and Energy's mines and mineral deposits information (MINEDEX) database

Appendix 4

Gold production in the north Eastern Goldfields between 1984 and 1996

Site/Project	*Minedex Project*	*1984*	*1985*	*1986*	*1987*	*1988*	*1989*	*1990*	*1991*	*1992*	*1993*	*1994*	*1995*	*1996*	*Total 1984–1996*
									Kilogram						
Emu–Leinster	J00098	118	115	512	1 974	2 268	2 508	3 204	3 167	3 280	3 755	4 075	4 467	4 178	33 621
Wiluna	J00362	–	–	–	2 096	2 233	3 691	4 124	3 480	3 435	3 075	3 244	3 184	3 320	31 883
Sir Samuel – Bellevue	J00329	–	–	216	667	1 909	2 289	3 007	3 389	2 772	2 056	1 526	831	538	19 200
Darlot	J00082	–	–	–	–	–	1 204	1 578	1 645	1 666	2 563	1 967	1 277	1 952	13 852
Bronzewing	J01577	–	–	–	–	–	–	–	–	–	–	299	3 861	8 407	12 567
Mount McClure	J00250	–	–	–	–	–	–	–	–	1 416	2 034	2 245	2 504	3 379	11 578
Jundee	–	–	–	–	–	–	–	–	–	–	–	–	187	7 414	7 601
Chalice	–	–	–	–	–	–	–	–	–	–	–	–	1 818	4 445	6 263
Matilda	J00263	–	–	–	719	1 282	527	764	1 378	510	–	–	–	–	5 180
Nimary	–	–	–	–	–	–	–	–	–	–	–	–	–	3 923	3 923
Wiluna Dumps	J00362	503	654	464	325	–	–	–	–	–	–	–	–	–	1 946
Mount Fisher	J00244	–	–	–	–	702	2	–	–	–	–	–	–	–	703
Duketon–Banyego	J00009	–	–	–	–	–	302	–	–	–	–	–	–	–	302
Total		**621**	**769**	**1 192**	**5 781**	**8 398**	**10 523**	**12 677**	**13 059**	**13 079**	**13 483**	**13 356**	**18 129**	**37 556**	**148 619**

Appendix 5

Mineral resources in the north Eastern Goldfields

Site	*Site code*	*Cat.*	*Res. type*	*Min. type*	*Resources (Mt)*	*Grade (g/t)*	*Min.*	*Cont. metal (t)*
Baneygo – Duketon Group	S00013	INF	I/S	AUSHER	1.037	1.7	Au	1.763
Baneygo – Duketon Group	S00013	IND	I/S	AUSHER	1.602	2.7	Au	4.325
Darlot Group	S00827	DEM	I/S		3.257	3.6	Au	11.725
Darlot Group	S00827	IND	MIN		0.777	4.4	Au	3.419
Darlot Underground	S04791	IND	I/S	AUSHER	2.8	3.8	Au	10.64
Darlot Underground	S04791	INF	I/S	AUSHER	0.013	2.7	Au	0.035
Darlot Underground	S04791	IND	MIN	AUSHER	0.671	4.7	Au	3.154
St George West	S04869	IND	I/S	AULAT	0.13	2.7	Au	0.351
Glasgow Lass	S00875	MES	I/S		0.065	2.6	Au	0.169
Glasgow Lass	S00875	IND	I/S		0.044	2.7	Au	0.119
Waroonga North	S02404	INF	I/S		0.23	2.5	Au	0.575
Waroonga North	S02404	DEM	MIN		0.118	2.5	Au	0.295
Genesis – Genesis North	S03246	MES	I/S	AUCONG	0.58	2.7	Au	1.566
Genesis – Genesis North	S03246	IND	I/S	AUCONG	0.078	2.3	Au	0.179
Genesis – Genesis North	S03246	IND	MIN	AUCONG	0.298	3.1	Au	0.924
Genesis – Genesis North	S03246	INF	I/S	AUCONG	0.01	2.7	Au	0.027
Genesis – Genesis North	S03246	MES	I/S	AUCONG	0.092	3.3	Au	0.304
Genesis – Genesis North	S03246	IND	I/S	AUCONG	0.02	1.9	Au	0.038
