Terrane accretion and Cu–Au mineralization at a province boundary: the Ravensthorpe greenstone belt, Western Australia

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Abstract

Two distinct geological terranes containing a diverse range of mineralization styles have been recognized in the Archaean Ravensthorpe greenstone belt in the southern Yilgarn Craton, Western Australia. The Ravensthorpe Terrane was thrust from the west, eastwards over the Jerdacuttup Terrane. Sheet-like granitoids were simultaneously emplaced below the greenstones. Fluids derived from Jerdacuttup Terrane rocks in response to new P–T conditions imposed by thrusting and granitoid intrusion were funnelled upwards along the gently inclined basal thrust surface and overlying thrusts in the Ravensthorpe Terrane. Low-level concentrations of copper and gold were leached from calc-alkaline rocks in the Ravensthorpe Terrane and redeposited in hanging-wall splay structures at shallower structural levels in response to changes in temperature or fluid chemistry. The geological history of the Ravensthorpe greenstone belt is especially significant because it elucidates the nature of Archaean province (superterrane) boundaries.

KEYWORDS: Archaean, thrust faults, copper, gold, mineralization, Ravensthorpe.

The Ravensthorpe greenstone belt is geologically significant for several reasons: 1) it lies on the southern margin of the Yilgarn Craton and has, to some extent been reworked during the mid-Proterozoic Albany–Fraser Orogeny; 2) it contains the boundary between the Western Gneiss Terrane and the Southern Cross Province; and 3) it contains a diverse range of mineralization styles, including an unusual (for the Yilgarn Craton) Cu–Au association. A spatial association with tonalite and andesite (rock types that are atypical for the Craton) has prompted a porphyry model for the Cu–Au mineralization (Sofoulis, 1958; Savage, 1992). Recent mapping of RAVENSTHORPE* (1:100 000) and COCANARUP by the Geological Survey of Western Australia suggests that the Cu–Au mineralization is related to tectonic accretion of units representing the Western Gneiss Terrane and the Southern Cross Province. This short paper summarizes the tectonic evolution of the Ravensthorpe greenstone belt and places the mineralization into this context.

The Ravensthorpe greenstone belt is a synformal enclave within granitoid gneiss in the southern Yilgarn Craton. It is unconformably overlain to the south by the Proterozoic Mount Barren Group. Archaean granitoid gneiss (Munglinup Gneiss), uplifted from relatively deep crustal levels, is exposed south of the Jerdacuttup Fault. Munglinup Gneiss and metasedimentary rocks of the Mount Barren Group were uplifted during the Albany–Fraser Orogeny at around 1300 Ma (Myers, 1993).

Two geological terranes are recognized within the greenstone belt: the Jerdacuttup Terrane and the Ravensthorpe Terrane (Fig. 1). These are correlated with the Southern Cross Province (West Central Yilgarn Superterrane) and the Western Gneiss Terrain (West Yilgarn Superterrane) respectively. These terranes are in tectonic contact with one another and preserve evidence for independent structural and metamorphic histories prior to accretion.

The Jerdacuttup Terrane

The Jerdacuttup Terrane occurs on the eastern limb of the Beulah Synform. It consists of komatiite, basalt, and metasedimentary rocks (the Chester Group), including meta-psammite, metapelite, and banded iron-formation. There are also minor felsic volcanic rocks, a sample of which has been dated using SHRIMP methods at 2958 ± 4 Ma (Nelson, 1995). The earliest fabric recognized (S_1) is preserved in the pressure shadows of porphyroblasts in metapelitic rocks. It may have formed during thrust stacking of greenstone units across low-angle faults. Lithological units are folded about asymmetric, southeasterly plunging folds (F_2), the most prominent of which is the Maydon Syncline (Fig. 1). Anticlinal axes are sheared out along planes

* Capitalized names refer to standard map sheets.

