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GSWA 2004 EXTENDED ABSTRACTS

PROMOTING THE PROSPECTIVITY OF WESTERN AUSTRALIA

Geological Survey of Western Australia

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

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Foreword

The Geological Survey of Western Australia (GSWA) open day has become a permanent fixture in Perth's exploration seminar calendar since the event was first held in 1998. As in previous years, GSWA 2004 will again present work in progress to customers interested in the regional geology and mineral prospectivity of Western Australia. The seminars and poster displays provide an opportunity for industry geoscientists to listen to technical presentations, view displays featuring both recently published work and work in progress, and interact with many of the geoscientists directly involved in the current work programs.

The focus of GSWA 2004 is to show explorers early results of the Survey's ongoing work program and to demonstrate the wide range of systems used to deliver its geoscience products and open-file exploration data. The electronic delivery of information over the internet has become a key focus of our recent product developments, with the aim of delivering products quickly and cheaply while still providing delivery options that suit all customers. The digital nature of much of GSWA's output also enables users to incorporate the data into their own databases and mapping systems in searchable and scaleable formats.

Talks will be presented throughout the day, and the expanded abstracts stand as a permanent record of the material presented. Although they represent a cross section of current activities within GSWA, they do not present a complete picture.

In addition to the talks, there will be live demonstrations of online databases and an extensive poster display outlining the recent work and publications of the Survey. Attendees are invited to spend time viewing these presentations and discuss products with the staff involved. GSWA 2004 is also an opportunity for you to provide feedback on GSWA's work programs and the way in which we deliver geoscience information.

The work of GSWA is continuing in a climate of increased optimism in the mineral exploration industry. We are confident that our work provides an invaluable source of pre-competitive information on the mineral and petroleum potential of Western Australia that will stimulate further exploration and assist in the continued expansion of the minerals industry for the benefit of all Western Australians.

TIM GRIFFIN
DIRECTOR

Contents

Using new-generation geological maps of the Pilbara to guide mineral exploration

by

A. H. Hickman

All field mapping required for the new 1:100 000 and 1:250 000 Geological Series maps of the Pilbara granite–greenstone terranes was completed in 2003. Since the North Pilbara Craton Project commenced in 1995, 22 first-edition 1:100 000 maps and three new (second- and third-edition) 1:250 000 maps have been released. By 2005, 31 new 1:100 000 maps and seven new 1:250 000 maps, plus a number of special terrane maps, will be available (Fig. 1). This has been one of the Geological Survey of Western Australia's (GSWA) largest ever mapping projects, and was a collaborative project with the Australian Geological Survey Organisation (AGSO, now Geoscience Australia). The Australian Geological Survey Organisation made a major contribution to new regional airborne geophysical surveys, while concentrating its fieldwork on mineralization studies. A separate, but complementary GSWA project reviewed all known mineral occurrences in the region. Over 75 000 km^2 of mainly highly prospective Archaean granite–greenstone terranes now have up-to-date geological and mineralization data to guide future mineral exploration.

Previous mapping

First- and second-edition 1:250 000-scale maps of the Pilbara Craton, produced between 1956 and 1982, were seriously outdated by the early 1990s. These maps were compiled from reconnaissance geological mapping using 1:40 000 to 1:80 000 aerial photography, mostly of very poor quality by today's standards. Fieldwork and map compilation were undertaken without the assistance of Landsat images or orthophotography, without aeromagnetic and radiometric data, with little or no geochronology or geochemistry, and without access to a Global Positioning System (GPS). Field mapping was rapid (averaging about 60 km^2 per day), but the processes involved in manual drafting and setting up for printing were time consuming, with the result that coloured maps were rarely published within 5 years. For economies of scale, the maps were printed in large numbers (typically about 2000), and thereafter any changes involved expensive reprinting.

New-generation maps

Today, new mapping techniques have vastly increased the range and amount of geoscience data collected, and substantially improved data quality (e.g. by accurate positioning using GPS). Today's mappers use 1:25 000-scale colour aerial photography for navigation and geological interpretation, and are assisted by Landsat, aeromagnetic, and radiometric data. Precise geochronology (e.g. U–Pb zircon dating by sensitive high-resolution ion microprobe: SHRIMP) constrains stratigraphic correlations and the timing of geological events, and geochemistry is available for petrogenetic interpretations. Map production involves either scanning of geologists' compilations or direct digital on-screen map compilation, and is more rapid than the manual drafting of the past. Coloured maps (plotted in small batches as required) can now be released within 12 months of field mapping.

Guide to mineral exploration

The new detailed geological mapping of the northern Pilbara has not only provided industry with better geological maps to assist mineral exploration programs, but has greatly improved our understanding of the region's crustal evolution, including its history of metallogenic events. Geological models have evolved during the mapping, with recent reviews describing the regional geology and tectonic evolution of the granite–greenstones (Van Kranendonk et al., 2002) and the timing of mineralizing events (Huston et al., 2002). The models provide interpretations that can be applied to: (a) explain the distribution of known mineral deposits, and (b) suggest additional areas to explore.

The potential of the new mapping to guide future exploration is illustrated by the recognition of a 200 km-long zone of sanukitoid (high-Mg diorite) and mafic–ultramafic intrusions in the Mallina Basin (Smithies and Champion, 1999). The maps (e.g. Smithies and Hickman, 2003) show that these 2.95 Ga intrusions were emplaced along a major east-northeasterly trending zone of faulting

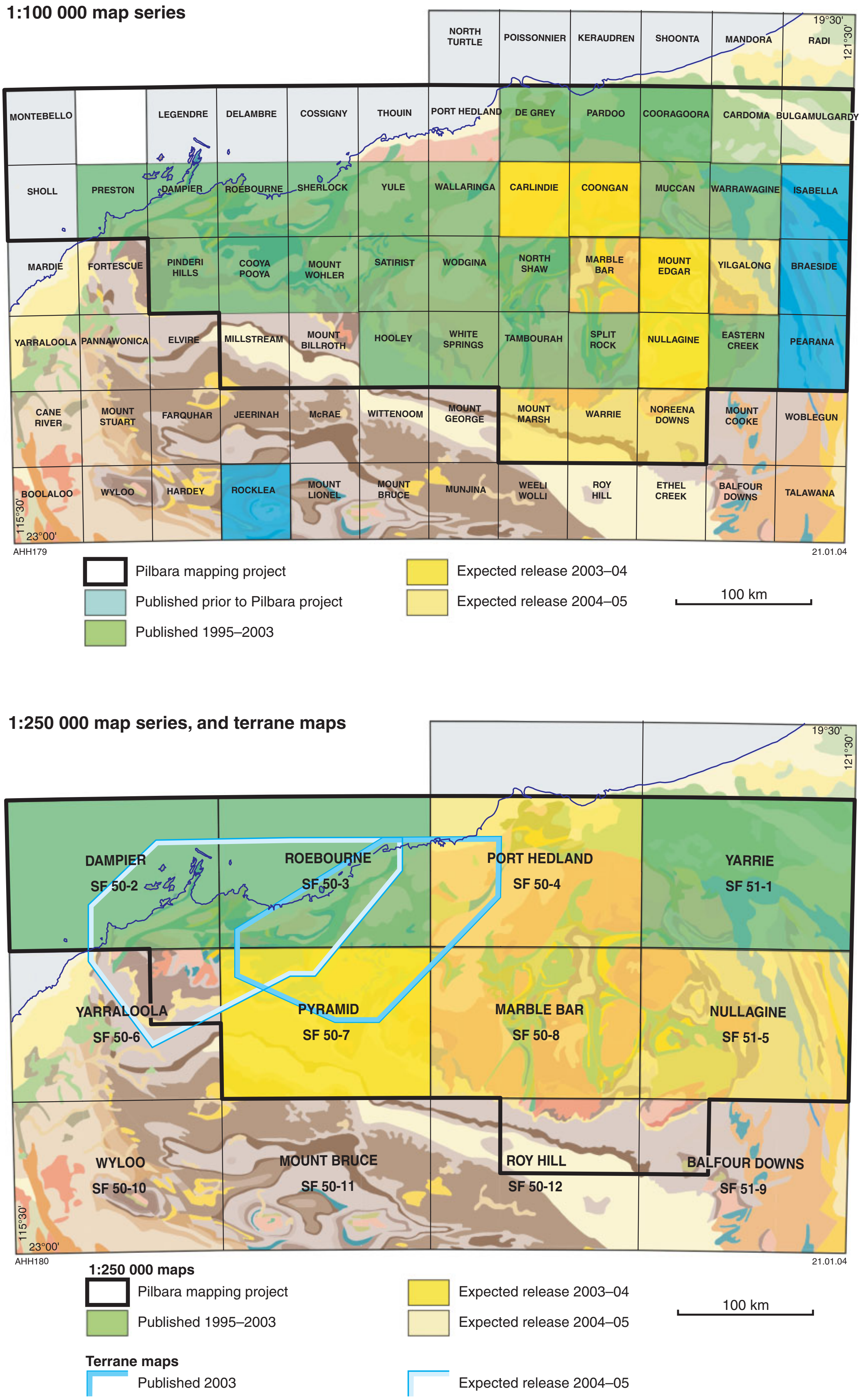

Figure 1. Publications generated by the North Pilbara Craton Project

(principally the Tabba Tabba Shear Zone in the east-northeast and the Wohler Shear Zone in the west-southwest), and to a lesser extent on splays from this zone (e.g. Mallina Shear Zone, and probably also the almost entirely concealed Jones River Fault). The recent discoveries of platinum group element (PGE), nickel–copper, and gold mineralization at Indee, along only 10 km of this 200 km zone, support comparisons with sanukitoid-related mineralization in the Wabigoon Subprovince of Ontario, which includes the Lac des Iles mine (published resources: 159 Mt at 1.55 g/t palladium). This suggests that much of the Mallina Basin should now be regarded as prospective for PGE and nickel–copper mineralization, in addition to potential for further discoveries of gold mineralization (Smithies and Champion, 1999).

The new mapping has provided geological bases for GSWA Reports (map and CD format) on mineralization in the west Pilbara (Ruddock, 1999) and east Pilbara (Ferguson and Ruddock, 2001), and contributed to understanding the structural, lithological, and stratigraphic controls on many of these deposits. Completion of the field mapping, and precise zircon U–Pb geochronology from about 200 sites, has now established an 'event stratigraphy' for the granite–greenstones of the northern Pilbara, and this correlates with the known periods of mineralization (Van Kranendonk et al., 2004). Compilation of all the new geological data into a seamless database will be the next phase of the Pilbara project, and this will take several years.

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Archaean supergroups and supersuites in the northern Pilbara Craton: the application of event stratigraphy to 1 Ga of crustal and metallogenic evolution

by

M. J. Van Kranendonk, R. H. Smithies, A. H. Hickman, L. Bagas, I. R. Williams, and T. R. Farrell

The recent completion of detailed geological mapping of the northern Pilbara Craton, combined with data from approximately two hundred precise sensitive high-resolution ion microprobe (SHRIMP) U–Pb zircon dates on intrusive and extrusive igneous rocks and clastic sedimentary rocks, allows redefinition of the lithostratigraphy and division of intrusive rocks into supersuites and suites. This new scheme facilitates recognition of the major geotectonic and mineralizing events across the different terranes of the Pilbara Craton (Fig. 1).

The new supersuite–suite scheme for igneous rocks consists of nine supersuites, four suites within the Sisters Supersuite, and three unassigned suites (Fig. 1). The division of igneous rocks into suites and supersuites better reflects the aerial distribution of magmatic products than did the previous scheme, which divided granitic rocks on the basis of their occurrence in domical granitoid complexes. The 3270–3235 Ma Cleland Supersuite and the 2955–2925 Ma Sisters Supersuite are present in both the east and west Pilbara, whereas the rest of the suites and supersuites are unique to one or the other terrane. Up to six of the supersuites occur in the nine domical granitic complexes of the East Pilbara Granite–Greenstone Terrane, although in variable proportions between complexes.

