Meso- to Neoproterozoic reworking in the Gascoyne Complex and what it means for mineral exploration

by

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The Gascoyne Complex is a major Proterozoic tectonic zone that separates the Archean Pilbara and Yilgarn Cratons. The complex hosts a variety of mineralization styles including intrusion- and shear zone-related Mo–Cu–W–Pb (e.g. Minnie Creek batholith); carbonatite-related rare earth elements including uranium (e.g. Gifford Creek Igneous Complex); scheelite skarns (e.g., Nardoo Well); rare metal (Ta, Bi, Be) pegmatites (e.g. Morrissey Hill) and Cu–Pb–Zn(–Au) base metal deposits (e.g. Mount James, Glenburgh, Star of Mangaroon). However, due to multiple reworking episodes, including complex (re)folding and tectonic disruption, the controls on known mineralization are poorly understood. This has implications for the success of future resource discoveries. Elucidating the tectonic evolution of the Gascoyne Complex is a critical step in greatly improving exploration targeting.

Reworking

The Gascoyne Complex records a series of regional-scale Paleoproterozoic tectonic and thermal events involving deformation, metamorphism, and granite intrusion. However, during the Meso- to Neoproterozoic, the complex was reworked at low- to medium-grade along several discrete tectonic corridors, resulting in most of the present-day structural complexity. Recent mapping in the centre of the complex (YINNETHARRA*, PINK HILLS, and CANDOLLE) combined with a regional program of SIMS U–Pb monazite, xenotime, and zircon dating, has provided a better understanding of the nature, timing, and significance of at least four distinct events.

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* Capitalized names refer to standard 1:100 000 map sheets, unless otherwise indicated

c. 1250 Ma event

Garnet–staurolite schists of the Morrissey Metamorphics around Tommie Well on EUDAMULLAH (Fig. 1) contain a well-developed medium-grade crenulation schistosity. Monazite parallel to relict, folded S_1 fabrics within garnet and staurolite porphyroblasts give consistent ages of c. 1280 Ma, whereas those within the main S_2 fabric give ages of c. 1250 Ma. Monazite appears not to record any younger Neoproterozoic event(s), which is surprising since these rocks and fabrics are in apparent structural continuity with similar grade schists to the southeast, from which 1030–990 Ma metamorphic monazite is known (Sheppard et al., 2007). Currently the extent and significance of this c. 1280–1250 Ma event is unknown.

1030–950 Ma Edmundian Orogeny

Field mapping has demonstrated that the central part of the complex is dissected by an anastomosing network of low- to medium-grade shear zones and faults, with the Ti Tree Shear Zone (Fig. 1) forming a major sinistrally transpressive discontinuity that separates medium-grade mid-amphibolite facies crust in the southwest (Mutherbukin zone) from low-grade upper crust to the northeast (Limejuice zone). The mid-crustal section is dominated by ductile shear zones and regional-scale tight to isoclinal folds (including the Ti Tree Syncline), with the production of new metamorphic fabrics and porphyroblasts. The upper crustal section contains brittle to brittle–ductile faults and open to tight folds, including the re-orientation of earlier folds and fabrics within narrow corridors.

Metamorphic zircon (as rims around older igneous cores) extracted from sinistral melt pockets within a c. 1665 Ma metamonzogranite in the Mutherbukin zone, gave a precise U–Pb SIMS (SHRIMP) age of 1006 ± 13 Ma, dating the main phase of sinistral-transpressional movement on the Ti Tree Shear Zone. This age is identical to in situ SIMS (SHRIMP) monazite and xenotime ages from nearby garnet–staurolite-bearing pelitic schists with estimated pressure–temperature conditions of 3–5 kbar and 500–550°C (Sheppard et al., 2007). These geochronological and metamorphic estimates suggest that Edmundian deformation

