The nature of c. 2.0 Ga crust along the southern margin of the Gascoyne Complex

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Abstract

The southern part of the Gascoyne Complex consists of foliated and gneissic granites of the Dalgaringa Supersuite, as well as pelitic and calc-silicate gneisses of the Camel Hills Metamorphics, the protoliths of which were deposited between c. 2025 and c. 1960 Ma. The Dalgaringa Supersuite mainly consists of 2005–1975 Ma foliated and gneissic tonalite, granodiorite, and monzogranite. SHRIMP U–Pb dating has not yet found any trace of Archaean rocks of the Yilgarn Craton in the southern Gascoyne Complex. The complex may have formed as a convergent continental margin above a northwesterly dipping subduction zone before it was accreted to the Yilgarn Craton at c. 1960 Ma during the Glenburgh Orogeny.

KEYWORDS: Proterozoic, structural terranes, granite, geochronology, Gascoyne Complex, Dalgaringa Supersuite, Camel Hills Metamorphics, Glenburgh Orogeny

Introduction

Granites and high-grade metamorphic rocks of the Gascoyne Complex are an important part of the Capricorn Orogen, a major tectonic zone formed during collision of the Archaean Yilgarn and Pilbara Cratons in the Palaeoproterozoic (Fig. 1). However, tectonic models for the Gascoyne Complex have been hampered by a lack of reliable geochronological data. The timing of granite intrusion, deformation, and metamorphism are poorly constrained.

Williams (1986) suggested that the southern part of the Gascoyne Complex consisted mainly of reworked Archaean gneisses of the Yilgarn Craton. Myers (1990) interpreted the southern part of the Gascoyne Complex as para-autochthonous Yilgarn Craton interleaved with Proterozoic rocks (his Zone B). He suggested that the Errabiddy Shear Zone (Fig. 1) marks the boundary between para-autochthonous Yilgarn Craton to the north, and unreworked Yilgarn Craton to the south. The granitic gneisses in the southern part of the Gascoyne Complex were interpreted as Archaean because they are similar in appearance to gneisses in the Narryer Terrane of the Yilgarn Craton, and because they have Sm–Nd chondritic model ages of 2700–2500 Ma (Fletcher et al., 1983). However, reconnaissance SHRIMP U–Pb dating by Nutman and Kinny (1994) failed to identify reworked Archaean crust in the southern Gascoyne Complex.

Remapping of the ROBINSON RANGE* and GLENBURGH 1:250 000 map sheets in 1997 and 1998, as part of the Southern Gascoyne Complex Project, combined with SHRIMP U–Pb zircon geochronology (Nelson, 1998, 1999), confirms that rocks of the Yilgarn Craton are not present north of the Errabiddy Shear Zone in the mapped area (Fig. 1). Instead, the crust along the southern margin of the Gascoyne Complex mainly, or entirely, formed between 2005 and 1975 Ma. Furthermore, this crust was deformed and metamorphosed at medium to high grade up to 150 million years before collision of the Yilgarn and Pilbara Cratons between 1840 and 1800 Ma (Tyler et al., 1998; Occhipinti et al., 1998).

The rocks in the southern part of the Gascoyne Complex are divided into three main stratigraphic units. These are 2005–1975 Ma granitic gneiss and granite of the Dalgaringa Supersuite, Palaeoproterozoic medium- to high-grade metasedimentary rocks of the Camel Hills Metamorphics, and 1830–1800 Ma granite and pegmatite dykes and plugs. In addition, two episodes of deformation and medium- to high-grade metamorphism that occurred between 1985 and 1945 Ma are collectively referred to here as the Glenburgh Orogeny. The 1830–1800 Ma granites are related to the Capricorn Orogeny (Occhipinti et al., 1998) and not discussed here.

In the following sections, sample numbers refer to samples analysed by Nelson (1999) unless otherwise referenced. The raw data and concordia plots for these samples are

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* Capitalized names refer to standard map sheets.