The proposed new lithostratigraphic scheme comprises the Pilbara (3530–3000 Ma) and De Grey (2975–2940 Ma) Supergroups, eleven groups and their component formations, and several unassigned formations (Fig. 1). The Pilbara Supergroup is mostly restricted to the east Pilbara, except for the Cleaverville Formation at the top of the Gorge Creek Group. The fault-bounded Roebourne Group of the west Pilbara may relate to the Pilbara Supergroup through rifting. The Pilbara Supergroup comprises the c. 3530–3425 Ma Warrawoona Group, the un-conformably overlying c. 3400–3315 Ma Kelly Group, whose base is marked by Earth's oldest quartzite–carbonate platform succession (Strelley Pool Chert), the unconformably overlying c. 3275–3235 Ma Sulphur Springs Group, and the disconformably overlying Gorge Creek Group. The c. 3120 Ma Whundo Group and c. 3010 Ma Whim Creek Group are unique to the west Pilbara and are not ascribed to a supergroup. The De Grey Supergroup spans the east and west Pilbara and comprises, from west to east, the Bookingarra and Croydon Groups in the Mallina Basin, the Goldsworthy Group in the east Pilbara, and the Nullagine Group in the Mosquito Creek Basin. Revisions of other groups, formations, and members are shown in Figure 1.

Granitic supersuites are associated with major deformation episodes and mineralization in the east Pilbara, except for the post-tectonic, c. 2860–2830 Ma Split Rock Supersuite with tin–tantalum–lithium–beryl mineralization. Mineralized tectono-magmatic events in the east Pilbara occurred at c. 3490–3470 Ma (volcanogenic massive sulfide (VMS) copper–zinc, barite), c. 3445–3400 Ma (porphyry copper–gold, shear zone gold), c. 3325–3300 Ma (porphyry copper, shear zone gold), c. 3240 Ma (VMS copper–zinc), c. 3070 Ma (nickel–copper–PGE in the ultramafic Dalton Suite), and 2940 Ma (shear zone gold, beryl). West Pilbara events include Kambalda-style nickel in the Roebourne Group (c. 3250 Ma), VMS copper–zinc in the Whundo (c. 3124 Ma), Bookingarra (c. 2950 Ma), and Whim Creek (c. 2950 Ma) Groups, shear-zone gold (2950–2890 Ma), and nickel–copper–PGE–vanadium deposits associated with c. 2925 Ma ultramafic intrusions of the Radley Suite.

Details of the new lithostratigraphic and suite nomenclature scheme for the Pilbara Craton will be published in 2004, where sources of information and references will be cited. Once fully evolved and approved, the new nomenclature will be incorporated into GSWA geological maps and digital database products from mid-2004, and new versions of all Pilbara 1:100 000 and 1:250 000 maps will be released in the new format over the next few years.

WEST PILBARA AND CENTRAL PILBARA

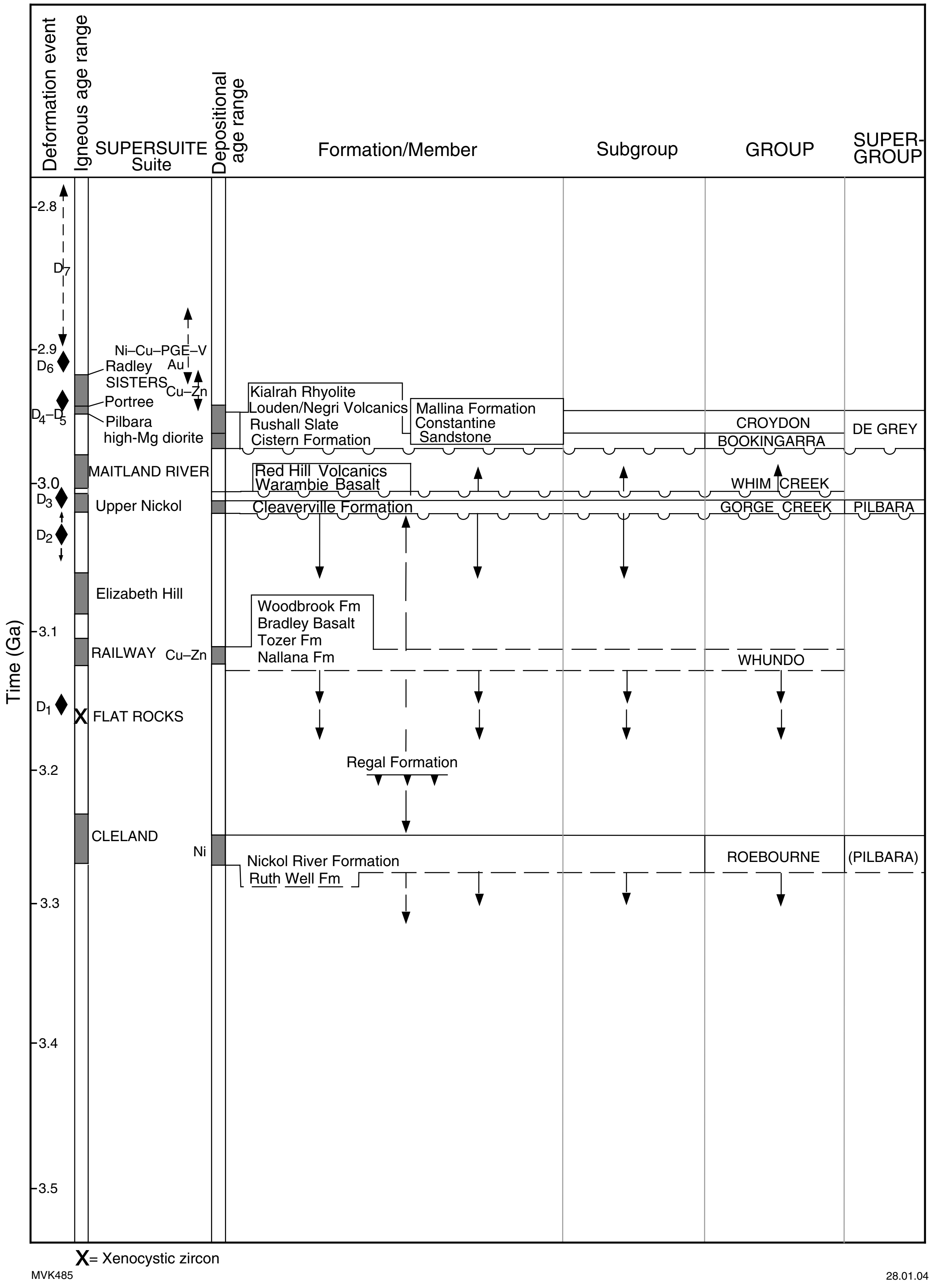

Figure 1. Proposed new lithostratigraphic and supersuite–suite scheme for the northern Pilbara Craton

Figure 1. (continued)

Using the East Yilgarn Geoscience Database in exploration targeting

by

P. B. Groenewald

The East Yilgarn Geoscience Database (EYGD) is the culmination of more than 100 person-years of mapping and interpretation in 150 000 km^2 of the Eastern Goldfields region, the richest gold and nickel metallogenic province in Australia. As an enormous seamless coverage, this geographic information system (GIS) comprises spatially precise geological, structural, mineralization, tenement, aeromagnetic, and cadastral information for fifty-seven 1:100 000 map sheets (Fig. 1). It thus provides a cornerstone for mineral exploration targeting in the region.

In detail, the EYGD comprises information coverages as follows:

- geological mapping of observed rock types, with definitions of lithological subdivisions, and lithostratigraphic and structural relationships. Field data points provide records of measured structural orientations;
- interpreted geology — extent, distribution, and structural relationships in the bedrock beneath the regolith cover that obscures 90% of the region;
- mineralization information from the MINEDEX and WAMIN databases, which represent operating or developing mines and mineral occurrences, respectively;
- tenements — incorporating tenement identifiers, type, status, extent, and location;
- aeromagnetic data, comprising the best available free raster data and vector interpretation;
- Landsat imagery, either as decorrelation stretch or principal component images; and,
- cadastral information, such as roads, tracks, bores, wells, and topographic features.

The wealth of data in the EYGD allows conceptual exploration targeting, at regional or local scales, using the best available information on rock types, their orientation, structural characteristics, and existing mineralization types. The database can be used as a brownfields tool, or in greenfields exploration planning such as, for example, the analysis of rock type distribution and structural features required to do comparative searches for mineralization settings equivalent to those identified in known deposits. Alternatively, the search could be for parameters that satisfy a process model for mineralization.

Regionally extensive and detailed databases such as the EYGD can act as a technological bonus whereby exploration success for a company can be achieved at reduced expenditure levels because the difficult and time-consuming compilation work is already done. Further work on the EYGD will include mapping of metamorphic and alteration characteristics to enhance understanding of deposit settings and provide previously unrecognized vectors to ore deposits. Another data enhancement in progress is the inclusion of more information on mineralization and exploration activities, which is of key importance in the analysis of existing deposits and the distribution of mineral occurrences.

Ongoing development of GIS packages such as the EYGD will greatly optimize exploration targeting and enhance the mineral prospectivity of Western Australia.

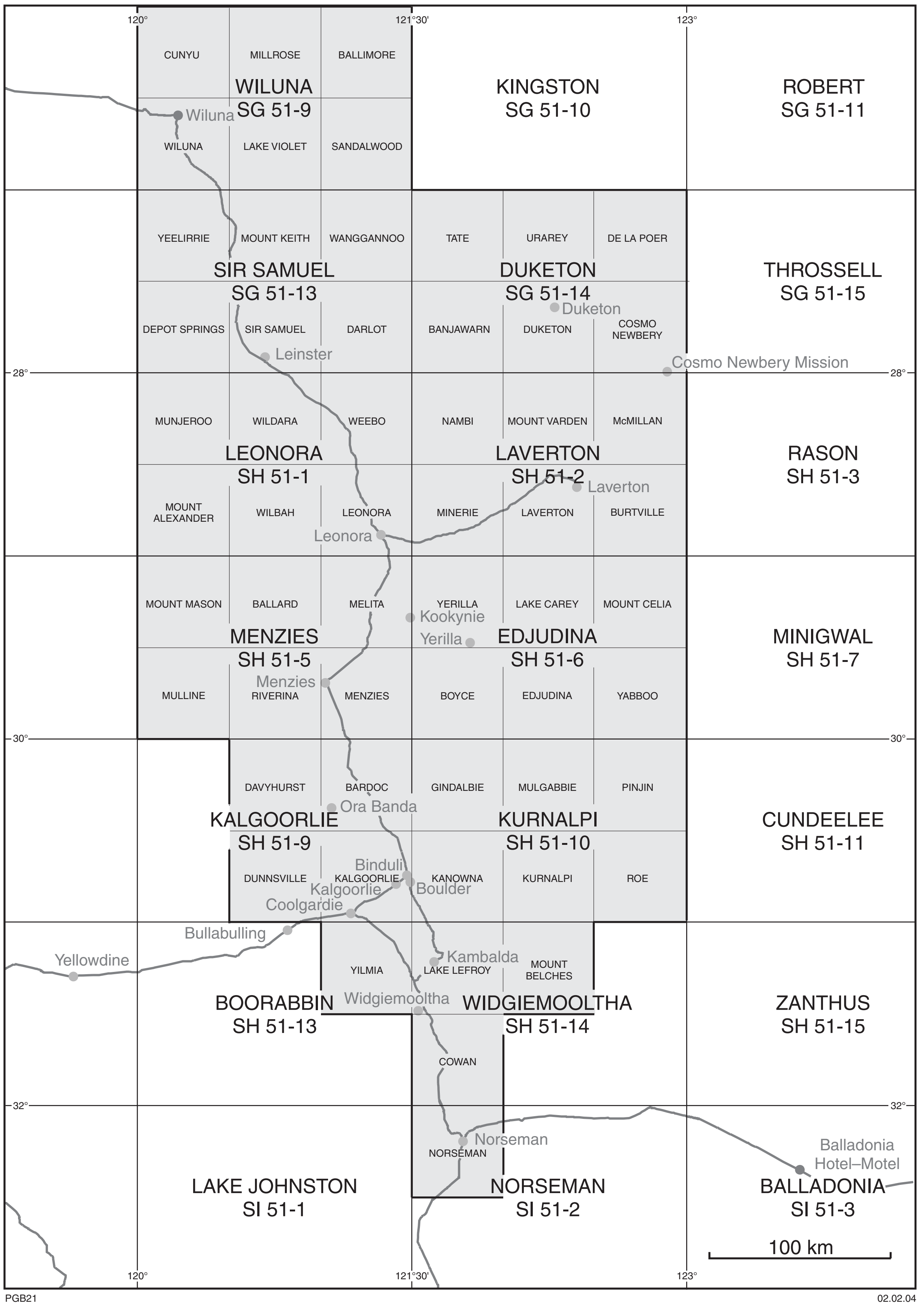

Figure 1. 1:100 000 maps covered by the East Yilgarn Geoscience Database

1:100 000 regolith reinterpretation of the Eastern Goldfields

by

A. Riganti and P. B. Groenewald

Regolith deposits cover about 90% of the Eastern Goldfields Granite–Greenstone Terrane of the Yilgarn Craton, and are host to significant mineral deposits, including lateritic gold, lateritic nickel, rare earth elements, and industrial minerals. Mineral exploration is also increasingly focused on the identification of mineral deposits hidden beneath thick residual or transported regolith cover. A correct interpretation of the regolith is therefore an essential tool in the search for new mineral deposits.

