Metallogenic potential of the felsic igneous rocks of the Tennant Creek and Davenport Provinces, Northern Territory

Is the enigma of the source of the gold at Tennant Creek resolved?

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A review of metallogenic potential suggests that the Au deposits in the Tennant Creek district (NT) are likely to be associated with the ~1820-Ma granites/felsic volcanics of the Treasure Suite, which is prominently exposed in the Davenport Province southeast of Tennant Creek. The ~1850-Ma Tennant Creek Supersuite, which comprises the main granite bodies exposed in the Tennant Creek Province, is a generally unfractionated, restite-rich supersuite older than the Au deposits, and probably had no direct role in ore formation, although its emplacement may have enhanced the formation of the ironstones which host most of the ore. Although the ~1710-Ma Devils Suite evolved a major late fluid phase and is associated with extensive alteration of both the granites and the surrounding country rocks, it had no association with Au mineralisation, and its potential is believed to be limited by the high F content of the parent magma.

The origin of Au–Cu–Bi deposits in the Palaeoproterozoic Tennant Creek district has inspired debate for over 70 years. Magmatic sources of metals and fluids have been an integral part of many models for the genesis of the deposits. However, age determinations have proved enigmatic, as the spatially nearest granites to the Tennant Creek goldfield appear to be at least 20 m.y. older than accepted ages for the mineralisation (Black 1977: BMR Journal of Australian Geology & Geophysics, 2, 111–122; Black 1984: Australian Journal of Earth Sciences, 31, 123–131; Compston & McDougall 1994: Precambrian Research, 71, 107–129; Compston & McDougall 1995: Australian Journal of Earth Sciences, 41, 609–616).

Two major and distinctive regional hydrothermal alteration events in the Tennant Creek Province may have contributed to the mineralisation process. During the first, ironstone hosts of the main Au deposits precipitated from basinal brines (Wedekind et al. 1989: Economic Geology, Monograph, 6, 168–179; Zaw et al. 1994: AusIMM Publication Series 5/94, 185–188) in dilational sites early during the regional deformation paragenesis (Ding & Giles 1993: Proceedings of the International Symposium on Gold Mining Technology, Beijing, 100). Hydrogen- and oxygen-isotope data imply that a magmatic fluid was unlikely to have been involved in the production of the ironstones (Wedekind 1989: 'Workshop Manual 3', June 1989, University of Tasmania, 45–55).

The second hydrothermal event occurred late in the deformation history (Ding & Giles 1993: op. cit.), and has been dated at 1830–1825 Ma by Ar–Ar techniques (Compston & McDougall 1994: op. cit.) and 1820–1805 Ma by Rb–Sr methods (Black 1977: op. cit.).

The sources of the metals and fluids during mineralisation have been extensively debated, and a magmatic input was postulated (Wedekind et al. 1989: op cit; Zhaw et al.1994: op. cit.). If magmas were directly involved, the question may be asked: Which one of the three main magma suites in the Tennant Creek/ Davenport Provinces sourced the mineralisation?

The ~1850-Ma Tennant Creek Supersuite

The components of the Tennant Creek Supersuite include the Tennant Creek Granite, Mumbilla Granodiorite, Cabbage Gum Granite, Hill of Leaders Granite, Channinggum Granite, the Epenarra and Warrego Volcanics, and various porphyries and volcanics of the Bernborough and Warramunga Formations (Donnellan et al. 1995: 'Flynn 5759, Tennant Creek 5758', Northern Territory Geological Survey, 1:100 000 Geological Map Series explanatory notes; Blake et al. 1987: BMR/AGSO Bulletin 226). Ages range from 1872–1837 Ma, and young progressively southeastwards (Black 1984: op. cit.). The supersuite is an I-(granodiorite) type and mainly unfractionated, although there is evidence of weak fractionation in the more felsic end members.

The Tennant Creek Supersuite has minimal **mineral potential**. It is associated with minor W mineralisation in the southeast, in the Mosquito Creek tungsten field (Fig. 26), where it is weakly fractionated. Although it appears to have no direct relationship to the Au–Cu–Bi deposits, it may have provided a heat source to enhance the circulation of the basinal brines that formed their ironstone hosts.

The ~1820-Ma Treasure Suite

The Treasure Suite is composed mainly of volcanics, and shallow intrusive granophyres and porphyries of the Wundirgi Formation, Treasure Volcanics, Arabulja Volcanics, and Newlands Volcanics in the Davenport Province; and unnamed diorites to monzodiorites, and felsic to intermediate volcanics of the Hayward Creek Formation of the Tomkinson Creek Subgroup, in the Tennant Creek Province (Blake et al. 1987: op. cit.; Donnellan et al. 1995: op. cit.). The suite, a fractionated I-(granodiorite) type, has its more mafic end-members preserved in the northwest Tennant Creek area, and more felsic fractionated members in the southeast, where volcanics and granophyres are more heavily concentrated.