Genesis – Genesis North	S03246	INF	I/S	AUCONG	0.008	1.5	Au	0.012
New Holland	S03743	DEM	MIN	AUCONG	0.836	4.1	Au	3.428
New Holland	S03743	MES	I/S	AUCONG	0.707	3.3	Au	2.333
New Holland	S03743	IND	I/S	AUCONG	0.238	3.5	Au	0.833
New Holland	S03743	INF	I/S	AUCONG	0.052	3.9	Au	0.203
Dobra Serica	S04569	MES	I/S	AUCONG	0.067	2.7	Au	0.181
Dobra Serica	S04569	IND	I/S	AUCONG	0.037	2.6	Au	0.096
Dobra Serica	S04569	INF	I/S	AUCONG	0.008	3	Au	0.024
Miranda Group	S00504	IND	I/S		0.657	6.7	Au	4.402
Miranda Group	S00504	INF	I/S		0.096	5.6	Au	0.538
Cams – Maria	S02117	MES	I/S		0.375	4.9	Au	1.837
Cams – Maria	S02117	IND	I/S		0.126	4.1	Au	0.517
Vivien	S04988	INF	I/S		0.365	17.9	Au	6.533
Vivien	S04988	INF	I/S		0.23	3.9	Au	0.897
Mossbecker	S00507	MES	DEV	AUCONG	0.492	3.62	Au	1.781
Mossbecker	S00507	IND	DEV	AUCONG	0.063	2.76	Au	0.174
Mossbecker	S00507	INF	I/S	AUCONG	0.006	2.68	Au	0.016
Mossbecker	S00507	DEM	MIN	AUCONG	0.368	4.08	Au	1.501
Kathleen Valley Group	S01066	MES	I/S	AUCONG	1.334	3.17	Au	4.229
Kathleen Valley Group	S01066	IND	I/S	AUCONG	0.339	2.81	Au	0.953
Kathleen Valley Group	S01066	INF	I/S	AUCONG	0.096	3.1	Au	0.298
Kathleen Valley Group	S01066	DEM	MIN	AUCONG	0.554	4.33	Au	2.399
Main Road – Kathleen Valley	S02721	MES	DEV	AUCONG	0.036	2.34	Au	0.084
Main Road – Kathleen Valley	S02721	IND	I/S		0.02	3.5	Au	0.07
Yellow Aster North	S03829	IND	I/S		0.149	2.68	Au	0.399
Yellow Aster North	S03829	INF	I/S		0.033	2.34	Au	0.077
Yellow Aster	S03894	DEM	MIN	AUCONG	0.12	4.9	Au	0.588
Yellow Aster	S03894	MES	I/S	AUCONG	0.636	2.68	Au	1.704
Yellow Aster	S03894	IND	I/S	AUCONG	0.033	2.38	Au	0.079
Carriport	S03895	MES	I/S	AUCONG	0.068	2.92	Au	0.199
Carriport	S03895	IND	I/S	AUCONG	0.029	3.84	Au	0.111
Carriport	S03895	INF	I/S	AUCONG	0.016	3.15	Au	0.05
Carriport	S03895	DEM	MIN	AUCONG	0.021	4.1	Au	0.086
Carriport	S03895	DEM	MIN	AUCONG	0.017	5.8	Au	0.099
Nil Desperandum – Kathleen Valley	S04372	MES	I/S		0.102	4.46	Au	0.455
Nil Desperandum – Kathleen Valley	S04372	IND	I/S		0.045	2.77	Au	0.125
Nil Desperandum – Kathleen Valley	S04372	INF	I/S		0.041	3.82	Au	0.157
Mount McClure Group	S00883	DEM	MIN		12.719	2.1	Au	26.71
Mount McClure Group	S00883	DEM	I/S		0.364	5.3	Au	1.929
Mount McClure Group	S00883	MES	MIN		0.487	1.3	Au	0.633
Mount McClure Group	S00883	INF	I/S		0.018	5	Au	0.09
Parmelia – Mount McClure	S01128	MES	DEV		0.003	1.1	Au	0.003
Cockburn	S02607	IND	MIN	AUBIF	11.302	1.9	Au	21.474
Lotus – Lotus North	S02608	IND	I/S	AULAT	0.138	1.4	Au	0.193
Lotus South	S03770	MES	MIN		0.523	2.12	Au	1.109