To serve the developing needs of the mineral exploration industry, the Geological Survey of Western Australia (GSWA) embarked upon a complete regolith reinterpretation for the area covered by the Combined East Yilgarn Geoscience Database (EYGD), in which the fifty-six 1:100 000 maps covering the Eastern Goldfields region are compiled. As this mapping was conducted and compiled over a period of more than eighteen years, a regolith reinterpretation was essential to produce a consistent coverage that accomodates recent advances in understanding the processes that control the formation and evolution of regolith deposits (compare Figs 1a and 1b). A full standardization of regolith codes across the area covered by the database was also introduced, according to the revised GSWA regolith classification scheme (Hocking et al., 2001), which is based on the Residual–Erosional–Depositional (RED) scheme of Anand et al. (1993). In addition to the erosional regime (X) typical of bedrock exposures, the main regolith elements are colluvial (C), alluvial (A), sheetwash (W), and lake deposits (L), representative of increasingly distal transport and deposition, and relict or residual deposits (R) representing either remnants of a previous land surface or weathering products of the underlying bedrock in situ. Eolian and residual sandplain deposits (S) are developed in various parts of the landform profile.

Reinterpretation of the regolith coverage was carried out largely using Landsat TM images and published geological maps. In addition to ground truthing in critical areas, the reinterpretaton drew heavily from the experience gained during several years of aerial photography- and Landsat-based regional field mapping. The Landsat TM images routinely used for the reinterpretation include:

- bands 7, 4, 1 (RGB) — these bands are the least correlated of all bands, and therefore provide a sensitive response across a broad spectrum of variations in composition;
- the Gozzard band ratio, 5/7, 4/7, 4/2 (RGB) provides finer subdivision in areas where iron and clay are important components of the regolith (Tapley and Gozzard, 1992).

The 1:100 000 regolith reinterpretation in the Combined EYGD represents a seamless and homogeneous regolith coverage across the Eastern Goldfields region, and represents the most extensive work undertaken thus far at this scale. The regolith geology for the area is resolved in much greater detail (Fig. 1), with a total of 46 regolith types recognized, and the number of regolith polygons increased by about 10% (from ~39 000 to ~43 000). It reflects our deeper understanding of regolith formation and evolution, and as such it is a critical tool in the search for mineral deposits in the deeply weathered terrain of the Eastern Goldfields.

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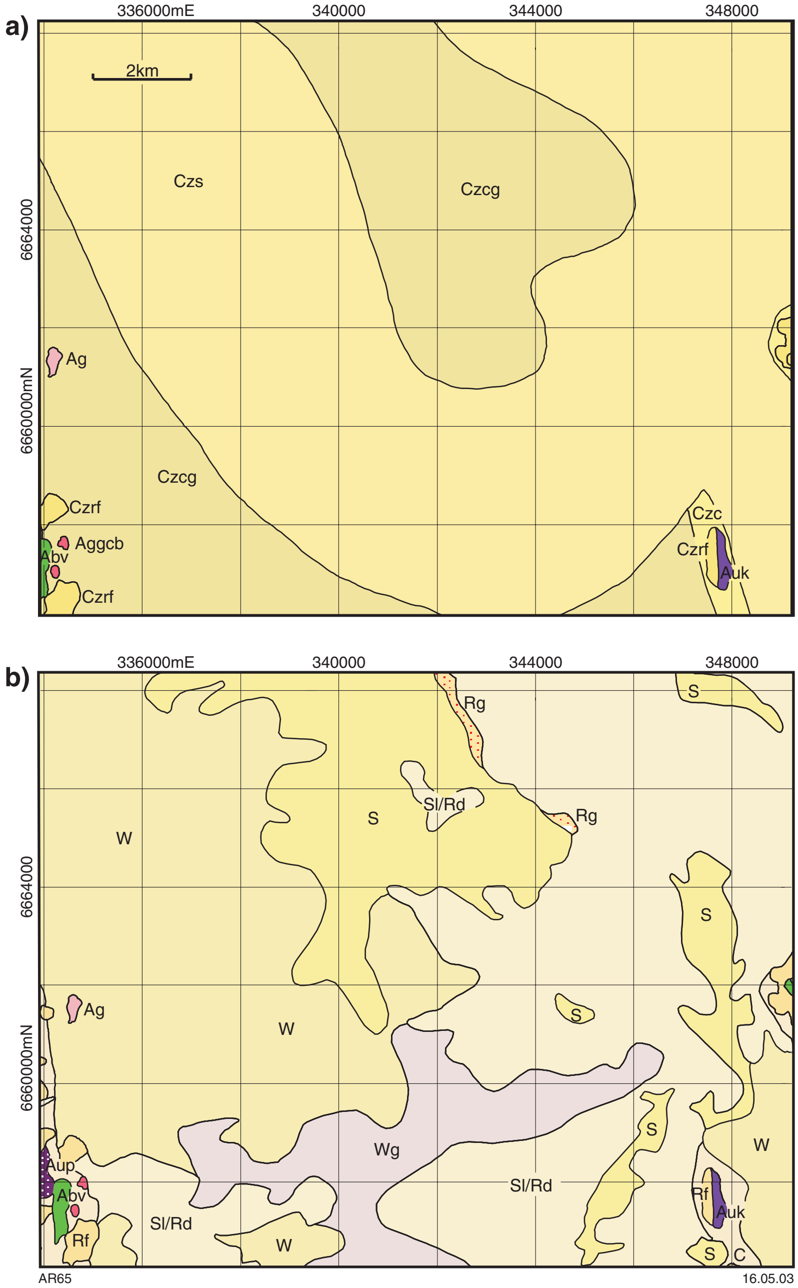

Figure 1. Comparison of a) original published (Witt and Swager, 1989) and b) reinterpreted regolith geology for a portion of the BARDOC 1:100 000 map sheet, illustrating the significant adjustments required by application of the GSWA regolith scheme (Hocking et al., 2001). Grid references in Figure 1a and b refer to the Australian Geodetic Datum 1966 (AGD66) and the Geocentric Datum of Australia 1994 (GDA94) respectively

Volcanological reconstruction of mineralized sequences in the Minerie – Murrin Murrin area, Archaean Kurnalpi Terrane

by

M. G. Doyle and P. B. Groenewald

Many volcanic sequences, particularly those deposited in water, include intercalated facies that are not genetically related. The result is a complex facies architecture that is characterized by juxtaposition of products from vastly different source environments. Each facies retains distinctive characteristics that relate to formative volcanic processes and volcano type and setting, proximity of the volcanic source, and temporal relations (syn- versus post-eruptive). Volcanic facies analysis provides a powerful tool to resolve the origins of these problematic rocks. This approach, which is applied here, has provided new constraints on the volcanic facies architecture, environment of eruption and emplacement, and tectono-stratigraphic evolution of sequences in the Minerie to Murrin Murrin area of the Kurnalpi Terrane, Yilgarn Craton (Fig. 1).

Three conformable lithofacies associations, from stratigraphic lowest to highest respectively, can be identified on the basis of composition, constituent facies, and provenance.

Association A: Post-eruptive volcanogenic sedimentary deposits and andesitic–dacitic lavas (Welcome Well Complex)

The Welcome Well Complex comprises volcanogenic sedimentary facies, intercalated with coherent andesite–dacite and associated autoclastic breccia facies. Massive and flow-banded andesite–dacite contains evenly distributed feldspar phenocrysts with groundmasses ranging from spherulitic to formerly glassy (perlitic). Flow interiors are coherent or cut by planar to curviplanar cooling contraction fractures, and grade out into marginal hyaloclastite facies formed during quenching by seawater.

The volcanogenic sedimentary facies comprises matrix- to clast-supported conglomerate, pebble–granule breccia, sandstone, and siltstone beds that are not related to contemporaneous eruptions and are characterized by polymictic clast assemblages, mixed provenance, abundant rounded texturally variable andesitic lithic clasts, and thin to thick sedimentation units. Diffuse bedding and grading within the conglomerate facies is defined by subtle variations in maximum and mean particle size, suggesting single depositional units are up to a few tens of metres thick. Amalgamated unit boundaries are common, implying sustained input of detritus from subaqueous density currents (principally grain flows and debris flows). Pebble-sandstone beds (3–4 m thick) comprise one or more high-concentration turbidite divisions. These may include: a lower division of planar and cross-laminated sandstone reflecting traction sedimentation (S_1); an interval of reversely graded traction-carpet deposits (S_2); with or without a grain-supported lithic and crystal-rich pebble–granule breccia and sandstone division, reflecting a declining sedimentation rate during accumulation from suspension (S_3).

Rounded to sub-angular clasts were reworked in above wave-base (fluvial, shoreline) environments prior to final deposition in flanking deeper water (below storm wave-base) environments. Blocky andesitic clasts have phenocryst populations and shapes that suggest some were sourced from the autoclastic carapace of intrabasinal lavas by sediment gravity flows that scoured the sea floor. Sedimentation accompanying degradation of an un-preserved medial emergent volcanic edifice was contemporaneous with subaqueous (below storm wave-base) eruption and reworking of proximal andesitic–dacitic lava facies.