The members of this suite range in age from 1829–1816 Ma (Blake & Page 1988: Precambrian Research, 40/41, 329–340). These ages are roughly equivalent to the Ar–Ar ages of muscovite formed during Au–Cu–Bi mineralisation at Tennant Creek — that is, 1830–1825 Ma (Compston & McDougall 1994: op. cit.).

The bulk of the Tennant Creek Au deposits coincide with a prominent gravity low (Fig. 26). Granite modelled underneath the Tennant Creek Au field (Rattenbury 1994: Mineralium Deposita, 29, 301–308) may be a pluton of the Treasure Suite, whose measured rock densities (2.63–2.68 t/m^3 with a mean of 2.65 t/m^3; Hone in Blake et al.1987: op. cit.) are compatible with the gravity model. In contrast, the measured densities of Tennant Creek Supersuite rocks (2.68–2.74 t/m^3 with a mean of 2.71 t/m^3; Hone in Blake et al.1987: op. cit.) are too high.

With regard to **mineral potential,** the Treasure Suite is clearly related to the Hatches Creek tungsten field. Dunnet & Harding's (1967: BMR Report 114) suggestion that the mafic diorites of the suite can be linked to the Au mineralisation at Tennant Creek is borne out by their similar (emplacement and mineralisation) ages. In addition, the total metal budget in the two deposit types is similar: the Hatches Creek W deposits contain Cu, Co, Bi, Mo, and minor U and Sn; and the associated elements in the Au deposits at Tennant Creek are Cu, Bi, Mo, Se, Pb, Co, and minor W and Sn (Large 1974: Economic Geology, 70, 1387–1413; Ferenczi 1994: AusIMM Publication Series, 5/94, 171–177). Perhaps the dominance of W in the Davenport Province reflects the more felsic compositions and the predominance of extrusive volcanics in the southeast. The Treasure Suite is also of a similar age to the major Au-related magmatic events farther north and west, in the Pine Creek and Tanami Provinces.

The ~1710-Ma Devils Suite

The Devils Suite is an extremely fractionated, oxidised, fluorite-bearing I-(granodiorite) type associated with minor vein-W deposits. Comprising the Devils Marbles, Elkedra, and Warrego Granites, it has a high but limited SiO_2 content, and shows abundant evidence of late magmatic–hydrothermal alteration, both within the granite and for some distance into the surrounding country rocks. The related thermal event has also caused considerable isotopic disturbance of the ore deposits in the northwestern part of the Tennant Creek Province (Black 1977: op. cit.; Compston & McDougall 1995: op. cit.). Despite Wedekind & Love's (1990: AusIMM, Monograph 14, 839–843) demonstration that the Warrego Granite has contact-metamorphosed the Warrego Au–Cu–Bi deposit, Stoltz & Morrison (1994: Mineralium Deposita, 29, 261–274) considered this granite to be genetically related to the Warrego deposit.

Although this suite attests to late magmatic fluid release, the presence of fluorite is believed to downgrade its **mineral potential**, and it probably has only limited potential for vein W. Even though cassiterite is ubiquitous in stream sediments (Hoatson & Cruikshank 1985: BMR Record 1985/44), and alluvial Sn has been extracted from watercourses draining the Wauchope tungsten field (P. Ferenczi, NTGS, written communication 1997), the Devils Suite is highly oxidised; consequently, the Sn probably occurs as cassiterite disseminated throughout its source granite, rather than in late veins.

Conclusions and future work

We consider that the Au mineralisation was associated with the emplacement of the ~1820-Ma Treasure Suite. The major, ironstone-hosted Au–Cu–Bi deposits occur in the Tennant Creek Province only, presumably because ironstones are poorly developed in the Davenport Province (Blake et al.1987: op. cit.). However, minor quartz-vein Au deposits occur in younger, mainly arenite-rich units and mafic and felsic intrusives/extrusives in both provinces (P. Ferenczi, NTGS, written communication 1997). Similar but larger deposits (cf. the Mount Todd Au deposit at Pine Creek) perhaps await discovery. If so, they will not be located by the magnetic-based exploration techniques which have been applied successfully to target the ironstone-hosted deposits.

For those espousing the view that Au is remobilised by magmatic fluids from country rock (rather than being sourced by granite), the Devils Suite offers food for thought. This suite provides abundant evidence for the release of a late magmatic fluid and attendant alteration of the surrounding country rock; even so, this alteration has clearly not remobilised any Au from the surrounding area. In contrast, the Au mineralisation appears to be related to an earlier suite that did not as pervasively alter the country rocks surrounding the intrusions.

In the Tennant Creek Province, much effort has been expended in applying geochemistry to distinguish between barren and mineralised ironstones. Even when 'prospective' ironstones are identified, the evidence of Au mineralisation presents a small and difficult target. A more effective methodology may be to investigate the alteration and geochemistry of the porphyries, granites, and quartzofeldspathic rocks surrounding the ironstones (and indeed away from the ironstones) as a means of determining the mineralisation-related fluid pathways.