Appendix 5 (continued)

Site	Site code	Cat.	Res. type	Min. type	Resources (Mt)	Grade (g/t)	Min.	Cont. metal (t)
Lotus Deeps	S03934	MES	I/S		0.156	4.8	Au	0.749
Lotus Deeps	S03934	MES	MIN		0.205	7.5	Au	1.537
Lotus Deeps	S03934	IND	MIN		0.17	10.3	Au	1.751
Lotus Deeps	S03934	IND	I/S		0.018	5	Au	0.09
Lotus West	S03935	MES	MIN		0.032	1.8	Au	0.058
Wiluna South – Matilda Group	S00952	MES	I/S	AUSHER	0.061	4	Au	0.244
Wiluna South – Matilda Group	S00952	INF	I/S	AUSHER	0.057	5.9	Au	0.336
Wiluna South – Matilda Group	S00952	MES	MIN	AUSHER	0.015	1.8	Au	0.027
Wiluna South – Matilda Group	S00952	IND	I/S	AUSHER	0.464	3.1	Au	1.438
Wiluna South – Matilda Group	S00952	INF	I/S	AUSHER	0.132	2.8	Au	0.37
Wiluna South – Matilda Group	S00952	IND	MIN	AUSHER	0.094	2.5	Au	0.235
Wiluna South – Matilda Group	S00952	IND	I/S	AUSHER	0.048	5.4	Au	0.259
Vanguard – Lawlers	S00720	IND	I/S	AUSHER	0.131	4.6	Au	0.603
Bellevue Underground Group	S00932	MES	I/S	AUSHER	0.063	21.5	Au	1.354
Bellevue Underground Group	S00932	INF	I/S	AUSHER	0.033	11.3	Au	0.373
Bellevue Underground Group	S00932	IND	I/S	AUSHER	0.026	15.9	Au	0.413
Bellevue Underground Group	S00932	MES	MIN	AUSHER	0.11	8.4	Au	0.924
Bellevue Underground Group	S00932	IND	MIN	AUSHER	0.019	12.6	Au	0.239
Bellevue Underground Group	S00932	INF	I/S	AUSHER	0.187	12	Au	2.244
New Orleans – Bellevue	S04515	INF	I/S		0.026	2.5	Au	0.065
New Orleans – Bellevue	S04515	MES	MIN		0.213	2.6	Au	0.554
New Orleans – Bellevue	S04515	MES	I/S		0.828	1.6	Au	1.325
New Orleans – Bellevue	S04515	IND	I/S		0.036	1.5	Au	0.054
Henderson North	S05641	DEM	MIN		0.05	0	Au	
Wiluna Group	S00780	IND	I/S	AUSHER	1.326	2.5	Au	3.315
Wiluna Group	S00780	IND	MIN	AUSHER	0.095	1.7	Au	0.161
Wiluna Group	S00780	IND	DEV		0.544	1	Au	0.544
Wiluna Group	S00780	INF	I/S	AUSHER	0.325	2.8	Au	0.91
Wiluna Group	S00780	MES	DEV		0.476	2.5	Au	1.19
Wiluna Group	S00780	MES	MIN	AUSHER	0.187	1.6	Au	0.299
Wiluna Underground Group	S00782	IND	MIN	AUSHER	2.282	7.9	Au	18.028
Wiluna Underground Group	S00782	MES	MIN	AUSHER	0.194	5.8	Au	1.125
Wiluna Dumps	S00784	DEM	MIN	AUSHER	1.2	1	Au	1.2
Wiluna Dumps	S00784	DEM	I/S	AUSHER	0.35	1	Au	0.35
Happy Jack – Tirau Underground	S03779	DEM	MIN	AUSHER	0.281	7.49	Au	2.105
Happy Jack – Tirau Underground	S03779	IND	I/S	AUSHER	0.291	8.5	Au	2.473
Happy Jack – Tirau Underground	S03779	INF	I/S	AUSHER	0.21	7.4	Au	1.554
Bulletin – Wiluna Underground	S03780	DEM	MIN	AUSHER	2.248	7.95	Au	17.872
Bulletin – Wiluna Underground	S03780	IND	I/S	AUSHER	0.171	5.2	Au	0.889
Bulletin – Wiluna Underground	S03780	INF	I/S	AUSHER	0.826	7.8	Au	6.443
Wiluna Open Pits Group	S03998	MES	MIN	AUSHER	0.069	4	Au	0.276
Yandal 2 Group	S03852	INF	I/S	AUGRAN	0.248	1.78	Au	0.441
Yandal 2 Group	S03852	IND	I/S	AUGRAN	0.401	1.81	Au	0.726
Famous Blue	S01154	MES	I/S	AUFVOL	0.857	1.6	Au	1.371
Famous Blue	S01154	DEM	MIN	AUFVOL	1.5	1.7	Au	2.55
Famous Blue	S01154	IND	I/S	AUFVOL	1.365	1.6	Au	2.184
Famous Blue	S01154	INF	I/S		0.072	0.67	Au	0.048
Famous Blue	S01154	INF	I/S		0.125	6.78	Au	0.847
British King	S01930	INF	I/S		0.018	19.4	Au	0.349
British King	S01930	DEM	MIN		0.024	14.2	Au	0.341
Bills Find	S02414	MES	MIN		0.219	3.75	Au	0.821
Bills Find	S02414	DEM	I/S		0.39	2.5	Au	0.975
Jundee Group	S02716	IND	I/S		1.191	2.5	Au	2.977
Jundee Group	S02716	INF	I/S		0.126	3.3	Au	0.416
Jundee Group	S02716	IND	MIN		0.184	2.8	Au	0.515
Jundee Group	S02716	IND	MIN		0.403	1	Au	0.403
Vause	S04002	INF	I/S		5.540	1.07	Au	5.928
Vause	S04002	INF	I/S	AULAT	2.030	1.82	Au	3.695
Nimone–Nimtwo	S03532	MES	MIN	AUSHER	0.358	8.03	Au	2.875
Nimone–Nimtwo	S03532	MES	I/S	AUSHER	0.396	8.53	Au	3.378
Nimthree	S03533	MES	I/S	AUSHER	1.592	8.2	Au	13.054
Nimthree	S03533	MES	MIN	AUSHER	1.457	8.03	Au	11.7
Nimthree	S03533	INF	I/S	AUSHER	0.255	10.17	Au	2.593
Nimthree	S03533	INF	I/S	AUSHER	0.269	3.8	Au	1.022
Nimary Group	S03534	MES	I/S		4.315	5.74	Au	24.768
Nimary Group	S03534	MES	MIN		3.487	5.94	Au	20.713
Nimary Group	S03534	IND	I/S		0.266	2.96	Au	0.787

Appendix 5 (continued)