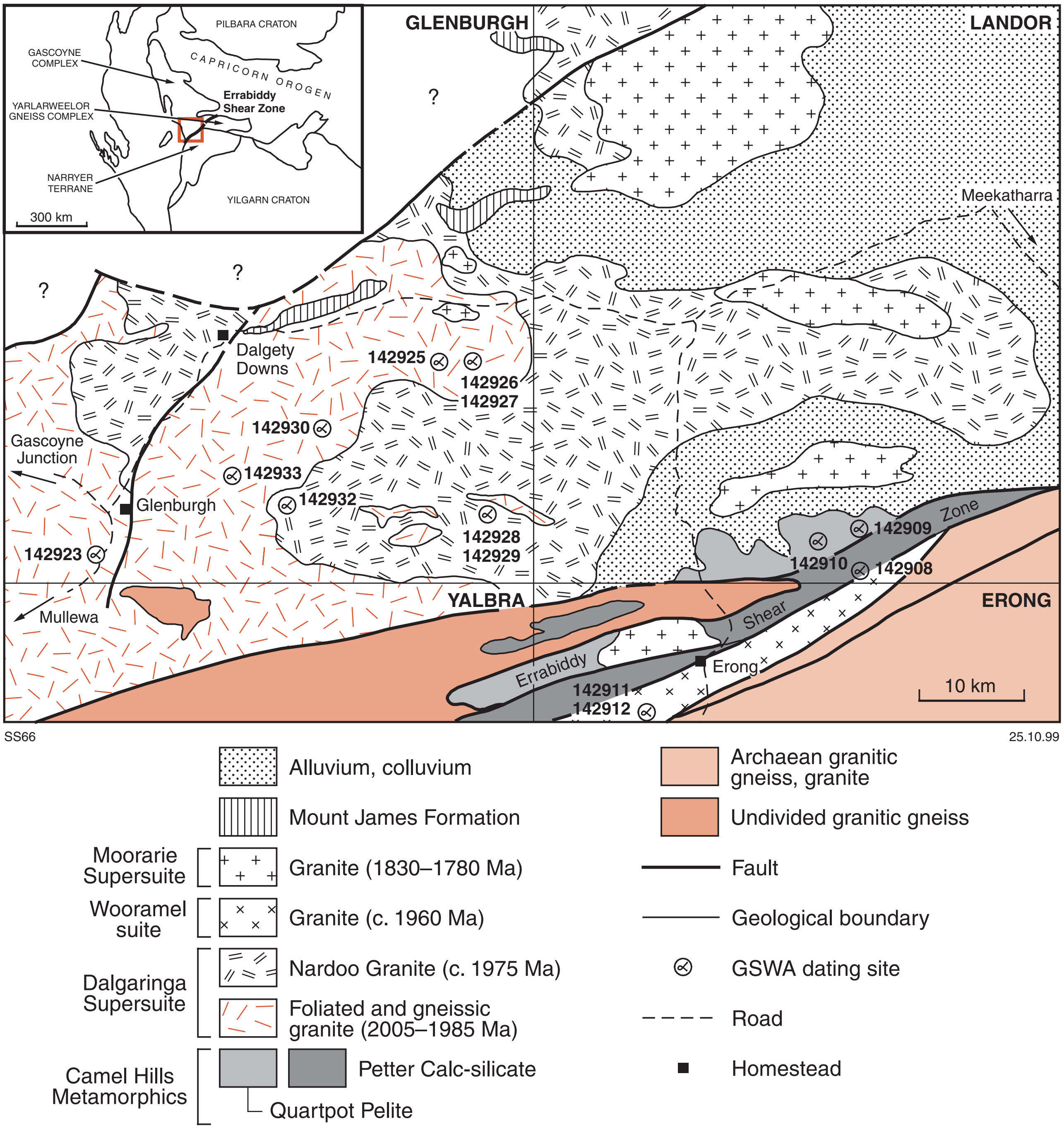

Figure 1. Simplified geology of the southern margin of the Gascoyne Complex on the GLENBURGH *1:250 000 map sheet. The names of the 1:100 000 map sheets are also shown*

contained in the same publication. Locations of the dated samples are shown on Figure 1.