Association B: Komatiitic basalt and tholeiitic basalt facies (Minerie sequence)

Association B is dominated by tholeiitic basalt intercalated with subordinate spinifex- and cumulate-textured komatiitic basalt units and crystal-vitric-lithic sandstone facies. Lateral and vertical transitions between massive coherent basalt facies, pillow lava, and autoclastic facies are widespread. Flow interiors are commonly crystalline (doleritic), whereas flow tops are marked by intervals of formerly glassy basalt and thin (metre thick) autoclastic breccia facies, reflecting asymmetric cooling and crystalliz-

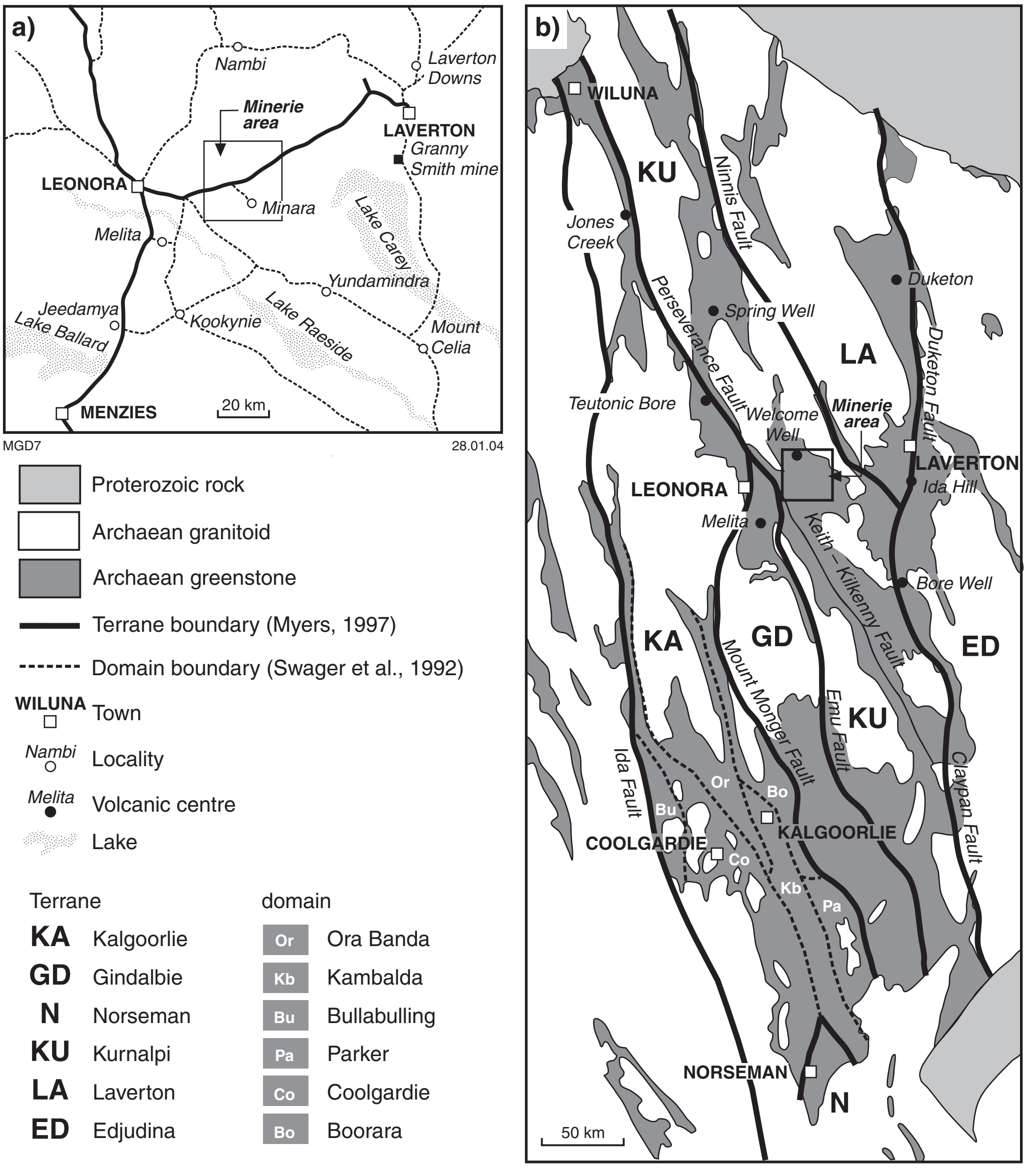

Figure 1. a) Location of the Minerie – Murrin Murrin area. b) Simplified geological map showing the distribution of granitoid and greenstone in the Eastern Goldfields Province. Terrane boundaries, faults, and the principal domains are also shown. Modified after Myers (1997) and Brown et al. (2001)

ation profiles. Autoclastic breccia facies are monomictic and comprise a complex arrangement of jigsaw-fit hyaloclastite, clast-rotated autoclastic breccia, pillow-fragment breccia, autobreccia, and pillow-lobe facies. Although typically massive, rare intervals display subtle variations in grainsize that may reflect limited syn-eruptive transport down flow fronts, possibly through rolling and tumbling. Extended breaks in mafic eruptive activity are marked by laterally continuous sandstone–siltstone beds, which are mainly felsic, post-eruptive turbiditity current deposits (Ta-c divisions) and suspension sedimentation deposits. The widespread occurrences of pillow lava, hyaloclastite, and turbidity current deposits suggest deposition in a relatively quiet, deep-submarine (below storm wave-base) depositional environment. Basaltic units are interpreted as the proximal–medial facies association of a subaqueous, non-explosive volcanic centre.

Association C: Komatiite and felsic syn- to post-eruptive facies (Murrin Murrin ultramafic complex)

The prospective Murrin Murrin ultramafic complex includes juxtaposed and intercalated komatiite, komatiitic basalt, felsic vitric-crystal-pumice breccia–sandstone, and siltstone–sandstone facies. Komatiitic basalt facies are texturally variable and locally contain around 10% (visual estimate) amygdales. Where exposed, upper komatiite flow margins are coherent or marked by a thin (<10 cm thick), incipiently quench-fractured zone (A_1) that typically passes downward through a random spinifex-textured zone (A_2), into a zone of aligned (stringy-beef textured) pyroxene needles (A_3). Horizons rich in varioles and ocelli are subparallel to bedding in felsic volcaniclastic facies interleaved with the komatiitic basalt sheets, and both are locally truncated at discordant contacts with cumulate facies. Overall there is an interdigitation between komatiitic basalt and differentiates with orthocumulate to gabbroic textures that is interpreted to reflect both intrusive and extrusive (endogenous) modes of emplacement.

Lower contacts between komatiitic basalt flows and the volcaniclastic substrate vary from planar and broadly conformable to invasive, and locally comprise jigsaw-fit hyaloclastite and blocky peperite zones. Because peperite is diagnostic of synvolcanic interaction of magma with unconsolidated sediment, the age of komatiite volcanism can be constrained by the depositional age (2698 ± 5 Ma; Nelson, in prep.) of the intermixed dacitic volcaniclastic facies. The dacitic facies comprise 1–3 m thick, non-welded, normally graded pumice-crystal breccia beds, accretionary lapilli-rich beds, and planar- and cross-laminated vitric-crystal sandstone–siltstone units (low- and high-concentration turbidites, water-settled ash fall). The lithofacies character suggests syn- to post-eruptive sedimentation of pyroclasts from medial to distal volcanic centre(s) characterized by explosive (magmatic–phreatomagmatic) eruptions. Depositional environments were subaqueous (below storm wave-base) within the proximal facies association of a separate volcanic centre characterized by non-explosive ultramafic volcanism.

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Recent mapping in the Sandstone region: implications for gold mineralization

by

S. Wyche, S. F. Chen, and M. G. Doyle

During 2002 and 2003, field mapping in the northern part of the Yilgarn Craton focused on the Sandstone, Booylgoo Range, Gum Creek, Barrambie, and Poison Hills greenstone belts (Fig. 1). Outside these major belts, a number of small patches of greenstone lie within broad granite areas of dominantly monzogranitic composition. Much of the new work is currently being compiled, so this paper contains preliminary observations about the stratigraphy in the greenstone belts, the regional structure, and their relationship with known gold deposits. Most greenstone successions in the region outcrop poorly, with the best exposures in the Booylgoo Range belt, locally around the margins of the Sandstone belt, and on the eastern side of the Gum Creek belt.

The Sandstone, Booylgoo Range, Gum Creek, Barrambie, and Poison Hills greenstone belts have similar stratigraphic packages that contain many elements comparable with those described in the mafic-dominated lower greenstone succession elsewhere in the Southern Cross Granite–Greenstone Terrane, including the Marda–Diemals area. However, unlike the Marda–Diemals region (Chen et al., 2003) where felsic volcanic rocks of the Marda Complex and clastic sedimentary rocks of the Diemals Formation unconformably overlie the mafic-dominated succession, both the Sandstone and Gum Creek belts contain interleaved clastic sedimentary rocks and minor felsic volcanic facies. Distinctive quartzites and quartz-rich metasedimentary rocks like those in the Maynard Hills and Illaara greenstone belts to the southeast are absent from the Sandstone, Booylgoo Range, Gum Creek, Barrambie, and Poison Hills greenstone belts.

Structural complexity in the Sandstone greenstone belt and the lack of continuous greenstone sections in the Barrambie and Poison Hills greenstone belts makes it difficult to establish clear stratigraphic successions; however, in all the belts, prominent units of ferruginous chert and banded iron-formation with intercalated mafic and ultramafic rocks are low in the succession. The chert and banded iron-formation are overlain by a thick unit of mainly tholeiitic metabasalt that contains a substantial interval of komatiitic basalt in its lower part in the Booylgoo Range belt. The upper part of the succession in the Gum Creek and Sandstone belts contains clastic metasedimentary rocks. They are very poorly exposed in the north of the Sandstone greenstone belt where they consist of shale and siltstone. More widespread metasedimentary rocks in the Gum Creek belt include shale, carbonaceous shale, sandstone, local conglomerate, and intercalated coherent rhyolite and dacite. The poor exposure in the western part of the Gum Creek belt, combined with structural complications, makes it difficult to establish an unequivocal stratigraphic succession. Sensitive high-resolution ion microprobe (SHRIMP) U–Pb zircon dating by Wang et al. (1998) suggests that at least some of the felsic and metasedimentary rocks are c. 2700 Ma or younger. If these ages are correct, then it is likely that the felsic and sedimentary part of the succession is unconformable on, or tectonically interleaved with, a mafic-dominated succession that is probably older than 2900 Ma. Layered mafic–ultramafic sills intrude all the greenstone belts at various levels.

Eisenlohr et al. (1993) described some of the major regional shear zones, and Beeson et al. (1993) carried out more detailed structural studies in the Gum Creek greenstone belt. The overall deformation history, which is supported by our recent studies, is similar to that described elsewhere in the Southern Cross Granite–Greenstone Terrane (Chen et al., 2003). An early, poorly recognized episode of recumbent folding and possible thrust faulting (D_1) was followed by a protracted period of broadly east–west compressional deformation that produced northerly to north-northwesterly trending upright folds and reverse faults (D_2), which are overprinted by sinistral north-northwesterly trending shear zones and dextral north-northeasterly trending shear zones (D_3). Late kinks and northeasterly and northwesterly trending brittle faults (D_4) overprint all earlier structures. These late structures may pre-date easterly to southeasterly trending brittle fractures that are evident on aeromagnetic images in areas of granite (Fig. 1). Some late fractures have been intruded by Proterozoic mafic–ultramafic dykes. Greenstones are metamorphosed to greenschist and amphibolite facies. Peak metamorphism coincided with widespread granite intrusion after c. 2685 Ma, probably during late D_2 and early D_3.