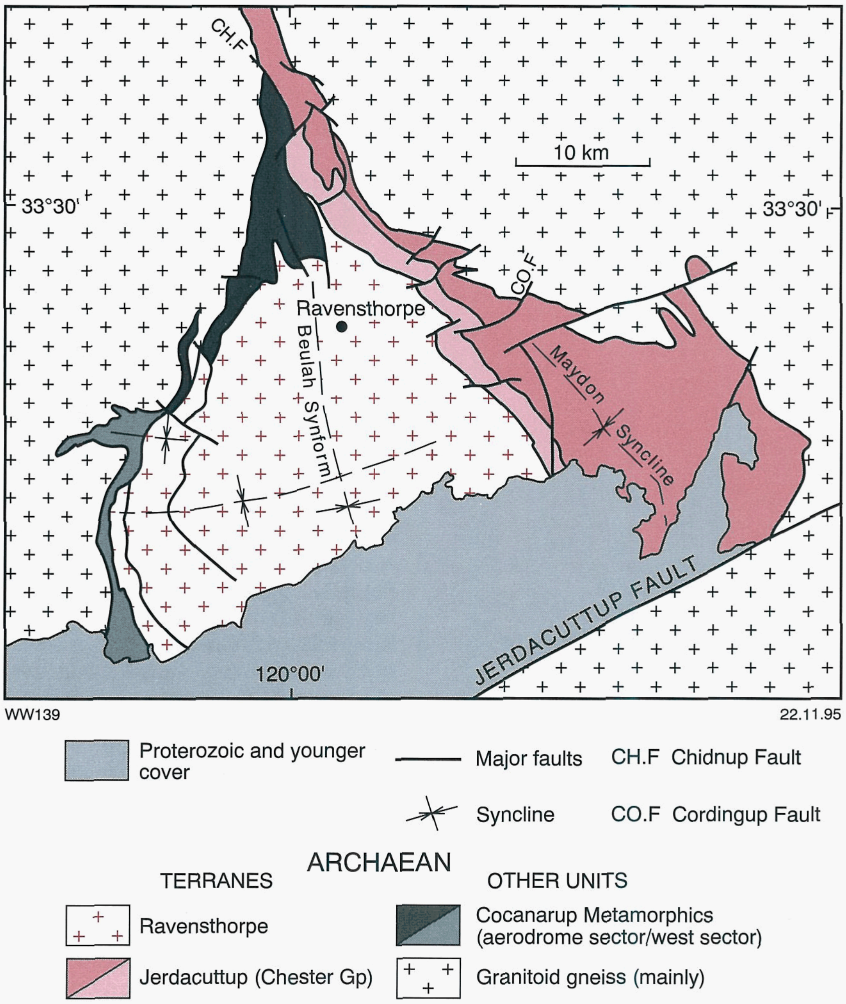


Figure 1. Geological map showing main tectonostratigraphic subdivisions and some of the main structures of the Ravensthorpe – West River greenstone belts

that are subparallel to fold axes. The shear zone west of the Maydon Syncline is also the terrane boundary with the Ravensthorpe Terrane. The dominant foliation in the terrane is S_2. It is parallel to the boundary between the Jerdacuttup Terrane and the Ravensthorpe Terrane, and the axial plane of the Maydon Syncline. Komatiite units on the northeastern limb of the Maydon Syncline contain nickel sulfide mineralization but the orebodies have been complexly deformed during faulting and shearing against the adjacent granitoid gneiss. Some of this deformation probably occurred during D_1 and D_2 but the contact is also the locus of northerly directed thrusting (D_4), which post-dated accretion (D_2) and formation of the Beulah Synform (D_3). Metapelitic units are associated with banded iron-formation and chert, which change along strike into massive pyritic units. An association with felsic volcanic rocks and Mn-rich metasedimentary rocks suggests some potential for 'distal facies' base-metal mineralization. At Bandalup, 30 km east of Ravensthorpe, magnesium derived from ultramafic rocks has been deposited as magnesite at the base of the overlying Tertiary Plantagenet Group.

The Ravensthorpe Terrane

The Ravensthorpe Terrane occurs to the west of the Jerdacuttup Terrane. Unlike the Jerdacuttup Terrane, it is not folded about the Maydon Syncline, but it does occupy the core of the Beulah Synform. It consists of tonalite and calc-alkaline volcanic rocks (the Manyutup Association) dominated by andesitic and dacitic volcaniclastic rocks. Tonalite from the Kundip mining area has been dated by SHRIMP methods at around 2980 Ma (Savage, M., pers. comm., 1994). Volcanogenic Cu–Zn mineralization is associated with widespread cordierite–ortho-amphibole rocks in upper amphibolite facies volcanic rocks at West River in the southwest extremity of the greenstone belt. Andesite and tonalite are completely absent from the Jerdacuttup Terrane, except as clasts in thin polymictic conglomerate units, which have been tectonically interleaved with other units on the northeast limb of the Maydon Syncline. The mainly metasedimentary Cocanarup Metamorphics occur along the western margin of the greenstone belt and are also assigned to the Ravensthorpe Terrane. They differ from the Chester Group in that they have a significant component of quartzofeldspathic metasedimentary