2005–1975 Ma Dalgaringa Supersuite

The Dalgaringa Supersuite consists of massive, foliated, and gneissic granites dated at 2005–1975 Ma. The supersuite comprises two episodes of magmatism, which are separated by a deformation and high-grade regional metamorphic event. The two episodes consist of 2005–1985 Ma foliated to gneissic tonalite to monzogranite, and c. 1975 Ma tonalite and granodiorite plutons.

2005–1985 Ma foliated and gneissic granite

Foliated and gneissic granites outcrop in a wide, easterly to east-northeasterly trending belt on the southern part of the GLENBURGH 1:100 000 map sheet (Fig. 1). The rocks range from strongly deformed and completely recrystallized, foliated and gneissic granite in zones of high strain, to statically recrystallized granites with intrusive relationships preserved in areas of low strain.

The most abundant, and oldest, rock type so far identified is a grey, fine- to medium-grained, foliated to gneissic tonalite. The rock commonly has a banded appearance owing to the presence of heterogeneously deformed pegmatite veins and dykes (Fig. 2a). In low-strain zones the rock is a medium-grained, even-textured biotite–quartz diorite or tonalite. Although this rock type resembles Archaean mesocratic granitic gneiss in the Narryer Terrane (Occhipinti et al., 1998; Sheppard and Swager, 1999), two samples of tonalite and quartz diorite (GSWA 142926 and 142933) on GLENBURGH gave SHRIMP U–Pb zircon dates for igneous crystallization of 2002 ± 2 Ma and 1989 ± 3 Ma respectively.

The tonalite is commonly interlayered tectonically with subordinate fine- to medium-grained, foliated biotite monzogranite and lesser leucocratic tonalite to form a composite gneissic granite unit. In areas of low strain, preserved igneous relationships show that the monzogranite intruded the tonalite. However, locally preserved net-vein textures imply that there is little age difference between the two rock types. A sample of the biotite monzogranite (GSWA 142927) gave a date for igneous crystallization of 1999 ± 5 Ma. This age is indistinguishable from that of tonalite sample GSWA 142926, which has been net-veined by the monzogranite. The tonalite has also been extensively intruded by sheets of medium- to coarse-grained biotite granodiorite and monzogranite, one of which (GSWA 142925) was dated at 2002 ± 3 Ma.

All of the above rock types are intruded by veins and sheets of medium- to coarse-grained biotite monzogranite or syenogranite, and pegmatite. The sheets are up to several metres thick, and locally contain up to 30% or more of the foliated and gneissic granites. Two of the sheets were dated. One of these, a foliated monzogranite (GSWA 142923), was re-sampled from site NP 19 of A. P. Nutman (1996, pers. comm.) and gave a date of 1987 ± 4 Ma, within error of the c. 1990 Ma age reported by Nutman and Kinny (1994). Sample GSWA 142930 from a foliated biotite pegmatite was dated at 1994 ± 2 Ma.

Nardoo Granite

The 2005–1985 Ma foliated and gneissic granites were intruded by a large pluton of biotite(–hornblende) tonalite and granodiorite. This intrusion, known as the Nardoo Granite, is equivalent to the gneissic biotite–hornblende granodiorite of the Dalgety Gneiss Dome of Williams (1986). The Nardoo Granite consists of weakly to strongly foliated or locally gneissic tonalite and granodiorite (Fig. 2b). The