Site	*Site code*	*Cat.*	*Res. type*	*Min. type*	*Resources (Mt)*	*Grade (g/t)*	*Min.*	*Cont. metal (t)*
Nimary Group	S03534	INF	I/S		0.648	5.6	Au	3.629
Nimary Group	S03534	INF	I/S		0.124	4.09	Au	0.507
Nimfour	S04572	MES	MIN	AUPOR	1.258	3.71	Au	4.667
Nimfour	S04572	MES	I/S	AUPOR	1.278	3.91	Au	4.997
Nimsix	S05336	IND	I/S		0.093	2.62	Au	0.244
Nimsix	S05336	MES	I/S		0.983	3.18	Au	3.126
Nimsix	S05336	MES	MIN		0.415	3.61	Au	1.498
Nimseven	S05337	MES	I/S	AUPOR	0.066	3.29	Au	0.217
Bronzewing Group	S03987	IND	I/S	AUSHER	6.76	4.6	Au	31.096
Bronzewing Group	S03987	MES	I/S	AUSHER	4.72	6.1	Au	28.792
Bronzewing Group	S03987	INF	I/S	AUSHER	19.35	1.7	Au	32.895
Bronzewing Group	S03987	MES	MIN		3.93	7.1	Au	27.903
Bronzewing Group	S03987	IND	MIN		3.26	5.7	Au	18.582
Bronzewing Group	S03987	DEM	DEV		1.87	1.7	Au	3.179
Bronzewing Discovery Pit	S04955	IND	I/S	AUSHER	6.6	3.1	Au	20.46
Bronzewing Discovery Pit	S04955	INF	I/S	AUSHER	1.4	2.5	Au	3.5
Bronzewing Discovery Pit	S04955	IND	MIN	AUSHER	0.1	1	Au	0.1
Bronzewing Discovery Pit	S04955	MES	MIN		0.29	6.4	Au	1.856
Bronzewing Laterite Pit	S04957	IND	MIN	AULAT	0.48	1.4	Au	0.672
Bronzewing Laterite Pit	S04957	IND	I/S	AULAT	0.5	1.5	Au	0.75
Bronzewing Central Zone	S04958	IND	I/S	AUSHER	10.2	3.8	Au	38.76
Bronzewing Central Zone	S04958	IND	MIN	AUSHER	4.72	4.8	Au	22.656
Bronzewing Central Zone	S04958	INF	I/S	AUSHER	0.9	3.2	Au	2.88
Bronzewing Western Zone	S04959	IND	I/S	AUSHER	0.8	7.1	Au	5.68
Bronzewing Western Zone	S04959	IND	MIN	AUSHER	0.152	16.3	Au	2.478
Shoot 39	S04960	IND	MIN	AUSHER	3.649	5.1	Au	18.61
Anzac	S04961	INF	I/S	AUSHER	0.3	1.5	Au	0.45
Flushing Meadows	S00426	MES	I/S	AUSHER	0.276	2.13	Au	0.588
Flushing Meadows	S00426	INF	I/S	AUSHER	0.05	1.81	Au	0.09
Flushing Meadows	S00426	IND	I/S	AUSHER	0.389	1.73	Au	0.673
Flushing Meadows	S00426	MES	I/S	AUSHER	0.514	1.5	Au	0.771
Flushing Meadows	S00426	IND	I/S	AUSHER	0.981	1.15	Au	1.128
Flushing Meadows	S00426	INF	I/S	AUSHER	0.108	1.26	Au	0.136
Jundee Group	S04630	MES	I/S	AUSHER	14.98	2.3	Au	34.454
Jundee Group	S04630	MES	MIN	AUSHER	10.04	2.1	Au	21.084
Jundee Group	S04630	IND	I/S	AUSHER	9.1	2.1	Au	19.11
Jundee Group	S04630	IND	MIN	AUSHER	2.26	2.3	Au	5.198
Jundee Group	S04630	DEM	DEV		0.83	1	Au	0.83
Jundee Group	S04630	INF	I/S	AUSHER	2.16	1.5	Au	3.24
Camp Oven Northwest	S05009	INF	I/S		0.065	2.5	Au	0.162
Centipede–Millipede	S00955	INF	I/S	UCALC	1.115	0.86	U_3O_8	0.959
Hinkler Well	S00959	INF	I/S	UCALC	0.1	0.6	U_3O_8	0.06
Lake Maitland / Chartfield	S00967	DEM	I/S	UCALC	11.6	0.51	U_3O_8	5.916
Lake Maitland / Chartfield	S00967	DEM	I/S	UCALC	1.7	1.11	U_3O_8	1.887
Lake Way	S00972	DEM	I/S	UCALC	5.441	0.68	U_3O_8	3.7
Lake Way	S00972	INF	I/S	UCALC	1.873	0.68	U_3O_8	1.274
Lake Way	S00972	MES	DEV	UCALC	3.77	0.98	U_3O_8	3.695
Lake Maitland / BS00994	INF	I/S		UCALC	1.25	0.4	U_3O_8	0.5
Rockys Reward Open Pit	S01583	DEM	I/S	NIVOLC	1.8	2.1	Ni	0.038
Leinster Underground Group	S01584	MES	MIN	NIINTR	4.9	1.9	Ni	0.093
Leinster Underground Group	S01584	IND	MIN	NIINTR	38.7	1.9	Ni	0.735
Leinster Underground Group	S01584	IND	I/S	NIINTR	6.6	2.3	Ni	0.152
Leinster Underground Group	S01584	INF	I/S	NIINTR	10	2	Ni	0.2
Perseverance Underground	S01585	DEM	DEV	NIVOLC	32.3	2.05	Ni	0.662
Sir Samuel	S02330	DEM	I/S	NIINTR	1.5	2	Ni	0.03
Rockys Reward Underground	S02738	DEM	DEV	NIVOLC	1.6	2.9	Ni	0.046
Rockys Reward Group	S03396	DEM	DEV	NIINTR	5.4	2.4	Ni	0.13
Leinster Open Pits Group	S03690	MES	MIN	NIINTR	0.5	1.8	Ni	0.009
Leinster Open Pits Group	S03690	MES	I/S	NIINTR	4.6	1.7	Ni	0.078
Leinster Open Pits Group	S03690	INF	I/S	NIINTR	127	0.6	Ni	0.762
Leinster Open Pits Group	S03690	IND	I/S	NIINTR	0.5	2.1	Ni	0.01
Honeymoon Well Group	S01273	INF	I/S	NIINTR	35	0.7	Ni	0.245
Honeymoon Well Group	S01273	INF	I/S	NIINTR	2.5	3.4	Ni	0.085
Honeymoon Well Group	S01273	IND	I/S	NIINTR	75	0.77	Ni	0.577
Goliath North	S01258	MES	I/S	NIINTR	31.8	0.62	Ni	0.197
Goliath North	S01258	IND	I/S	NIINTR	3.8	0.76	Ni	0.029
Goliath North	S01258	IND	I/S	NIINTR	9.6	0.61	Ni	0.059