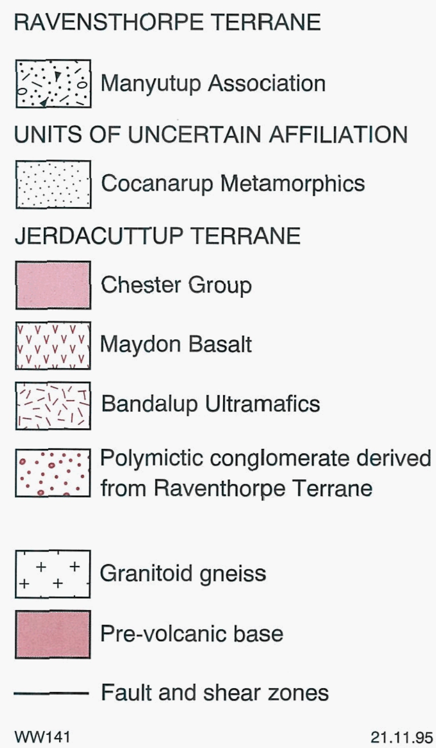
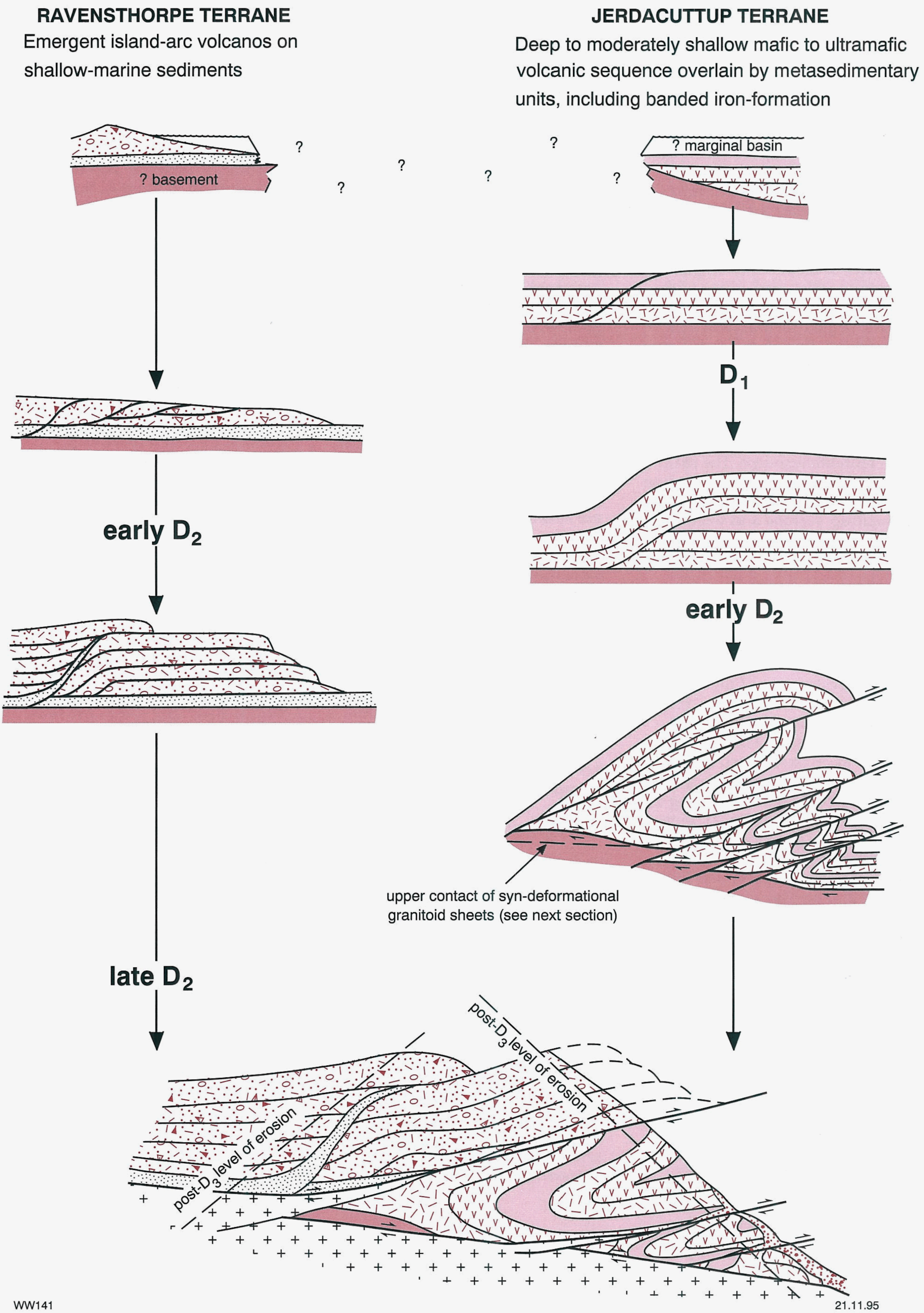


Figure 2. (opposite: reference above) Reconstructed tectonic histories of the Jerdacuttup and Ravensthorpe Terranes up to the time of amalgamation (prior to formation of the Beulah Synform)