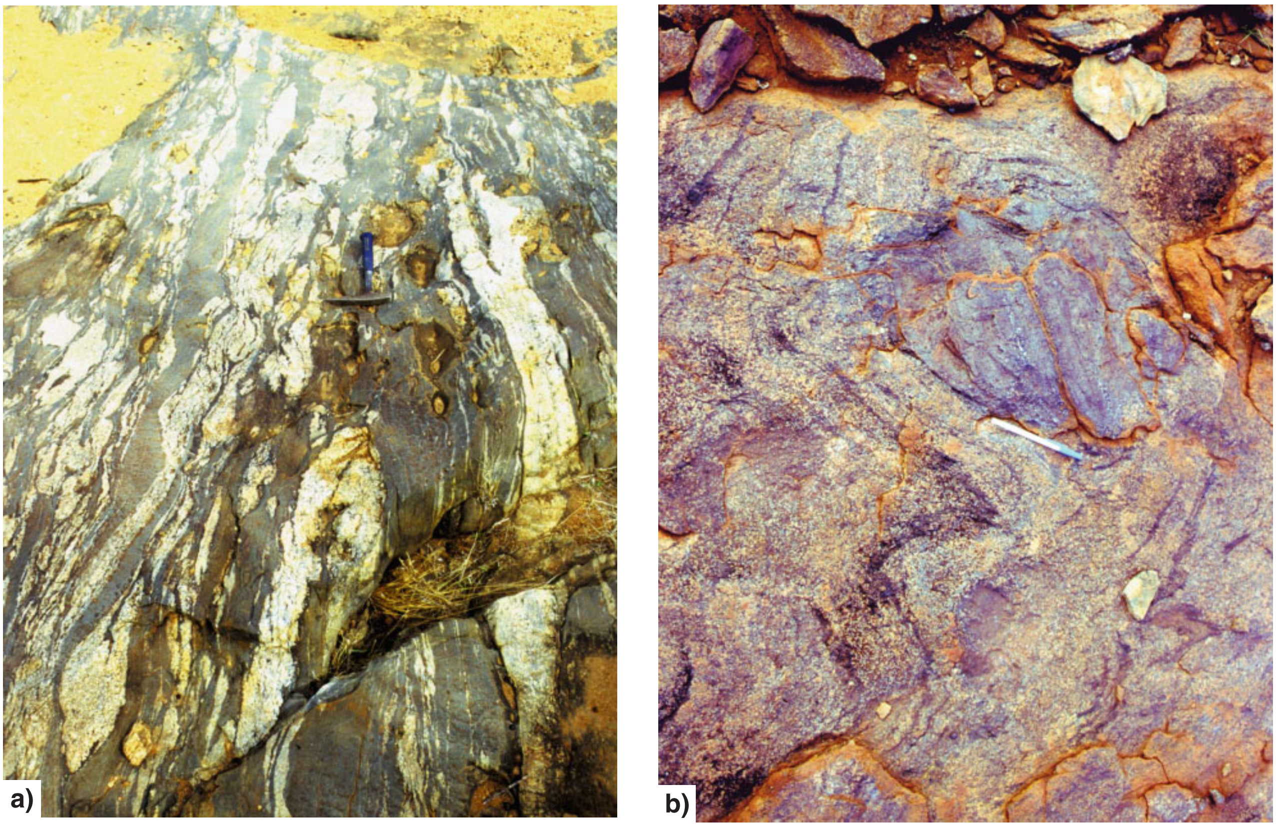

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Figure 2. a) Pegmatite-banded tonalite gneiss in creek pavement about 500 m east of sample site GSWA 142933; b) Foliated granodiorite of the Nardoo Granite with an inclusion of low-strain tonalite gneiss, about 6 km east-southeast of sample site GSWA 142932

margins of the intrusion are commonly more strongly deformed than the core, and the contact with the surrounding gneissic tonalite to monzogranite is not sharp. The contact is marked by inclusions and rafts of the gneissic tonalite to monzogranite in the Nardoo Granite, and decreasing numbers of veins and sheets of Nardoo Granite intruded into the country rock.

The Nardoo Granite consists of two mappable rock types: a medium-grained, porphyritic biotite–hornblende tonalite, and a medium-grained, even-textured or weakly porphyritic leucocratic biotite granodiorite. Contacts between the two are generally sharp, but in places the two rock types grade into each other. In low-strain zones, irregular veins and dykes of granodiorite have consistently intruded the tonalite. Nevertheless, the tonalite and granodiorite are the same age; a sample of the tonalite (GSWA 142932) gave a date of 1977 ± 4 Ma, while a sample of the granodiorite (GSWA 142928) was dated at 1974 ± 4 Ma.