There is little evidence of D_1 structures in most of the greenstone belts, with the best evidence being local intrafolial and refolded folds in banded iron-formation and

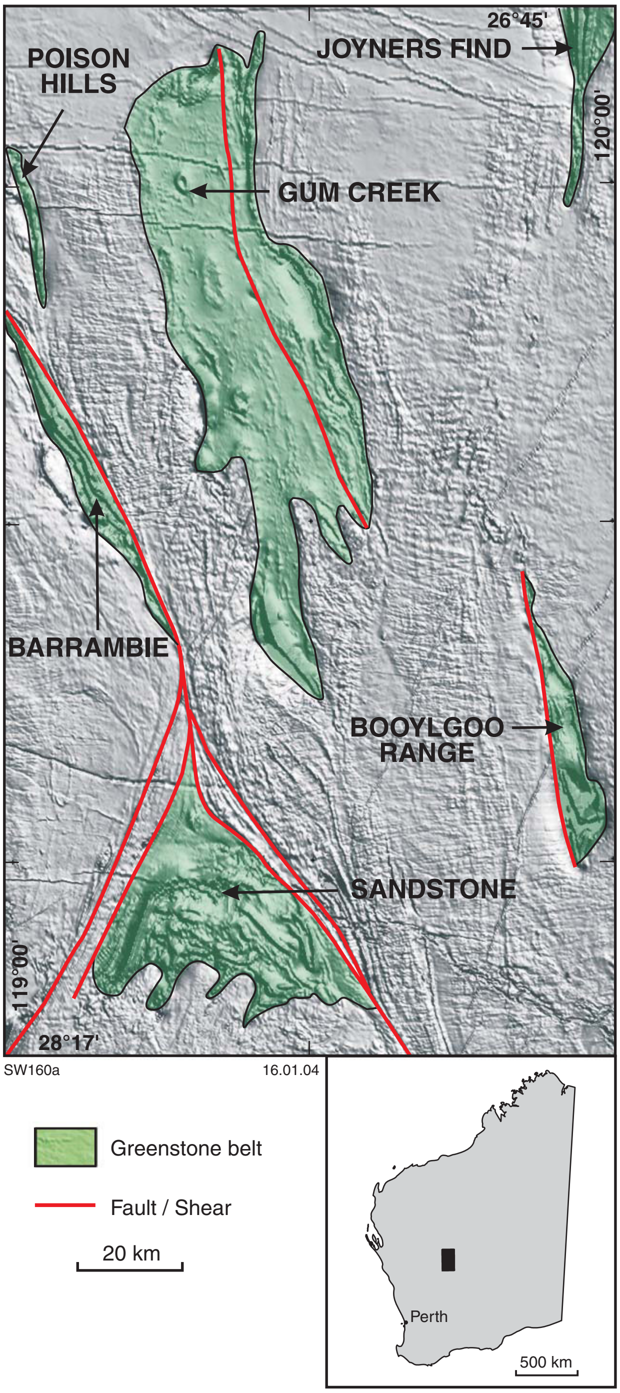

Figure 1. Aeromagnetic image showing the Sandstone, Booylgoo Range, Gum Creek, Barrambie, Joyners Find, and Poison Hills greenstone belts in the northern Yilgarn Craton

chert. In the Sandstone belt, the distribution of outcrops, and patterns on aeromagnetic images, suggest the presence of large-scale F_1 folds and possible thrust faults that have been refolded during D_2. The belt-scale F_2 fold has been variously interpreted as an antiform (Stewart et al., 1983) and a synform (Chen, 2003).

The overall form of the Gum Creek and Booylgoo Range greenstone belts has been shaped by synclinal structures formed during D_2. In the Gum Creek belt, Beeson et al. (1993) interpreted a synclinorium that has been disrupted by a major D_3 shear zone towards its eastern side. In the Booylgoo Range belt, a keel-shaped F_2 syncline outlined by banded iron-formation has been disrupted by the development of D_2 reverse faults.

The Sandstone and Gum Creek greenstone belts have the largest recorded historical gold production in the region with more than 28 t and 39 t respectively. Mining is still active in these belts with current production from Troy Resources' Bulchina operation in the Sandstone greenstone belt, and Legend Mining's Gidgee gold mine in the Gum Creek belt. Substantial historical gold production (695 kg) has also been recorded from the Barrambie greenstone belt, which lies to the west of the Gum Creek belt. There is no recorded production, and no evidence of any historical mining activity, in the Booylgoo Range greenstone belt in the east. This poor endowment appears to be typical of the belts in the eastern part of the Central Yilgarn region with most belts having no recorded gold production and only sparse and shallow workings. The exception is the Joyners Find greenstone belt to the northeast of the Gum Creek belt, which has a recorded historical production of about 374 kg.

There have been few detailed studies of gold mineralization, with the best documented deposits in the Gum Creek greenstone belt. Although some of the richest deposits in the region are hosted by mafic rocks, examples of deposits hosted by banded iron-formation, felsic porphyry, granite, and probable metasedimentary schist are also known. Whereas many deposits such as those at Omega (Beeson et al., 1993; Ross and Smith, 1998) and Kingfisher (Hazard, 1998) appear to have formed in favourable sites where competency contrasts or early deformation events have been overprinted by late (?D_4) structures, the origin of other deposits is more equivocal. Beeson et al. (1993) argued that a number of significant deposits such as those at Gidgee may have formed during D_3 shearing or earlier.

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The Virtual Tour: an explorationist's guide to the GSWA website

by

S. G. Bandy

The Department of Industry and Resources (DoIR) has recently launched a better, more client-focused website. As a result of this change, the Geological Survey of Western Australia (GSWA) now has a new home page offering easier access and improved services (www.doir.wa.gov.au/gswa; Fig. 1).

GSWA produces a huge collection of books, maps, and state-of-the-art databases for the benefit of the Western Australian community, including prospectors, explorers, miners, and investors. For many years, GSWA has provided products and data systems online. The Survey is now providing easier access to products and integrating data systems to improve functionality. GSWA is moving to a one-stop approach for the delivery of geoscience data and products.

The Virtual Tour of the GSWA website highlights many of the new features of our data systems.

Products and Services

The Products and Services part of the website refers and links to publications and maps produced by the GSWA (Fig. 2).

Catalogue of Geological Maps and Publications

Maps and books available for purchase from GSWA are described in PDF versions of the **Catalogue of pre-1980 geological publications** and **Catalogue of geological maps and publications 1980–2004**. The catalogues provide prices for all books and maps, as well as detailed index maps. The catalogues can be viewed online using Adobe Acrobat Reader or downloaded free of charge.

Hot off the Press

The Hot off the Press page provides links to recently released mineral and petroleum publications.

Online Publications

A selection of GSWA publications in PDF format can be viewed or downloaded free of charge. These include:

- Mineral Resources Bulletins
- Reports
- Records

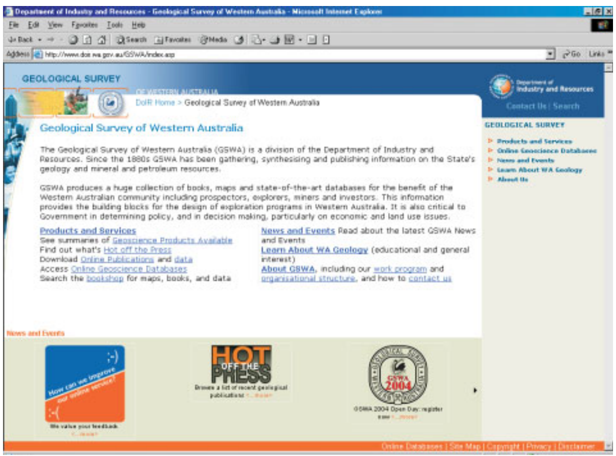

Figure 1. GSWA's home page

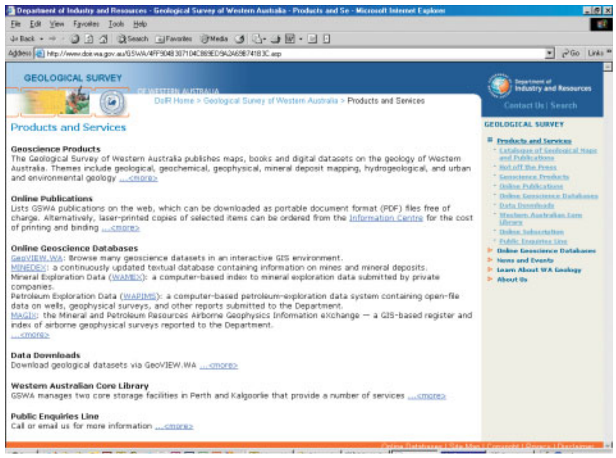

Figure 2. Products and Services page

- Explanatory Notes
- Maps

Data Downloads

The Data Download Centre enables you to download geoscience datasets as .ZIP files. Each .ZIP file contains a metadata statement, the dataset in either ESRI Shapefile or MapInfo TAB file formats, and a licence file.

Online Subscription

You can register your email address with us so that we can keep you informed of new products and services on the following:

- All aspects of GSWA including product information, data releases, and media statements and releases
- Fieldnotes
- GSWA products and services relating to minerals
- GSWA products and services relating to petroleum
- GSWA products and services relating to GIS datasets

Online geoscience databases

Mineral exploration data (WAMEX)

Indexes to available mineral exploration reports have been available at the Department's website for several years (WAMEX; Fig. 3). An online user-friendly interface enables customers to search by various parameters, most of which have drop-down lists to assist in formulating the search. Where reports have been scanned, the WAMEX interface allows you to view these reports online in PDF format.

Access to the WAMEX database is unrestricted with no registration or membership required.

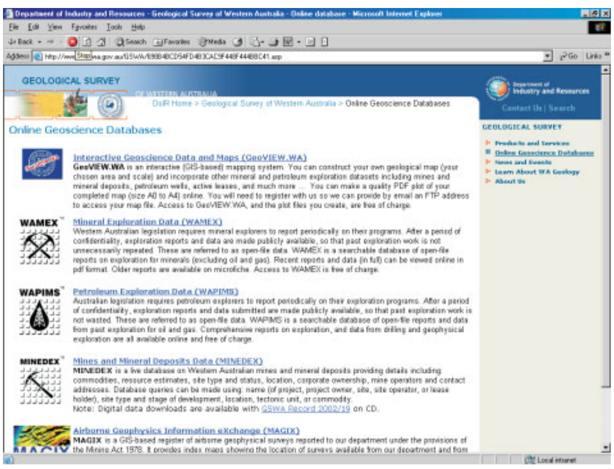

Figure 3. Online databases home page

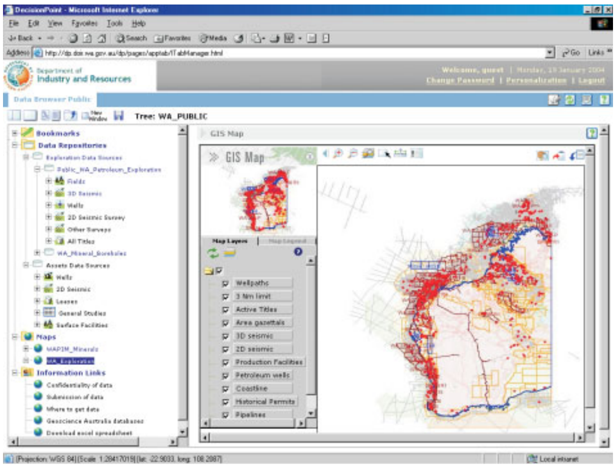

Figure 4. Petroleum exploration data (WAPIMS) screen

Petroleum exploration data (WAPIMS)

The WAPIMS (Fig. 4) system has undergone a major upgrade that has resulted in significant advances in providing customer access to petroleum data. This includes data on petroleum titles; details of all wells and geophysical surveys; production data; reports; well logs; seismic lines; maps; samples; and digital data submitted by explorers.

Customers are able to search either spatially or textually for these data.

Mines and mineral deposits data (MINEDEX)

MINEDEX is a continuously-updated textual database containing information on mines and mineral deposits in Western Australia. A web interface enables customers to search by various parameters, most of which have drop-down lists or check boxes to assist in formulating the search.

The online user interface includes access to project and current project ownership, sites details, commodity group, mineral resource estimates, and notice of intent for development. In addition, the latest MINEDEX database is available for download from the introduction page.

