Relative age of felsic magmatism, gold mineralization, and deformation in the central and eastern Yilgarn Craton, Western Australia

by

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Recent mapping, structural studies, interpretation of newly acquired aeromagnetic data, and new SHRIMP (sensitive high-resolution ion microprobe) U–Pb zircon geochronology have identified a sequence of geological events in the central Southern Cross Province of the central Yilgarn Craton that allows direct comparison with events in the Eastern Goldfields Province, in the eastern Yilgarn Craton (Fig. 1).

In the central Southern Cross Province, a c. 3.0 Ga age of deposition is inferred for the mafic-dominated lower greenstone succession from an intrusive felsic porphyry dated at 3023 ± 10 Ma. The first recognizable deformation event (D_1) in the greenstones produced originally easterly trending recumbent folds and thrusts. Upright, north-trending folds, which overprint D_1 structures, formed during D_2 east–west compression. Late-D_2 to post-D_2 magmatism is represented by granitoids of mainly monzogranite composition aged between c. 2730 and c. 2680 Ma. Uplift and erosion of the lower greenstone succession in the Marda–Diemals area was followed by the deposition of an upper greenstone succession that

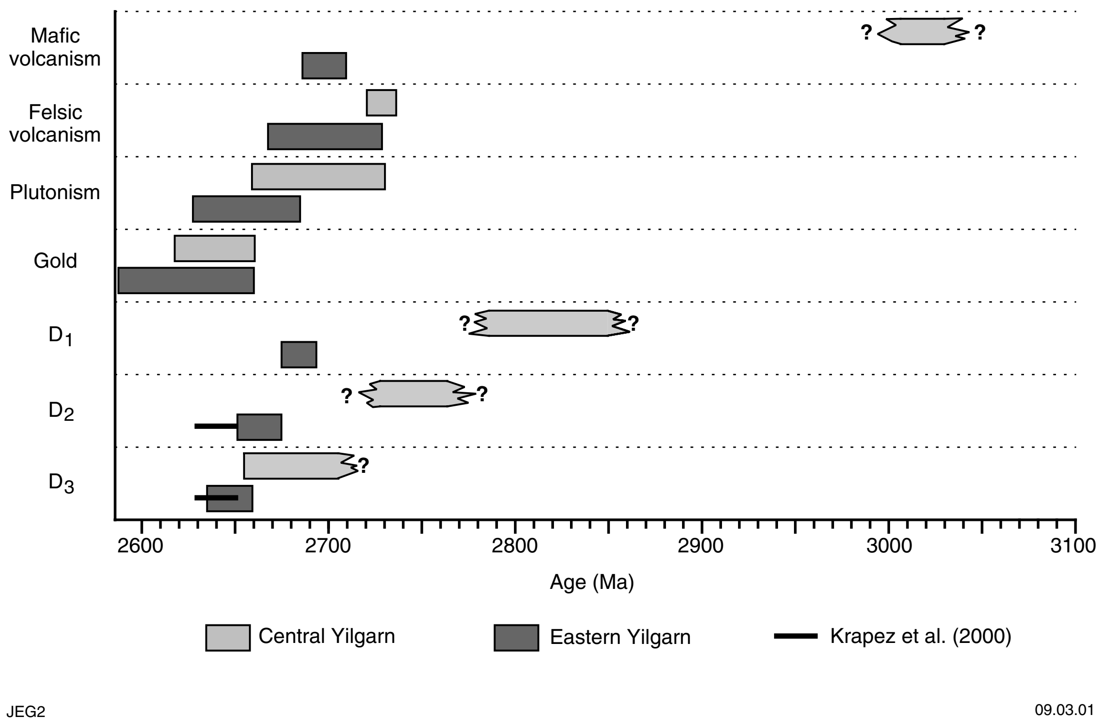

Figure 1. Comparison of published radiometric age ranges (including new unpublished data) between geological events in the central Yilgarn Craton and south Eastern Goldfields Province. Data sources: Groves et al. (1998), Kent et al. (1996), Nelson (1997, in prep.), Qiu et al. (1999), Yeats et al. (1999), Krapez et al. (2000) and references therein