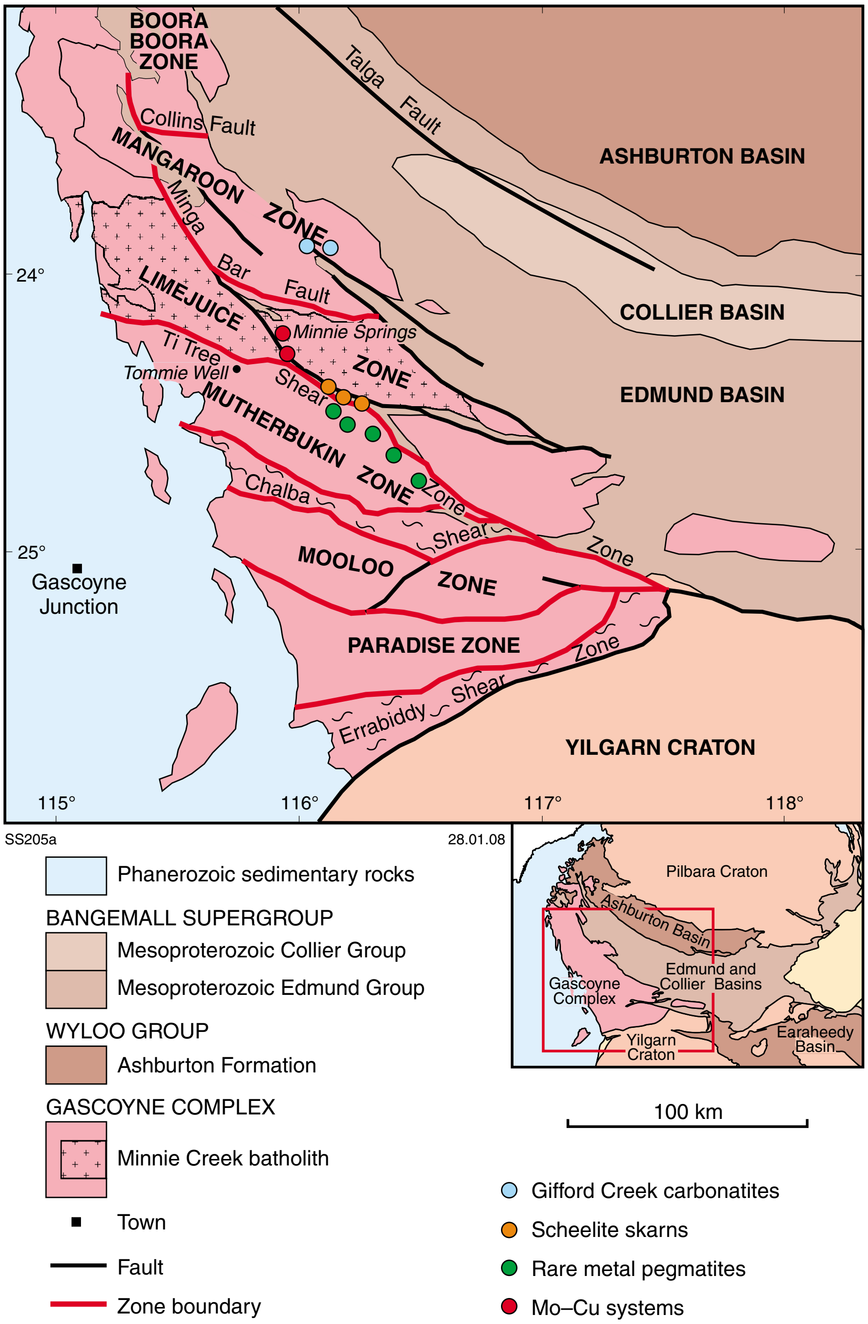

Figure 1. Simplified geological map of the Gascoyne Complex and associated mineral deposits. Inset shows the tectonic setting of the Gascoyne Complex

and metamorphism had an important effect on the Gascoyne Complex. Deformation reflects strike-slip to transpressive re-organization of the middle to upper crust, and is not related to crustal thickening.