Airborne geophysics information exchange (MAGIX)

The MAGIX web page contains information related to GSWA's airborne geophysical survey register and data repository. From this page you can:

- register a Survey
- access the Airborne Survey Reporting Policy
- download MAGIX index files
- request MAGIX open-file digital data
- request Government digital data from Geoscience Australia

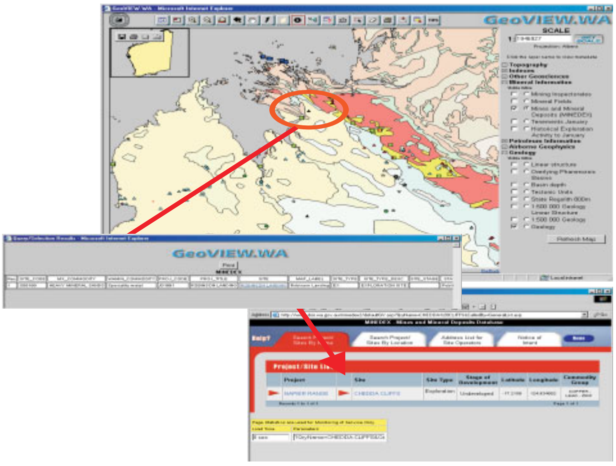

Figure 5. GeoVIEW.WA, GSWA's web-mapping application, showing its integration with the MINEDEX database

GeoVIEW.WA

GeoVIEW.WA is a web mapping application to view and query a number of integrated geoscientific and related datasets. Including:

- 1:2 500 000, 1:500 000, 1:250 000, and 1:100 000 scale geology
- geochronology
- mines and mineral deposits (MINEDEX)
- open-file geophysics index
- petroleum titles
- 2D and 3D seismic line data index
- mining tenements
- historic exploration activity
- special category lands e.g. native-title land claims, Conservation and Land Management (CALM) estate
- boundaries of departmental administrative regions

In addition to tools that zoom in, zoom out, pan, query, and drill down to display associated textual data in the viewing window, GeoVIEW.WA now provides:

- a mapping tool to produce a hard copy of the map shown in the web view
- a product search tool
- a data download facility

GeoVIEW.WA has also integrated the spatial data with the text-based WAMEX and MINEDEX systems. By clicking on the hyperlinked Site Name it will seamlessly take the customer to the MINEDEX interface (Fig. 5).

DoIR Bookshop

You can browse and purchase the full range of GSWA publications in the DoIR bookshop. Customers can select items for purchase and pay for them by credit card or by cheque or money order.

News and Events

The News and Events page contains articles of general interest and issues relating to GSWA programs and activities.

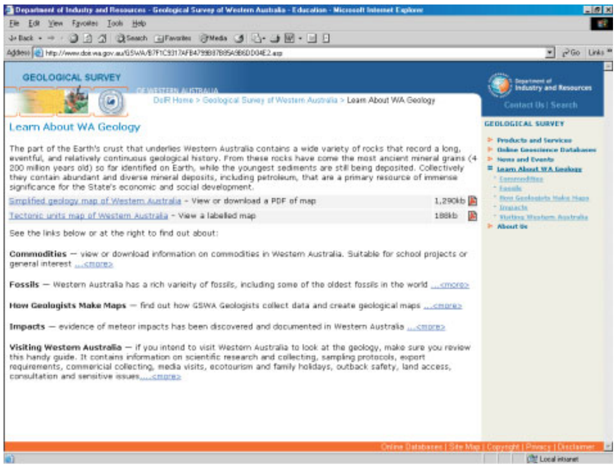

Figure 6. The Learn About WA Geology page

Learn About WA Geology

The Learn About WA Geology page (Fig. 6) presents a brief overview of geology in Western Australia and provides links to find out about:

- Commodities in Western Australia. Suitable for school projects or general interest
- Fossils
- How geologists make maps
- Evidence of meteorite impacts documented in Western Australia
- Information you should know when visiting Western Australia to look at the geology of the State

Mineral deposits and exploration activity in the Kimberley

by

I. Ruddock and L. Y. Hassan

The Kimberley region covers an area of about 400 000 km^2. It contains the largest range of mineral commodities of any region in Western Australia. Operating mines include the world's largest diamond mine at Argyle, another diamond mine at Ellendale, an iron ore mine at Cockatoo Island, and significant resources to support future mining of zinc–lead–silver at the Lennard Shelf, nickel sulfides at Sally Malay, platinum group elements (PGE) at Panton Sill, and bauxite at Mitchell Plateau.

With the imminent release of Report 88 on the west Kimberley, the Geological Survey will have completed data packages for the three mineral prospectivity studies that cover the Kimberley region:

- Report 74: East Kimberley (published in 2000)
- Report 85: North Kimberley (published in 2003)
- Report 88: West Kimberley (to be published in 2004)

The data packages include a Report, a 1:500 000-scale mineralization map, and a CD containing GIS-compatible digital datasets. Each Report includes sections on geological setting, history of mining and exploration, mineralization styles and commodities, and potential for further exploration. The CDs include two major datasets: one is for mineral deposits and occurrences; and the other is a graphics front-end for exploration activities in the Western Australian mineral exploration database (WAMEX) open-file reports.

The diverse geological framework of the Kimberley includes favourable hosts and settings for numerous styles of mineralization (Fig. 1), but much of the region has only been explored at the reconnaissance level. Since the late 1960s, the most intensive exploration has been undertaken in the following areas:

- the Lamboo Complex, in environments that are favourable for copper–zinc–silver in stratabound volcanic massive sulfides (VMS), orthomagmatic PGE and nickel sulfides in layered-mafic intrusions, and vein and hydrothermal gold;
- the Devonian reef carbonates of the Lennard Shelf and Sorby Hills for Mississippi Valley-style stratabound lead–zinc–silver;
- the lamproite and kimberlite fields around Argyle, Ellendale, the northeast Kimberley, and Aries in the central Kimberley for diamonds.

The central part of the region is occupied by sedimentary and volcanic rocks of the Palaeoproterozoic Kimberley and Speewah Basins that cover about 160 000 km^2. The margins of these basins are flanked by the King Leopold Orogen (containing metavolcanic, metasedimentary, and igneous rocks of the Palaeoproterozoic Hooper Complex) and the Halls Creek Orogen (containing metavolcanic, metasedimentary and igneous rocks of the Palaeoproterozoic Lamboo Complex) to the southwest and southeast. These in turn are flanked by thick sedimentary sequences of the Phanerozoic Canning, Ord, and Bonaparte Basins.

The early mining history of the Kimberley was dominated by gold after Western Australia's first payable gold deposits were discovered at Halls Creek in 1885; however, deposits in the east Kimberley proved to be small and there has been relatively minor production. Most of the known gold mineralization is within the Eastern Zone of the Lamboo Complex, but new fields may be emerging in the Kimberley Basin, following the 2002 announcement of alluvial gold at Oombulgurri in the northeast Kimberley and the rediscovery of a 1907 government report on auriferous veins in the southwest of the basin.

Since the 1950s, exploration has led to the discovery of a number of significant deposits of other minerals but many of these have remained undeveloped because of unfavourable economic circumstances, partly due to their isolated locations.

Mineral production in the Kimberley is currently dominated by diamonds from lamproite and alluvial deposits at Argyle and Ellendale. Until late 2002, the Lennard Shelf area was a major producer of zinc–lead–silver, from a number of Mississippi Valley-style carbonate-hosted deposits, but operations were shut down in 2003 pending an improvement in commodity market conditions. Iron ore production from sediment-hosted deposits on Cockatoo Island recommenced in late 2000 and there are plans to reopen the iron ore operation at

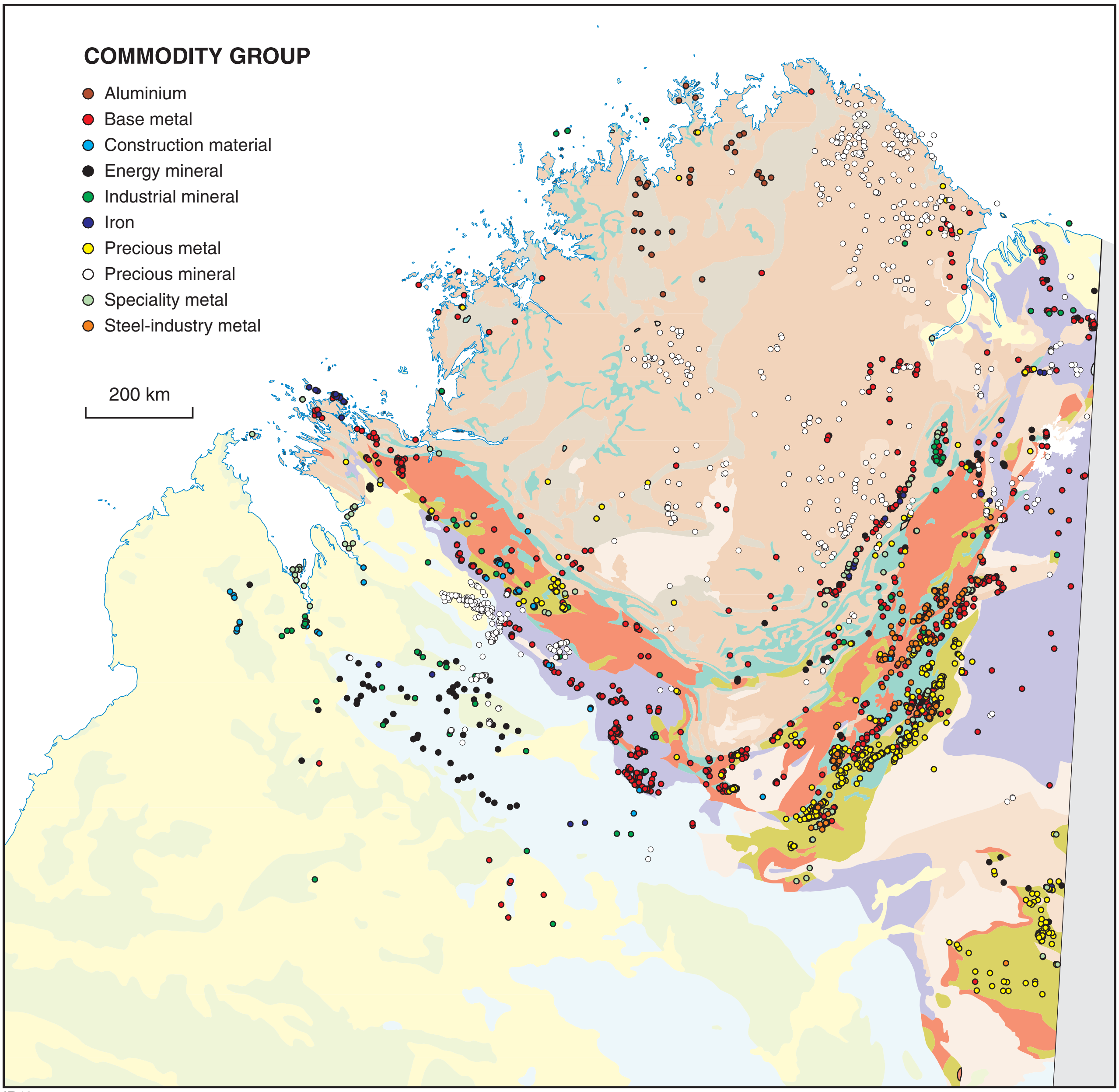

Figure 1. Mineral deposits and occurrences of the Kimberley region (note: the precious mineral commodity group includes mainly diamond sites; the precious metal commodity group includes gold sites and PGE sites)

nearby Koolan Island. Both deposits produced high-grade ore from the 1950s to late 1990s and were the region's most significant production sites until the Argyle diamond mine was opened in 1985. The Kimberley region will soon become a nickel producer with mining about to commence at the Sally Malay nickel sulfide deposit that was first outlined in the late 1970s in a layered mafic intrusion northeast of Halls Creek.

Other developments that may occur in the short to medium term are:

- PGEs at the Panton Sill layered mafic intrusion, where feasibility studies in 2003 showed that development would depend on sustained higher prices for platinum and palladium. Further metallurgical recovery investigations are in progress.
- Diamonds in a kimberlite pipe at Seppelt 2, where bulk samples showing very promising grades were announced in 2002 (up to 2.2 carats per ton). Sampling of Seppelt 2 in 2003 confirmed these results and initial sampling from another intrusion called Seppelt 5 is showing similar high grades.
- Nickel–copper sulfides at Copernicus in a layered mafic intrusion about 35 km south of the Sally Malay deposit. Encouraging results have been obtained from drilling in 2003 and a feasibility study is planned for this year.

- Volcanic massive sulfide copper–zinc–lead–silver deposits found at Koongie Park southwest of Halls Creek in the 1970s during the base metals and nickel boom. Resources are not large enough to be economic and further exploration is needed to locate additional ore to support a mining operation.
- Rare earth elements and tantalum at the Brockman deposits that were first assessed in 1988. A new joint venture partner is assessing potential for tantalum production.