includes clastic sediments of the Diemals Formation, and calc-alkaline volcanic rocks of the Marda Complex (2732 ± 3 Ma); and intrusion of the Pigeon Rocks and Butcher Bird Monzogranites (2729 ± 4 Ma). Westward-directed D_3 inhomogeneous shortening reoriented earlier D_2 structural trends and produced movement on major shear zones. A late, undeformed pluton that intruded a D_3 shear zone has been dated at 2656 ± 4 Ma (Qiu et al., 1999), and provides a minimum age for D_3 in the central Yilgarn, although this date is within error of a deformed granite from the Evanston area (see below). Post-D_3 conjugate north-northeasterly trending dextral and east-southeasterly trending sinistral brittle faults, and ?Proterozoic, mainly easterly trending, fractures traverse the entire Yilgarn Craton.

In the south Eastern Goldfields Province, greenstones include mafic, ultramafic, sedimentary, and felsic volcanic rocks that were deposited between c. 2720 and c. 2650 Ma (Nelson, 1997, Krapez et al., 2000). Recumbent folds and thrusts with evidence of northward movement (D_1) preceded a D_2 event that produced north-northwesterly trending folds and thrust faults (Swager, 1997). The D_3 event involved strong east–west compression, resulting in strike-slip movement on major shear zones and related folding. Widespread granite magmatism between c. 2685 and c. 2640 Ma peaked at c. 2660 Ma (Nelson, 1997). According to Nelson (1997), deformation relationships within dated granites from the south Eastern Goldfields constrain D_2 between c. 2675 and c. 2657 Ma, and D_3 between c. 2663 and c. 2635 Ma. However, recent dating of detrital zircons from sedimentary basins suggests that D_2 was active after c. 2660 Ma, and constrains D_3 to between c. 2650 and c. 2630 Ma (Fig. 1; Krapez et al., 2000).

Gold mineralization in the Marda–Diemals area was epigenetic, structurally controlled, and commonly associated with quartz veining. Total gold produced before 1986 was approximately 2481 kg (Townsend et al., 2000). There is a wide range of host rocks, but gold is commonly associated with banded iron-formation. Most deposits lie within the lower greenstone succession and are typically located near greenstone margins; however, an exception is the Marda mining centre, where gold mineralization is hosted by felsic volcanic and volcaniclastic rocks of the Marda Complex. Common alteration styles include carbonation and sulfidation. The Evanston mining area, which hosts the most significant deposit in the central Southern Cross Province, has produced over 1100 kg of gold at 18 g/t Au. Mineralization at Evanston was syn-peak metamorphism (amphibolite facies) and coincided with D_3 strike-slip deformation in the Evanston Shear Zone (Dalstra, 1995). A sheared granitoid adjacent to the deposit has been dated at 2654 ± 6 Ma, thus providing a maximum age for the mineralization. This is consistent with c. 2640 to c. 2620 Ma minimum age contraints on mineralization farther south in the Southern Cross greenstone belt (Kent et al., 1996).

The majority of gold deposits in the eastern Yilgarn Craton have similar affinities to deposits in the central Yilgarn Craton, including a late D_3 or post-D_3 structural control on mineralization (Groves et al., 1998). It has been argued that the timing of gold mineralization is broadly synchronous across the craton, and is constrained between c. 2640 and c. 2600 Ma (e.g. Kent et al., 1996), although recent work in the Yandal greenstone belt (northeastern Yilgarn Craton) suggests a >c. 2660 Ma age for gold mineralization in several major deposits (Yeats et al., 1999).