Future work in the Tennant Creek Province should focus on tapping into the wealth of alteration data in the AGSO ROCKCHEM dataset, to try to delineate vectors to ore in the quartzofeldspathic sequences. Many of the members of the Tennant Creek Supersuite have either a Na- or K-alteration overprint, whereas the younger suites have a K overprint only. Huston & Cozens (1994: Mineralium Deposita, 29, 275–287) recorded a mineralised post-ironstone porphyry with K-alteration geochemistry similar to that documented in the AGSO dataset.

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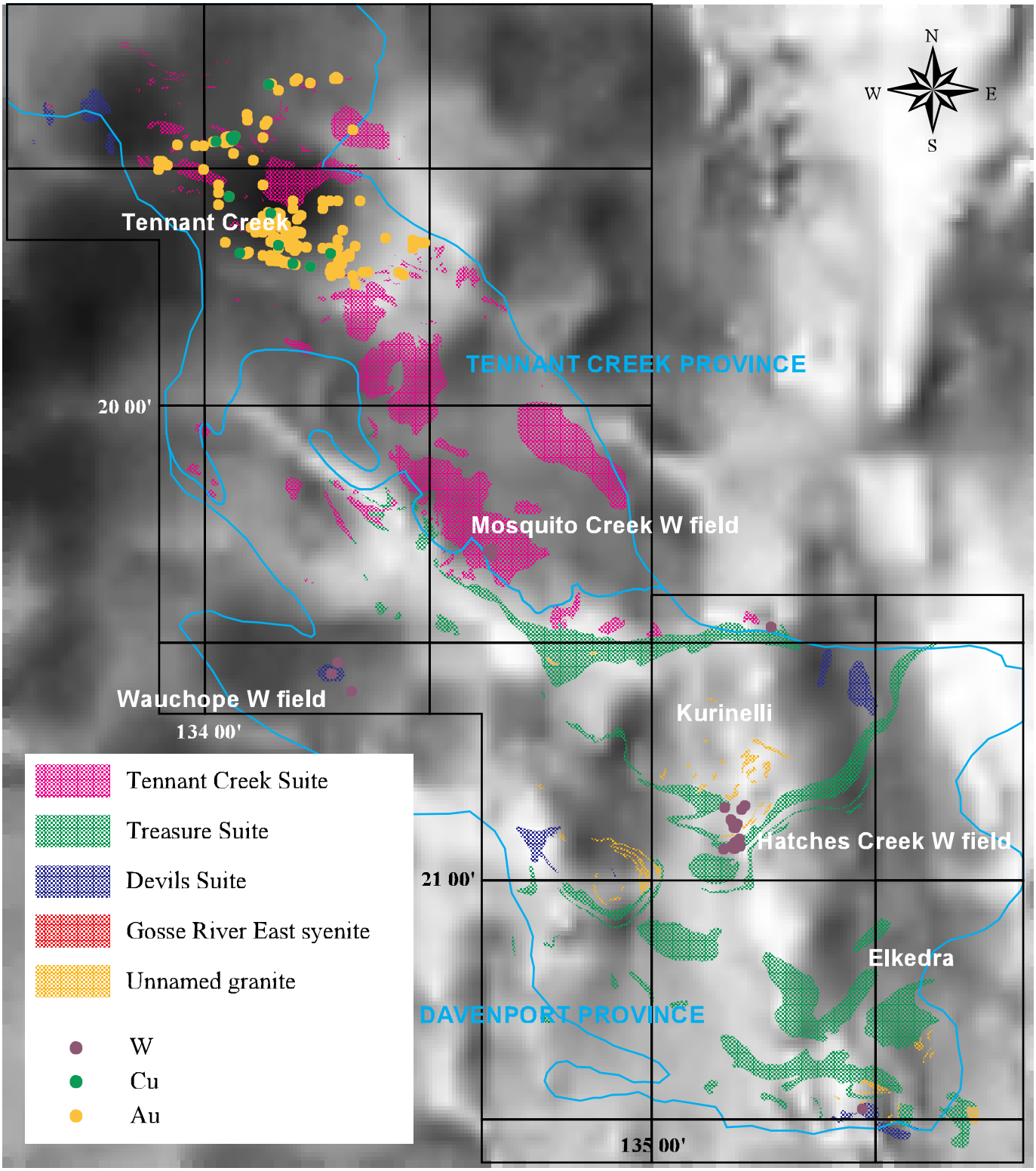

Fig. 26. Distribution of the various granite suites of the Tennant Creek/Davenport Provinces overlain on an image prepared from AGSO's 'Australian national gravity' database. Mineral deposit locations and commodities are from the AGSO/BRS MINLOC database. Note that the Gosse River syenite appears as a small outcrop in the southeast Tennant Creek Sheet area, and is represented by the tiny speck 2–3 mm below the 'A' of 'TENNANT CREEK PROVINCE'.