Longer term developments may include:

- Bauxite at Mitchell Plateau and Cape Bougainville, where major deposits were delineated in the late 1960s. Although these contain almost 50% of the State's alumina resources, a number of feasibility studies at various times have concluded that development was uneconomic given the logistics of the remote location and minimal infrastructure.
- Coal at Liveringa in Upper Permian rocks of the Fitzroy Trough (Canning Basin).
- Uranium at Oobagooma.
- Rare earth element mineralization in a carbonatite intrusion at Cummins Range.
- Fluorite at Speewah.
- Offshore diamonds along the coastline of the northeast Kimberley.

Very large gas reserves at the Scott Reef and Brecknock Gasfields in the Browse Basin, about 300 km offshore to the north of Broome, could be used in future mineral developments in the region.

The Musgrave Complex in Western Australia: a new GSWA frontier in a greenfields environment

by

R. H. Smithies, F. Pirajno, and H. M. Howard

Towards the end of the 2003 field season, the Geoloigcal Survey of Western Australia (GSWA) commenced detailed regional mapping of the Western Australian part of the central Australian Musgrave Complex, renewing an acquaintance left dormant for over 30 years. Our renewed interest in this region reflects GSWA's charter of promoting mineral exploration in greenfields areas of the State. The prospectivity has been recently enhanced by WMC's discoveries of nickel sulfides at the Babel and Nebo prospects south of the Jameson Range. The Musgrave region also forms the junction of Proterozoic orogenic trends in central and southern Western Australia, and there has been a growing recognition that this poorly understood area may hold many of the answers that have eluded attempts to understand the regional geological evolution of Proterozoic Australia.

The extremely varied geology encompasses structurally complex low- to high-grade metamorphic terranes that record a Meso- to Neoproterozoic history involving up to six magmatic and deformational events, including the Mesoproterozoic Musgravian Orogeny, the Neoproterozoic–Cambrian Petermann Orogeny, and the Devonian Alice Springs Orogeny. A basement sequence — the Birksgate complex — comprises pre-Musgravian high-grade gneisses and is interpreted to be of volcano-sedimentary origin. These gneisses were intruded, during the Musgravian Orogeny, first by a series of granitic magmas and then by the voluminous layered mafic–ultramafic Giles intrusions, and temporally associated felsic volcanic rocks and alkaline granites, prior to further high-grade metamorphism. It is the Giles intrusions, and their nickel–copper and platinum-group element (PGE) potential, that have attracted most economic interest to date, and whereas the Musgrave Complex straddles the borders between Western Australia, South Australia, and the Northern Territory, the majority of the Giles intrusions fall within Western Australia (Fig. 1).

The recent mineral discoveries have clearly highlighted a great potential, but the full potential is far from being realized. For example, silicic extrusive rocks such as the Tollu Group volcanic rocks and anorogenic granites are more or less coeval with the spatially associated Giles intrusions, and may have a relationship similar to that between the mafic–ultramafic Rustenburg Layered Suite in the Bushveld Complex (South Africa) and the temporally associated felsic extrusive and intrusive rocks. The felsic rocks of the Bushveld Complex are world renowned for their mineral wealth, including tin–tungsten, mesothermal and epithermal gold, base metals, and industrial minerals.

Our mapping program has been designed with the help and cooperation of the Ngaanyatjarra Council and local traditional landowners, in a way that allows Government geologists to access the area without compromising cultural sensitivities. In addition to providing new detailed geological maps of the Musgrave Complex and new insights into the geological evolution of the region, the project also will accumulate a regional digital dataset that incorporates all legacy data with recently acquired imagery. Initial release of this product is planned for early 2004 and the datasets in this version will include (but are not restricted to):

- geological and tectonic units based on previous GSWA mapping
- mining tenement data
- Landsat TM and Aster imagery
- orthorectified aerial photography
- airborne geophysical data (magnetics and radiometrics)
- a regional solid geological map from interpretation of the airborne magnetic data.

This dataset package will be continuously updated and re-released throughout the duration of the mapping project as new geological observations and analyses become available, and new interpretations that reflect a better understanding of the geological evolution of the region are made.

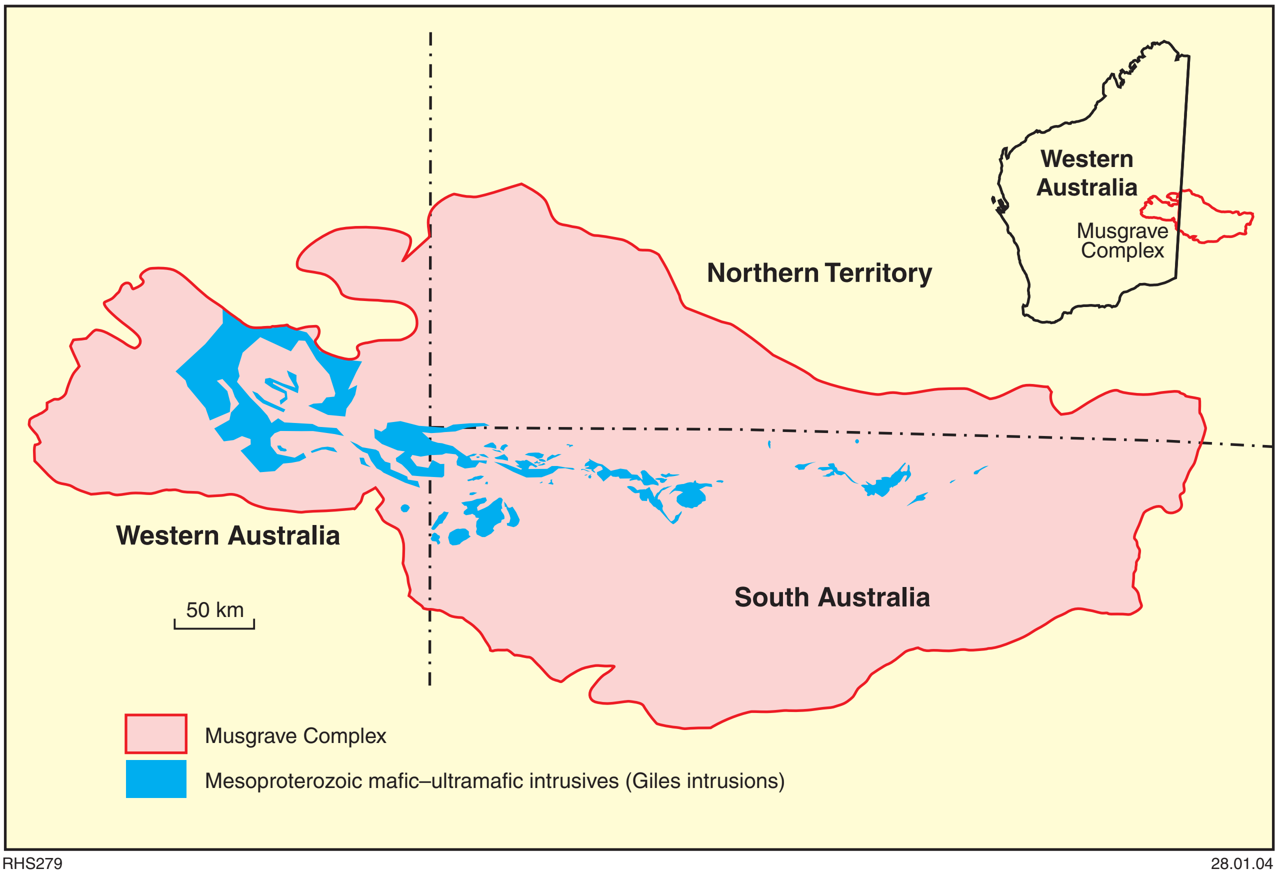

Figure 1. The location of the Musgrave Complex showing the distribution of the Giles intrusions. Modified after PIRSA, 2003, Prospectors and Developers Conference poster

Unravelling the complexity of the Gascoyne Complex

by

S. Sheppard

The Gascoyne Complex is located at the western end of the presently exposed Proterozoic Capricorn Orogen, which includes numerous basins (Fig. 1) filled with low-grade metasedimentary rock and some mafic metavolcanic rock (Cawood and Tyler, in press). The orogen is widely considered to have formed during oblique collision of the Archaean Yilgarn and Pilbara Cratons during the 1830–1780 Ma Capricorn Orogeny (e.g. Tyler and Thorne, 1990; Powell and Horwitz, 1994; Krapez, 1999; Evans et al., 2003); however, views on the timing of rifting and convergence, and the polarity of subduction vary widely, in part because these models are based on interpretations of poorly dated metasedimentary successions in the northern part of the orogen. The ages of these successions are weakly constrained because they do not contain rocks suitable for the isotopic determination of depositional ages. In contrast, the medium- to high-grade metamorphic rocks and the intermediate to silicic igneous rocks of the Gascoyne Complex provide a nearly 400 million-year record of the tectonothermal evolution of the western part of the orogen.

The Gascoyne Complex comprises several terranes, each with a discrete geological history, bounded by large east-southeasterly trending faults or shear zones (Fig. 2). Each terrane is characterized by a metasedimentary package (or packages) together with granitic supersuites that differ in either age or composition, or both, from those