RAVENSTHORPE TERRANE
Emergent island-arc volcanos on shallow-marine sediments
JERDACUTTUP TERRANE
Deep to moderately shallow mafic to ultramafic volcanic sequence overlain by metasedimentary units, including banded iron-formation
? basement
? marginal basin
D1
early D2
early D2
upper contact of syn-deformational granitoid sheets (see next section)
late D2
post-D3 level of erosion
post-D3 level of erosion
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rocks and only minor banded iron-formation units. The Cocanarup Metamorphics have a strong foliation that is parallel to the contact with granitoid gneiss, and a steep linear fabric is widely preserved on this contact. Much of the Manyutup Association is only weakly deformed but contains a number of poorly exposed shear zones that are subparallel to the boundary with the Jerdacuttup Terrane. These are recognized as thin slices of tectonically emplaced ultramafic schist, and, along with the terrane boundary itself, were a locus of pegmatite intrusion and local deformation. A pervasive, terrane boundary-parallel foliation is developed for about one kilometre west of the terrane boundary. One of the pegmatites, at Cattlin Creek, contains 1.3 Mt of spodumene and a small tantalite resource. The main fabrics in the Ravensthorpe Terrane are correlated with D_2 in the Jerdacuttup Terrane and were developed during accretion of the two terranes.

Tectonic history

Discounting the effects of the Beulah Synform (restoration of the greenstone–granitoid gneiss contacts to their original subhorizontal attitude) reveals the Maydon Syncline as an overturned fold with eastward vergence and with the Ravensthorpe Terrane overlying the Jerdacuttup Terrane (Fig. 2). Linear fabrics in the Cocanarup Metamorphics, and the eastward vergence of the Maydon Syncline, suggest that the Ravensthorpe Terrane was thrust into this position from the west. Clasts of tonalite and calc-alkaline volcanic rocks in polymictic conglomerate on the northeast limb of the Maydon Syncline were probably eroded from the Ravensthorpe Terrane as it was thrust up over the Jerdacuttup Terrane. Pegmatites that were intruded into shear zones parallel to terrane boundaries are partly deformed suggesting syntectonic intrusion. The crystallization age of the pegmatites should therefore date the age of terrane accretion. As yet, only imprecise Rb–Sr and K–Ar ages of around 2800 Ma for the Cattlin Creek pegmatite are available.

Metamorphic isograds cut across the terrane boundary and are grossly discordant with the tonalite component of the Manyutup Association. Metamorphic grade typically increases toward contacts between granitoid gneiss and greenstones. Fabric relationships indicate that metamorphic assemblages in both terranes equilibrated syn- to post-accretion. These observations suggest that regional metamorphism was related to emplacement of the granitoid sheets, which were emplaced at the base of the exposed greenstones during accretion. These granitoid sheets were precursors to the gneiss, which envelopes the greenstones at the present erosion surface, and presumably were genetically related to the pegmatite swarms that were intruded into syn-accretionary faults. Previous descriptions attributed regional metamorphism to emplacement of the tonalite (Sofoulis, 1958).

Pre-accretion metamorphic fabrics are also locally preserved in both terranes. The Cocanarup Metamorphics preserve evidence for an earlier fabric defined by sillimanite within andalusite porphyroblasts, consistent with uplift (decreasing pressure) during terrane accretion. Uplift is supported by an increase in the iron content from core to rim in garnet from the Cocanarup Metamorphics (Spear, 1993). No early, high pressure or high temperature assemblages have been recognized in Chester Group metapelites from the Jerdacuttup Terrane, where S_1 is defined by quartz, biotite, and opaque minerals.

Cu–Au mineralization

Quartz veins and small-scale shear zones containing copper and gold mineralization are concentrated in a zone immediately west of the terrane boundary. They occur mainly in the Ravensthorpe Terrane, in andesite, and to a lesser extent in tonalite, but significantly there is a minor amount of mineralization in the adjacent Jerdacuttup Terrane. Mineralization must have therefore been synchronous with or have post-dated terrane accretion. Furthermore, alteration assemblages in Cu–Au deposits vary sympathetically with regional metamorphic grade suggesting mineralization was contemporaneous with metamorphism. Dehydration of Jerdacuttup Terrane rocks, particularly metapelites, as they adjusted to new P–T conditions imposed by overthrusting of the Ravensthorpe Terrane yielded large quantities of fluids that were funnelled along the basal thrust surface (terrane boundary) during accretion. These fluids leached copper and gold from the calc-alkaline Manyutup Association at deeper, hotter levels and relatively low fluid/rock ratios. As fluid/rock ratios increased at higher structural levels, the same metals were redeposited in brittle and brittle–ductile splay structures, mainly in the hanging wall of the basal thrust, in response to changes in temperature and/or fluid chemistry.

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