Appendix 5 (continued)

Site	*Site code*	*Cat.*	*Res. type*	*Min. type*	*Resources (Mt)*	*Grade (g/t)*	*Min.*	*Cont. metal (t)*
Goliath North	S01258	MES	MIN	NIINTR	24.7	0.6	Ni	0.148
Goliath North	S01258	IND	MIN	NIINTR	7.5	0.6	Ni	0.045
Six Mile	S01456	MES	MIN	NIINTR	37.1	0.56	Ni	0.208
Six Mile	S01456	IND	MIN	NIINTR	58	0.56	Ni	0.325
Six Mile	S01456	MES	I/S	NIINTR	54.6	0.59	Ni	0.322
Six Mile	S01456	IND	I/S	NIINTR	10.4	0.8	Ni	0.083
Six Mile	S01456	IND	I/S	NIINTR	59.1	0.58	Ni	0.343
Six Mile	S01456	INF	I/S	NIINTR	0.5	0.6	Ni	0.003
Six Mile	S01456	INF	I/S	NIINTR	26.2	0.6	Ni	0.157
Yakabindie Group	S01519	DEM	I/S	NILAT	183.8	0.59	Ni	1.084
Yakabindie Group	S01519	DEM	MIN	NILAT	193	0.51	Ni	0.984
David	S04931	INF	I/S		2.3	0.5	Ni	0.011
Serpentine Hill	S04932	DEM	I/S		1.33	0.9	Ni	0.012
Serpentine Hill	S04932	DEM	MIN		0.947	0.97	Ni	0.009
Mount Keith / WMC	S01667	IND	I/S	NIINTR	230	0.6	Ni	1.38
Mount Keith / WMC	S01667	IND	MIN	NIINTR	112	0.6	Ni	0.672
Mount Keith / WMC	S01667	MES	MIN	NIINTR	14.6	0.6	Ni	0.088
Mount Keith / WMC	S01667	INF	I/S	NIINTR	114	0.6	Ni	0.684

SOURCE: Department of Minerals and Energy's mines and mineral deposits information (MINEDEX) database. All information in the database is from published sources

NOTES:

Site: site name in MINEDEX /company name

Site code: MINEDEX site number

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

Res. type: resource type
- I/S: in situ
- DEV: developable
- MIN: mineable

Min. type: mineralization type
- AUSHER: shear-hosted gold
- AUCONG: conglomerate-hosted gold
- AUBIF: BIF-hosted gold
- AULAT: laterite-hosted gold
- AUGRAN: granite-hosted gold
- AUFVOL: felsic volcanic-hosted gold
- AUPOR: porphyry-hosted gold
- UCALC: calcrete-hosted uranium
- NIVOLC: volcanic-hosted nickel
- NIINTR: intrusive-hosted nickel
- NILAT: laterite-hosted nickel

Resources: in millions of tonnes (Mt)

Grade: in grams per tonne (g/t)

Min: mineral

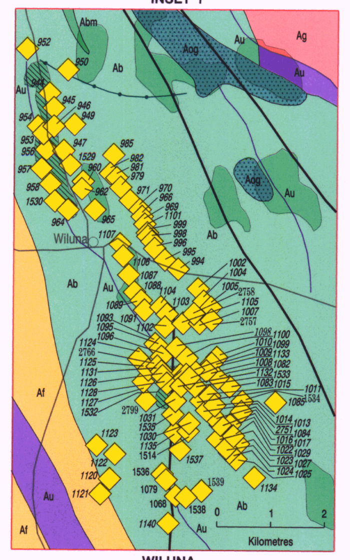
Cont. metal: contained metal in tonnes

MINERAL OCCURRENCES OF THE NORTH EASTERN GOLDFIELDS

* KEY TO OPERATING STATUS

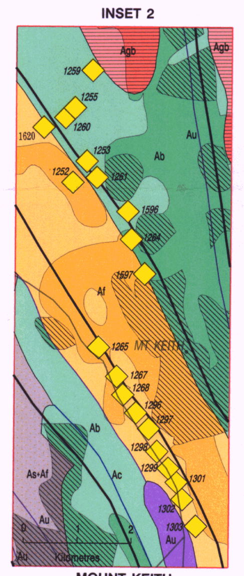
Bold numbers	Operating mine
Bold and italic nimbers	Abandoned mine
Plain numbers	Mineral deposit
Italic numbers	Mineral occurrence or prospect

NUMBER*	COMMODITY	EASTING	NORTHING	NAME
PRECIOUS METAL — Au, PGE				
Orthomagmatic mafic and ultramafic — komatiitic or dunitic				
1592	PGE	345550	6959550	Freemans (Pt)
Vein and hydrothermal — undivided				
732	Au	434729	6904768	Mistake South
733	Au	434810	6905024	Mistake
734	Au	434987	6905772	Mistake North
735	Au	434917	6905909	Mistake North
736	Au	434857	6905315	Mistake (vein)
737	Au	435625	6905185	Worthington
738	Au	433600	6904900	
739	Au	436638	6908732	
740	Au	436591	6908530	
743	Au	433460	6910091	McKenzie
745	Au	431450	6908676	Baneygo North
746	Au	431778	6907852	