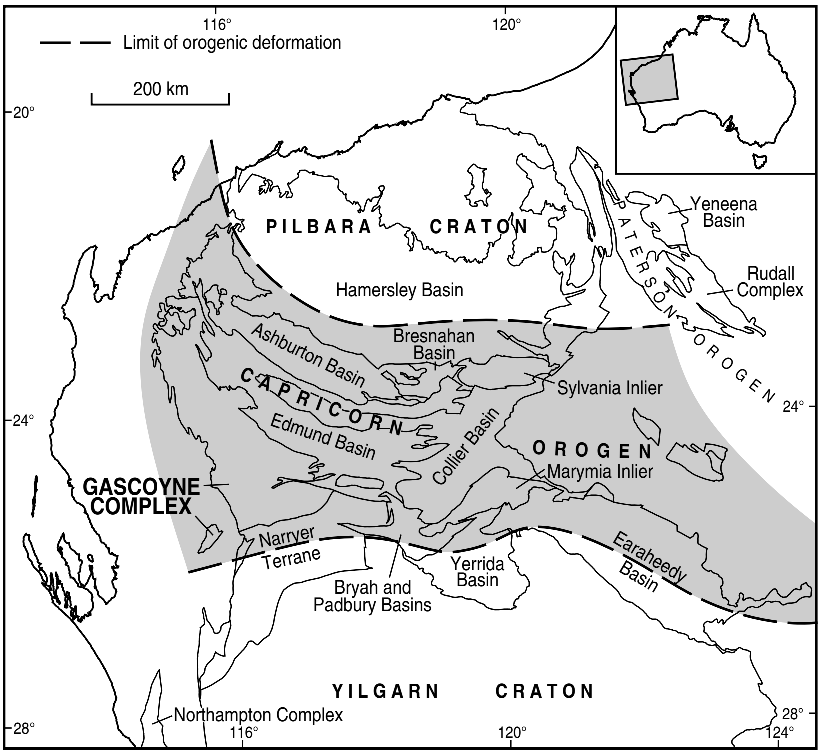

Figure 1. Location of the Capricorn Orogen and its constituent tectonic units

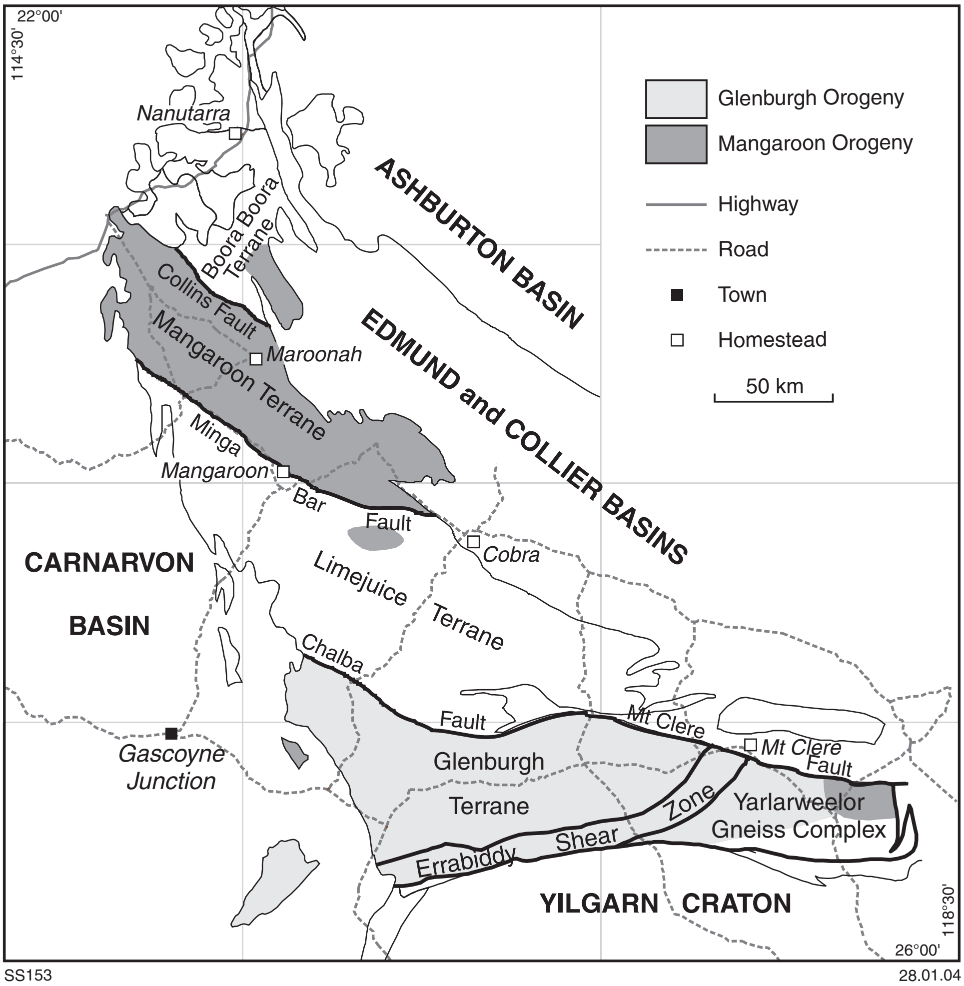

Figure 2. **Subdivision of the Gascoyne Complex into terranes. The areal extent of the Glenburgh and Mangaroon Orogenies is also shown. The entire Gascyone Complex was affected by the Capricorn Orogeny**

in adjacent terranes. The metamorphic and structural history of each terrane also contrasts with the histories of the terranes that bound it.

At the southern end of the complex, the Glenburgh Terrane consists of c. 2550 Ma granitic basement to a 2005–1970 Ma granitic batholith. This terrane is exotic to the Yilgarn Craton, but the relationship of the Glenburgh and Limejuice Terranes is unclear. The Limejuice Terrane is dominated by medium-grade metasedimentary rocks with protolith ages younger than 1840 Ma, which were intruded by granites with crystallization ages of c. 1785 and c. 1650 Ma (Varvell et al., 2003; Nelson, in prep.). The Boora Boora Terrane at the northern end of the complex has a similar geological history to the Limejuice Terrane, suggesting that this crust is contiguous underneath the Mangaroon Terrane.

Recent U–Pb sensitive high-resolution ion microprobe (SHRIMP) geochronological studies show that the Gascoyne Complex was primarily shaped by three separate orogenic events: the 2005–1970 Ma Glenburgh Orogeny, the 1830–1780 Ma Capricorn Orogeny, and the 1685–1650 Ma Mangaroon Orogeny. The effects of a fourth event (the Neoproterozoic Edmundian Orogeny) are mainly confined to fault and shear zone reactivation.

There are structures, metamorphic assemblages, and extensive granitic intrusions related to the Capricorn Orogeny across the whole Gascoyne Complex, whereas the other two orogenies have a more restricted distribution (Fig. 2). The Glenburgh Orogeny, which reflects the collision of the Glenburgh Terrane (or a combined Pilbara–Gascoyne craton) with the Yilgarn Craton, affected the Glenburgh Terrane and adjacent parts of the Yilgarn Craton (Occhipinti et al., in press; Sheppard et al., in press). Intracontinental reworking during the Mangaroon Orogeny is mainly confined to the Mangaroon Terrane in the north of the complex (Sheppard and Occhipinti, in prep.).

Within the Gascoyne Complex, only the Glenburgh Terrane contains evidence of a volcanic–plutonic arc, either of oceanic or continental affinity: this arc reflects subduction under the southern edge of the Glenburgh Terrane prior to amalgamation with the Yilgarn Craton at c. 1960 Ma (Sheppard et al., in press). Nowhere in the terranes of the Gascoyne Complex are igneous rocks present that could be interpreted as a convergent margin that evolved before a postulated continent–continent collision during the Capricorn Orogeny. Indeed, there are no rocks with depositional or crystallization ages between c. 1960 and c. 1840 Ma. The paucity or absence of volcanic rocks does not reflect the current level of exposure, because metasedimentary rocks are abundant throughout the complex.

Granitic rocks intruded during the Capricorn Orogeny are either silicic I-types formed by remelting of older crust, or S-types. These compositions, and the lack of associated gabbros, distinguish the granites from batholiths formed at Andean-type margins and at island arcs. Therefore, it is very unlikely that granites intruded during the Capricorn Orogeny reflect subduction of oceanic crust. The 'Capricorn' granites in the Gascoyne Complex have broad similarities with Phanerozoic granites interpreted to have formed in post-collisional settings (e.g. Hercynides, Caledonides, Lachlan Fold Belt: Sylvester, 1998); however, the Gascoyne Complex, unlike these Phanerozoic orogens, apparently has no prior convergent margin activity.

If there was no subduction prior to, and during, the Capricorn Orogeny, then the Yilgarn and Pilbara Cratons must have been more or less in their current relative positions (other than probable dextral strike-slip movement during the Capricorn Orogeny: Tyler and Thorne, 1990; Occhipinti et al., 1998; Evans et al., 2003). A corollary of this conclusion is that the Capricorn Orogeny was probably intracratonic. If this is correct, then the earlier Glenburgh Orogeny, rather than marking accretion of a microcontinent to the Yilgarn as Sheppard et al. (in press) suggest, may record collision of a combined Pilbara–Gascoyne ('Pilboyne') Craton with the Yilgarn Craton. Ongoing mapping and associated geochronological, structural, metamorphic, and geochemical studies in the Gascoyne Complex will continue to test various tectonic models.

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Geological mapping in the eastern Capricorn Orogen: implications for mineral exploration

by

F. Pirajno

A new initiative was begun in 1994 to map the geology of the eastern Capricorn Orogen. This region includes the Palaeoproterozoic Bryah–Padbury Basins, Yerrida Basin, and Earaheedy Basin, formerly known collectively as the Nabberu Province. Fieldwork in these tectonic units is now completed and Geological Survey of Western Australia (GSWA) products published to date arising from this new mapping initiative are shown in Figure 1. The results of this mapping, together with new geochronological, geochemical, geophysical, and petrographic data, have led to the recognition of the above-mentioned tectonic units, which span a period of almost 400 m.y. (Yerrida Basin, 2.17–1.84 Ga; Bryah–Padbury Basins, 2.0–1.9 Ga; Earaheedy Basin, c. 1.8 Ga). The term Nabberu Province is now obsolete.

These newly recognized tectonic units and the style of their contained mineral deposits have led to a holistic model of geodynamic evolution within the framework of the Capricorn Orogen. This, in turn, provided useful insights into the exploration potential of the region.

Known metallic mineralization in the Bryah and Padbury Basins includes volcanogenic massive sulfides, manganese, and iron oxides, and orogenic lode-gold deposits. The latter is a distinctive class of gold deposits, associated in space and time with collisional and accretionary tectonics. The Bryah Group contains mafic and ultramafic rocks of oceanic plateau affinity that were accreted onto the northwest margin of the Yilgarn Craton. Apart from orogenic gold lodes, these rocks may also host sulfide deposits generated through venting of hydrothermal fluids on the sea floor.

The Yerrida Basin is less well-endowed with known mineralization, but its geodynamic history and tectonic

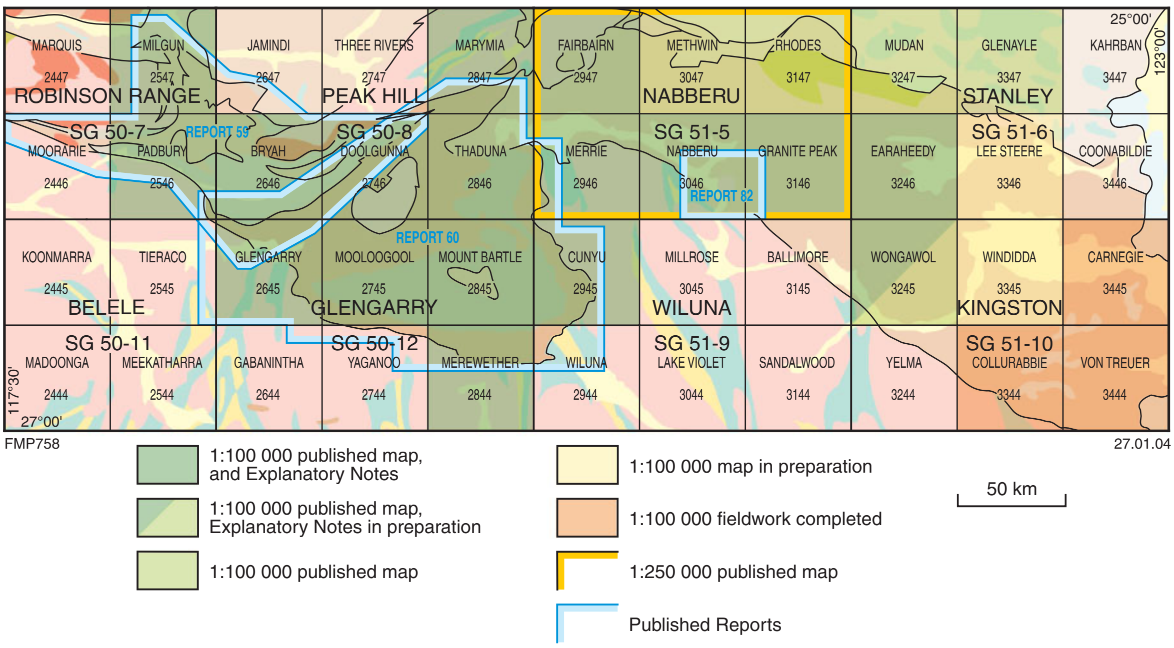

Figure 1. Completed and in progress series map sheets, Explanatory Notes, and Reports published 1995–2003 by the Glengarry and Earaheedy project teams

setting suggest potential for precious metals in hot-spring chemical precipitates and in black shale. In addition, intraplate intrusive and extrusive mafic rocks (Killara Formation) may host Noril'sk style nickel–copper–platinum group element (PGE) deposits.

The Earaheedy Group contains hydrothermal ore deposits that include Mississippi valley-type zinc–lead in carbonate units of the basal Yelma Formation and non-sulfide lead (oxides only), also in the Yelma Formation or at the unconformity with the underlying youngest unit of the Yerrida Basin (Mooloogool Group). The Superior-type granular iron-formation beds of the Frere Formation extend along strike for a total of approximately 500 km, constituting a significant iron resource. The Stanley Fold Belt, on the northern margin of the Earaheedy Basin, is the result of transpressive tectonics and may host orogenic type gold. Although not part of the Capricorn Orogen, strictly speaking, the Glenayle sill complex is in fault contact with the northern margin of the Earaheedy Basin, and is part of a recently discovered 1070 Ma large igneous province, which includes the Giles intrusions of the Musgrave Complex. The Glenayle sill complex is prospective for nickel–copper–PGE.