The Nardoo Granite has a different composition to the potassic granites which are typical of much of the Palaeoproterozoic in Australia (Wyborn et al., 1992). On mantle-normalized diagrams these potassic granites have pronounced high La and Ce contents, Ba and Sr 'troughs', and little or no depletion in Y relative to Na (Fig. 3). In contrast, the Nardoo Granite is similar to Phanerozoic granites from convergent margin settings, in having lower La and Ce contents, no Ba 'trough', and a marked Y depletion (Fig. 3). The two samples of the Nardoo Granite plotted show a small Sr 'trough', although many other samples do not.

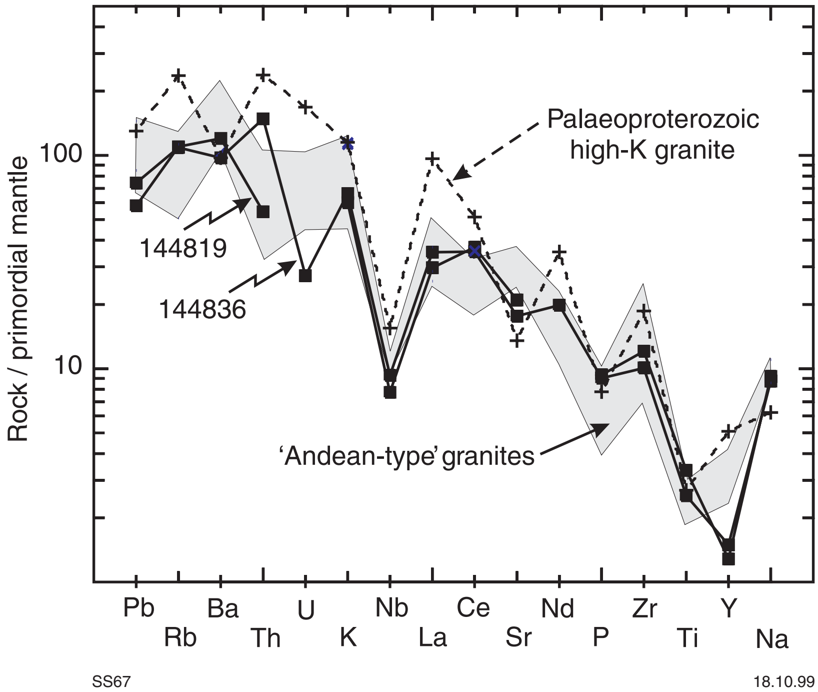

Figure 3 Mantle-normalized plot comparing the Nardoo Granite (GSWA 144819 and 144836) with Andean-type granites from the Cretaceous Coastal Batholith of Peru (Atherton and Sanderson, 1985) and the Eocene Coast Batholith of Alaska (Arth et al., 1988). The Palaeoproterozoic high-K granite is from the Paperbark supersuite in the Halls Creek Orogen (GSWA 113401; Sheppard et al., 1997). The low U contents in the Nardoo Granite are a secondary feature; the U content in GSWA 144819 is below the detection limit.

Camel Hills Metamorphics

Medium- to high-grade metasedimentary rocks, referred to here as the Camel Hills Metamorphics, outcrop in a belt about 150 km long between Archaean rocks of the Narryer Terrane and Palaeoproterozoic granitic gneiss and granite of the Gascoyne Complex (Fig. 1). These metasedimentary rocks were previously included within the Morrissey Metamorphic Suite (Williams, 1986). The Camel Hills Metamorphics is subdivided into the Quartpot Pelite and the Petter Calc-silicate.