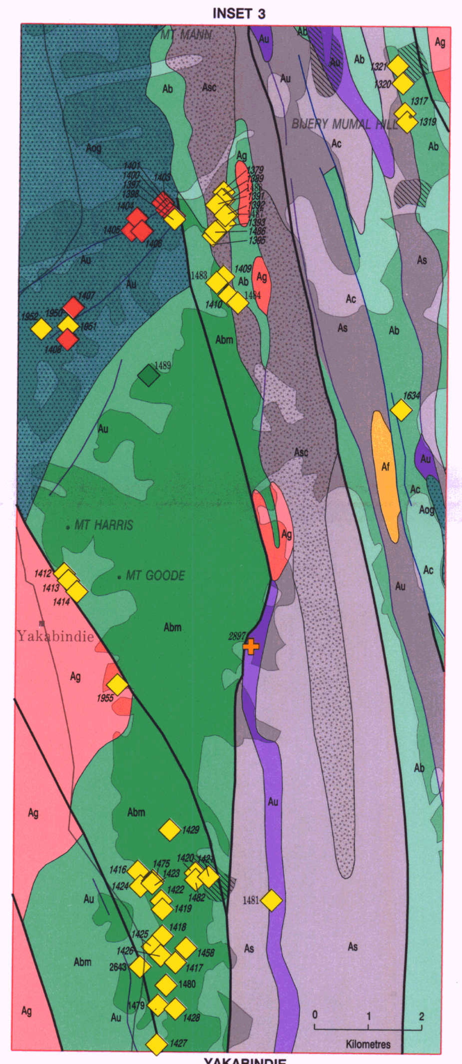
INSET 1

WILUNA



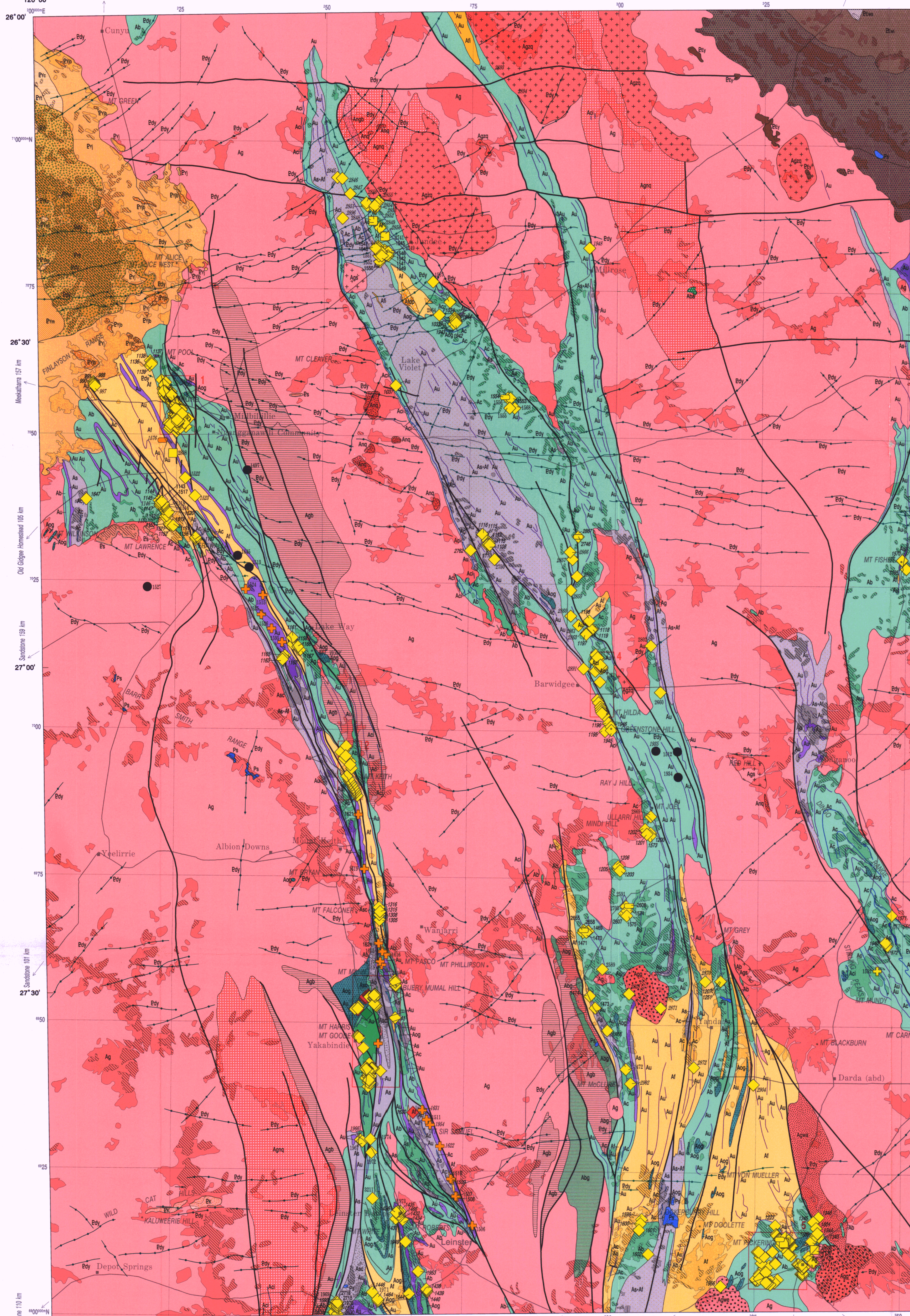
INSET 2

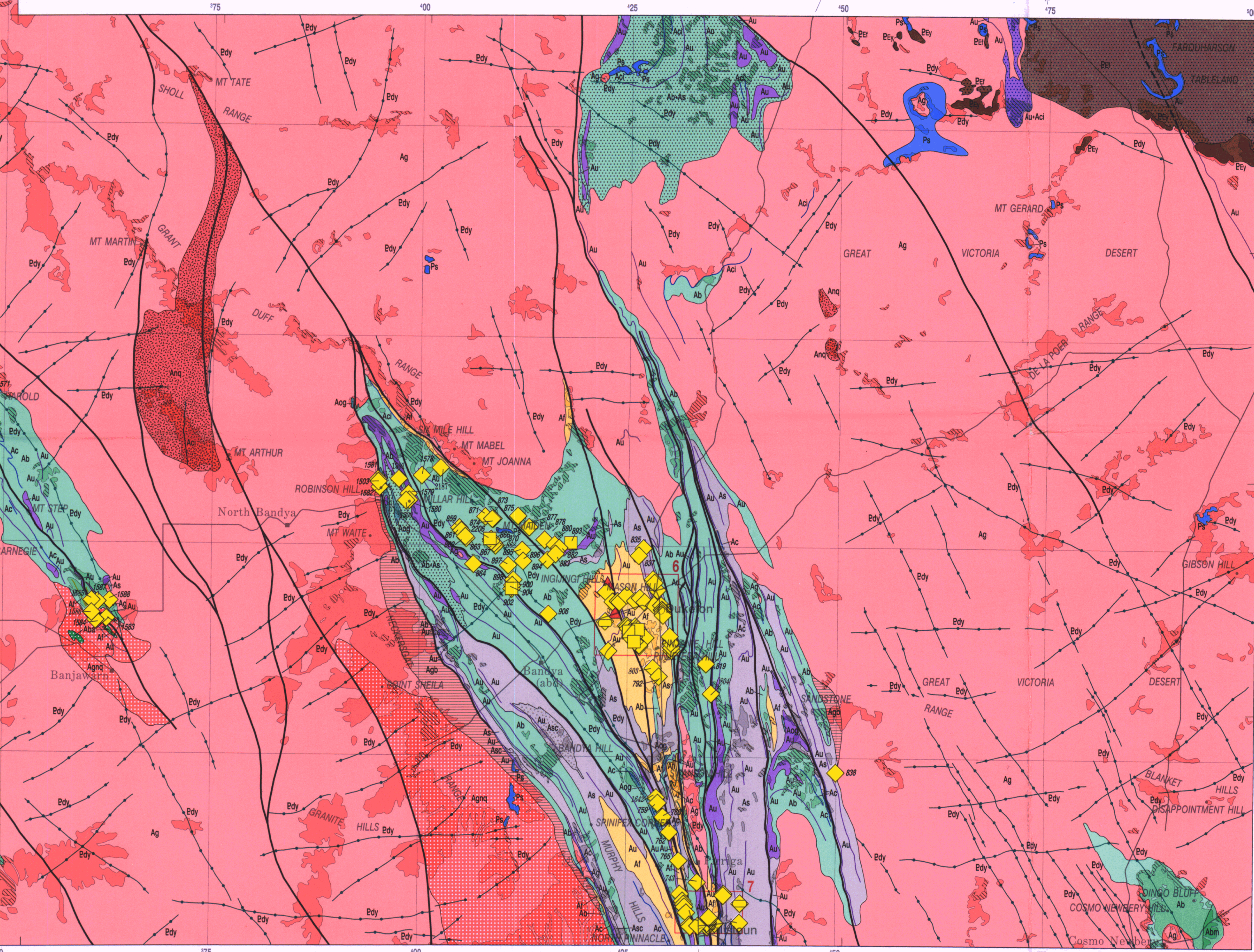
MOUNT KEITH

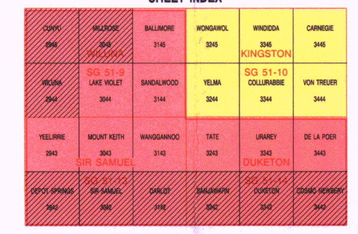


INSET 3

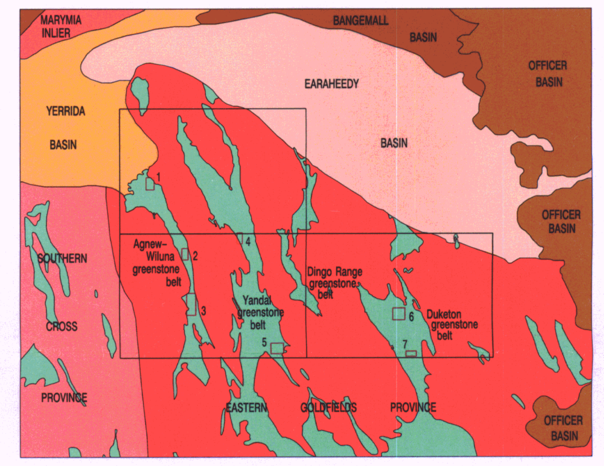
YAKABINDIE







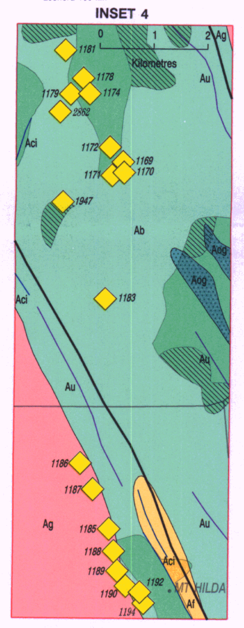
SHEET INDEX



SIMPLIFIED GEOLOGY

SCALE 1:5 000 000

REFERENCE



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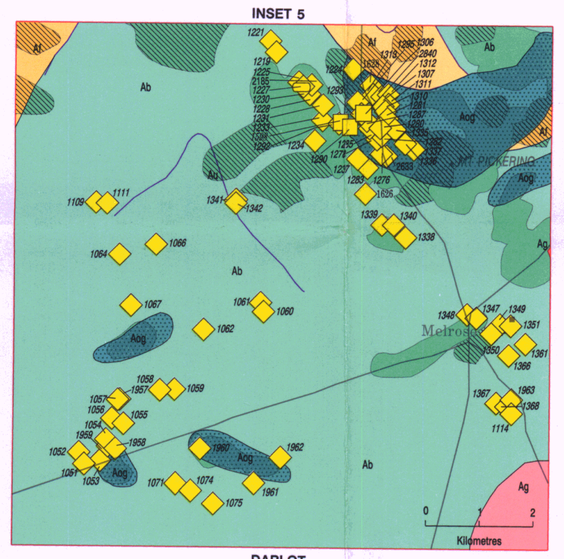

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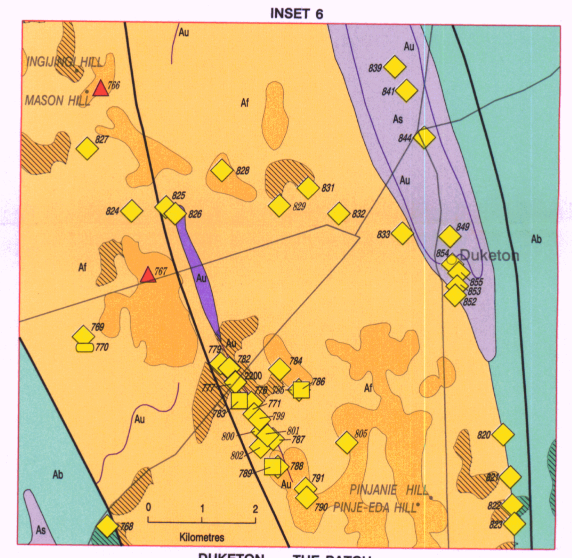
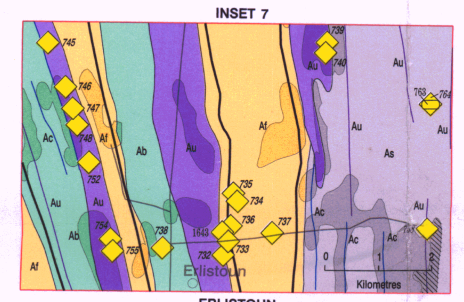
DARLOT



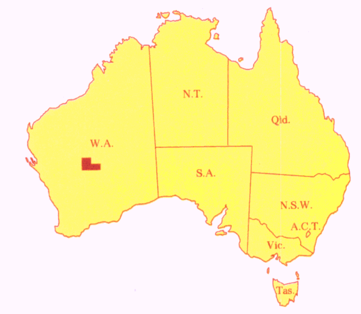
INSET 6

DUKETON — THE PATCH



INSET 7

ERLISTOUN



Au Metamorphosed ultramafic rock dominant

Au+Aci Mixed sequence of metamorphosed ultramafic rock and banded iron-formation