The data presented here provide constraints on crustal evolution models for the Eastern Goldfields and central Southern Cross Provinces:

- Although similar in style, D_1 is older in the Southern Cross Province than in the Eastern Goldfields Province.
- The c. 2.73 Ga felsic volcanism in the Southern Cross Province is older than felsic volcanism in the south Eastern Goldfields Province, and was not associated with contemporaneous deposition of mafic and ultramafic rocks.
- Limited geochronological data suggest that felsic volcanic rocks broadly young from west to east across the Yilgarn Craton. Felsic volcanic rocks in younger greenstone assemblages in the Murchison Province to the west are mainly c. 2.75 Ga (Pidgeon and Hallberg, 2000), 10–30 m.y. older than the Marda Complex felsic volcanic rocks, and 30–75 m.y. older than those in the Eastern Goldfields.
- The geometry and structural style of the upright folding (D_2) and regional-scale shear zones (D_3) in the central Southern Cross Province are broadly similar to structures in the Eastern Goldfields Province. However, constraints on the age of these structures suggest that, in the Southern Cross Province, these events may have begun 10–40 m.y. before the same style of deformation in the south Eastern Goldfields.
- Gold mineralization in both provinces was late in the major deformation cycle (i.e. late D_3 to post-D_3).
- Limited geochronological data suggest that D_3 began earlier in the central Southern Cross Province than in the south Eastern Goldfields Province.

These data indicate that the tectonic processes involved in the development of late Archaean granite–greenstones in the Yilgarn Craton were similar, but active in different areas at different times.

References

DALSTRA, H. J., 1995, Metamorphic and structural evolution of the greenstone belts of the Southern Cross – Diemals region of the Yilgarn Block, Western Australia, and its relationship to the gold mineralisation: University of Western Australia, PhD thesis (unpublished).

GROVES, D. I., GOLDFARB, R. J., GEBRE-MARIAM, M., HAGEMANN, S. G., and ROBERT, F., 1998, Orogenic gold deposits: a proposed classification in the context of their crustal distribution and relationship to other gold deposits: Ore Geology Reviews, v. 13, p. 7–27.

KENT, A. J. R., CASSIDY, K. F., FANNING, C. M. F., 1996, Gold mineralization synchronous with the final stages of cratonization, Yilgarn Craton, Western Australia: evidence from Sm–Nd and U–Pb ages of cross-cutting (post-gold) dykes: Geology, v. 24, p. 573–588.

KRAPEZ, B., BROWN, S. J. A., HAND, J., BARLEY, M. E., and CAS, R. A. F., 2000, Age constraints on recycled crustal and supracrustal sources of Archaean metasedimentary sequences, Eastern Goldfields Province, Western Australia: evidence from SHRIMP zircon dating: Tectonophysics, v. 322, p. 89–133.

NELSON, D. R., 1997, Evolution of the Archaean granite–greenstone terranes of the Eastern Goldfields, Western Australia: Precambrian Research, v. 83, p. 57–81.

NELSON, D. R., in prep., Compilation of geochronology data, 2000: Western Australia Geological Survey, Record 2001/2.

PIDGEON, R. T., and HALLBERG, J. A., 2000, Age relationships in supracrustal sequences in the northern part of the Murchison Terrane, Archaean Yilgarn Craton, Western Australia: a combined field and zircon U–Pb study: Australian Journal of Earth Sciences, v. 47, p. 153–165.

QIU, Y. M., McNAUGHTON, N. J., GROVES, D. I., and DALSTRA, H. J., 1999, Ages of internal granioids in the Southern Cross region, Yilgarn Craton, Western Australia, and their crustal evolution and tectonic implications: Australian Journal of Earth Sciences, v. 46, p. 971–981.

SWAGER, C. P., 1997, Tectono-stratigraphy of late Archaean greenstone terranes in the southern Eastern Goldfields, Western Australia: Precambrian Research, v. 83, p. 11–42.

TOWNSEND, D. B., GAO MAI, and MORGAN, W. R., 2000, Mines and mineral deposits of Western Australia: digital extract from MINEDEX — an explanatory note: Western Australia Geological Survey, Record 2000/13, 28p.

YEATS, C. J., McNAUGHTON, N. J., RUETTGER, D., BATEMAN, R., GROVES, D. I., HARRIS, J. L., KOHLER, E., 1999, Evidence for diachronous Archaean lode-gold mineralization in the Yilgarn Craton, Western Australia: A SHRIMP U–Pb study of intrusive rocks: Economic Geology, v. 94, p. 1259–1276.