The Quartpot Pelite consists of pelitic schist and migmatitic pelitic gneiss, with minor amounts of inter-layered quartzite, calc-silicate schist and gneiss, and amphibolite. SHRIMP U–Pb zircon data were obtained for two samples of migmatitic pelitic gneiss (sample GSWA 142905, Nelson, 1998; sample GSWA 142910, Nelson, 1999). The youngest zircon ages in each sample are c. 1960 Ma, which have been obtained from rims and cores with very low Th/U ratios. Although one of the authors (Nelson, 1998, 1999) has interpreted these as detrital zircons, their Th/U ratios suggest that they grew during the high-grade metamorphism that produced partial melting of these rocks. Zircons between 2025 and 2550 Ma dominate the detrital zircon populations, with a small contribution in one sample (GSWA 142910) from zircons older than 2600 Ma in age. The maximum depositional age is thus constrained to c. 2025 Ma.

The Petter Calc-silicate is composed of calc-silicate schist or gneiss and interlayered quartzite, and minor pelitic schist or migmatitic pelitic gneiss and amphibolite. The maximum depositional age for a quartz-rich calc-silicate gneiss on the LANDOR 1:100 000 map sheet (sample GSWA 142908) of 1944 ± 5 Ma is only provided by a single detrital zircon grain. The bulk of the zircons are 2700–2600 Ma in age, with a small number older than 3000 Ma. These ages imply that the Petter Calc-silicate had a different provenance to the Quartpot Pelite.

Glenburgh Orogeny

The oldest fabric in the southern Gascoyne Complex is a regionally extensive gneissic layering in the 2005–1985 Ma gneissic tonalites and monzogranites, which is cut by sheets of the Nardoo Granite. Inclusions of pegmatite-banded gneissic tonalite and monzogranite are abundant in the Nardoo Granite (Fig. 2b). Therefore, the Nardoo

Granite was intruded after deformation and regional metamorphism that took place between c. 1985 and c. 1975 Ma.

Inclusions of gneissic tonalite and monzogranite in the Nardoo Granite are commonly folded about an axial surface parallel to a penetrative foliation in the Nardoo Granite. This foliation is cut by a dyke of biotite monzogranite that has been dated at 1945 ± 14 Ma (sample GSWA 142929). In the migmatitic pelitic gneiss of the Camel Hills Metamorphics, widespread high-grade metamorphism and partial melting were dated at c. 1960 Ma. Therefore, the rocks in the southern part of the Gascoyne Complex were also deformed and metamorphosed at medium to high grade at c. 1960 Ma, after intrusion of the Nardoo Granite. The second deformation and metamorphism was concomitant with intrusion of monzogranite plutons of the Wooramel suite into the northwest margin of the Yilgarn Craton at c. 1960 Ma (Fig. 1; sample GSWA 142911, Nelson, 1998; sample GSWA 142912, Nelson, 1999).

The two deformation and regional metamorphic events identified here are much older than the Capricorn Orogeny. The two events are referred to as the Glenburgh Orogeny (Occhipinti et al., 1999).

Discussion

Our mapping and SHRIMP geochronology support the suggestion of Nutman and Kinny (1994) that the southern Gascoyne Complex probably formed a terrane separate from the Yilgarn Craton until c. 1960 Ma. No evidence has been found along the southern margin of the Gascoyne Complex for reworked Archaean rocks of the Yilgarn Craton.

The nature and age of the basement to the southern Gascoyne Complex is unclear, but there are indications that it is continental crust of latest Archaean to early Palaeoproterozoic age. Nutman and Kinny (1994) reported an age of c. 2500 Ma for a sample of banded gneiss in the Carandibby Inlier, which is part of the Gascoyne Complex, about 60 km to the west-southwest of Dalgety Downs Homestead (Fig. 1). In addition, detrital zircons identified in two migmatitic pelitic gneiss samples from the Quartpot Pelite may reflect the age of the basement. These zircons give ages of 2025–2550 Ma, and are younger than dated rocks from the northwestern part of the Yilgarn Craton, which are all older than 2600 Ma.