c. 900–850 Ma event

The 'Gurun Gutta granite' (in the Nardoo Hills area, northern Mutherbukin zone) is an undeformed granite pluton that cuts medium-grade fabrics related to the Edmundian Orogeny within the Pooranoo Metamorphics (Sheppard et al., 2007). A previous SIMS (SHRIMP) U–Pb zircon age of 1652 ± 4 Ma for the granite (Varvell, 2001) reflects the presence of a xenocrystic zircon component. Reconnaissance U–Th–Pb SIMS (SHRIMP) dating of monazite from this granite gave an age of c. 910 Ma, interpreted as the timing of igneous crystallization. This date is very similar to other preliminary in situ monazite and xenotime SIMS (SHRIMP) ages from low-grade Edmund Group slates within the Ti Tree Syncline (900–850 Ma; unpublished data), and with $^{40}Ar/^{39}Ar$ mica ages (960–820 Ma) obtained from various rock units from the Errabiddy Shear Zone and southern Gascoyne Complex (Occhipinti, 2007). Although the extent and significance of the c. 900–850 Ma event has yet to be fully determined, it may represent a period of extensive low-temperature (<325°C) fault- and shear-zone reactivation resulting in exhumation of parts of the complex (Occhipinti, 2007; Sheppard et al., 2007).

c. 570 Ma Mulka Tectonic Event

The Chalba Shear Zone is a 5–10 km-wide zone of metre-wide interlinked brittle–ductile dextral faults and shears that cut both the Gascoyne Complex and Bangemall Supergroup. Many of the brittle faults are defined by quartz veins. Shearing and faulting are dated at c. 570 Ma by in situ $^{40}Ar/^{39}Ar$ on newly grown muscovite in a small dextral shear zone. The low-grade nature of this dextral strike-slip event indicates that the complex was at upper crustal levels by c. 570 Ma, recording an episode of intraplate re-organization.

Reworking and mineral systems

The Gascoyne Complex has traditionally been thought of solely as a Paleoproterozoic entity, but it is now clear that the complex has had an extended history of reworking and reactivation (Sheppard et al., 2008), which needs to be taken into account during mineral exploration.

Carbonatitic rocks and ultramafic lamprophyres with associated REE and U mineralization at Gifford Creek (Fig. 1) locally intrude the base of the Edmund Group. This is consistent with limited geochronology data suggesting Meso- and Neoproterozoic igneous crystallization ages (Pearson, 1996). These intrusions comprise an alkaline igneous complex accompanied by alkaline metasomatism (Pearson, 1996; Pirajno et al., 2008). Emplacement of the complex is probably related to shearing and faulting during the Edmundian Orogeny, and may be associated with thinning and erosion of the lithosphere (Foley, 2008).

Farther south in the Mutherbukin zone, where high-T/low-P Edmundian-aged deformation is ubiquitous, abundant Be–Nb–Ta-bearing pegmatites appear to be spatially associated with the Morrissey Metamorphics. One of these pegmatites is dated at c. 955 Ma (Sheppard et al., 2007). The pegmatite field lacks any significant zonation in rare elements, and no granites of this age are known within the region (see below). These relationships could suggest that pegmatite generation is instead linked to metamorphically derived ?hydrothermal fluids, but intrusion of the pegmatites post-dates peak metamorphism by some 40–45 million years.

In the northern part of the Mutherbukin zone, W skarns appear to be related to leucocratic tourmaline-bearing granites (including the 'Gurun Gutta granite') that post-date Edmundian structures and metamorphism. A preliminary age of c. 910 Ma for one of these granites confirms the original suggestion by Trautman (1992), based on geochemical considerations, that they cannot be parental to the c. 955 Ma Be–Nb–Ta-bearing pegmatites.

At the Minnie Springs Mo–Cu prospect, disseminated molybdenite dated at c. 1770 Ma (F Pirajno, 2008, written comm.) has been locally remobilized into discrete quartz–molybdenite veins that are parallel to the pervasive schistosity in the Ti Tree Shear Zone (Pirajno et al., 2007). It is unclear whether these veins are related to Edmundian deformation or the reworking of Edmundian structures during the subsequent Mulka Tectonic Event.

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