Mineral occurrence data compiled by A. H. Hickman 1990 and K. M. Ferguson 1998

Geology compiled by T.R. Farrell 1997 using GSWA and AGSO maps (see sheet index)

Edited by N. Tetlaw and G. Loan

Cartography by P. Taylor, B. Williams, and G. van Burgel

Mineralization information on this map is largely derived from non-confidential data held in the WAMIN database, GSWA at February 1998

Topography from the Department of Land Administration sheets SG 51-9, -13, -14

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Data presented on this map are available in digital form

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The recommended reference for this map is:
FERGUSON, K. M., FARRELL, T. R., and HICKMAN, A. H., 1998, Mineralization and geology of the north Eastern Goldfields (1:500 000 scale), *in* Mineral occurrences and exploration potential of the north Eastern Goldfields *by* K. M. FERGUSON: Western Australia Geological Survey, Report 63, Plate 1.

GOVERNMENT OF WESTERN AUSTRALIA
HON. NORMAN MOORE, M.L.C.
MINISTER FOR MINES

DEPARTMENT OF MINERALS AND ENERGY
L. C. RANFORD, DIRECTOR GENERAL

NGMA
PRODUCT OF THE NATIONAL GEOSCIENCE MAPPING ACCORD

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
DAVID BLIGHT, DIRECTOR

SCALE 1:500 000

TRANSVERSE MERCATOR PROJECTION
HORIZONTAL DATUM: AUSTRALIAN GEODETIC DATUM 1984
VERTICAL DATUM: AUSTRALIAN HEIGHT DATUM

Grid lines indicate 25 000 metre interval of the Australian Map Grid Zone 51

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
REPORT 63 PLATE 1
MINERALIZATION AND GEOLOGY OF THE NORTH EASTERN GOLDFIELDS

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