The preponderance of tonalite and granodiorite in the Dalgaringa Supersuite is in contrast to most Palaeoproterozoic batholiths in northern Australia, which are dominated by monzogranite and granodiorite. In addition, the Nardoo Granite shares some of the characteristics of Phanerozoic subduction-related granites (Fig. 3). The Dalgaringa Supersuite may thus represent the product of convergent margin magmatism developed on early Palaeoproterozoic crust that subsequently collided with the passive margin of the Yilgarn Craton. The presence of c. 1960 Ma granites intruded into the northern margin of the Yilgarn Craton, and c. 1945 Ma granite dykes in the southern part of the Gascoyne Complex, suggests that the southern part of the Gascoyne Complex was accreted by this time. The early Palaeoproterozoic tectonic history of the Gascoyne Complex may be dominated by processes of subduction and terrane accretion before final collision of the Yilgarn and Pilbara Cratons during the Capricorn Orogeny between 1840 and 1800 Ma (Tyler et al., 1998; Occhipinti et al., 1998).

References

ARTH, J. G., BARKER, F., and STERN, T. W., 1988, Coast batholith and Taku plutons near Ketchikan, Alaska — petrography, geochronology, geochemistry and isotopic character: American Journal of Science, v. 288-A, p. 461–489.

ATHERTON, M. P., and SANDERSON, L. M., 1985, The chemical variation and evolution of the super-units of the segmented Coastal Batholith, *in* Magmatism at a plate edge — the Peruvian Andes *edited by* W. S. PITCHER, M. P. ATHERTON, E. J. COBBING, and R. D. BECKINSALE: Glasgow, Blackie, p. 208–227.

FLETCHER, I. R., WILLIAMS, S. J., GEE, R. D., and ROSMAN, K. J. R., 1983, Sm–Nd model ages across the margins of the Archaean Yilgarn Block, Western Australia — northwest transect into the Proterozoic Gascoyne Province: Journal of the Geological Society of Australia, v. 30, p. 168–174.

MYERS, J. S., 1990, Gascoyne Complex, *in* Geology and mineral resources of Western Australia: Western Australia Geological Survey, Memoir 3, p. 198–202.

NELSON, D. R., 1998, Compilation of SHRIMP U–Pb zircon geochronology data, 1997: Western Australia Geological Survey, Record 1998/2, 242p.

NELSON, D. R., 1999, Compilation of geochronology data, 1998: Western Australia Geological Survey, Record 1999/2, 222p.

NUTMAN, A. P., and KINNY, P. D., 1994, SHRIMP zircon geochronology of the southern Gascoyne Province and the northwestern margin of the Yilgarn Craton, W.A.: Geological Society of Australia, Abstracts, v. 37, p. 320–321.

OCCHIPINTI, S. A., SHEPPARD, S., NELSON, D. R., MYERS, J. S., and TYLER, I. M., 1998, Syntectonic granite in the southern margin of the Palaeoproterozoic Capricorn Orogen, Western Australia: Australian Journal of Earth Sciences, v. 45, p. 509–512.

OCCHIPINTI, S. A., SHEPPARD, S., and TYLER, I. M., 1999, The Palaeoproterozoic tectonic evolution of the southern margin of the Capricorn Orogen, Western Australia: Geological Society of Australia, Abstracts, no. 53, p. 173–174.

SHEPPARD, S., GRIFFIN, T. J., and TYLER, I. M., 1997, Compilation of whole-rock geochemical data for the King Leopold and Halls Creek Orogens: Western Australia Geological Survey, Record 1997/4, 138p.

SHEPPARD, S., and SWAGER, C. P., 1999, Geology of the Marquis 1:100 000 sheet: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes, 21p.

TYLER, I. M., PIRAJNO, F., BAGAS, L., MYERS, J. S., and PRESTON, W. A., 1998, The geology and mineral deposits of the Proterozoic in Western Australia: Australian Geological Survey Organisation, Journal of Australian Geology and Geophysics, v. 17, p. 223–244.

WILLIAMS, S. J., 1986, Geology of the Gascoyne Province, Western Australia: Western Australia Geological Survey, Report 15, 85p.

WYBORN, L. A. I., WYBORN, D., WARREN, R. G., and DRUMMOND, B. J., 1992, Proterozoic granite types in Australia — implications for lower crust composition, structure and evolution: Transactions of the Royal Society of Edinburgh, Earth Sciences, v. 83, p. 201–209.