The contribution of geochronology to GSWA's mapping programs: current perspectives and future directions

by

S. Bodorkos and M. T. D. Wingate

Radiogenic isotope geochronology is aimed at determining absolute ages of rocks and geological events. As an integral part of most GSWA mapping programs, it has played a pivotal role in revolutionizing our understanding of the geology of Western Australia. Regional mapping programs require direct dating of geological events as diverse as igneous crystallization (U–Pb zircon, monazite, or baddeleyite), metamorphism (U–Pb monazite or titanite), cooling (Ar–Ar hornblende, muscovite, or biotite), and deformation (in situ laser Ar–Ar muscovite). Geochronology also has several important additional applications, including provenance analysis and maximum depositional ages of sedimentary rocks, and constraining the ages of tectonothermal events via the dating of pre-, syn-, and post-tectonic igneous rocks.

Between 1991 and 2004, GSWA obtained 654 sample-specific geochronological results, of which over 95% are sensitive high-resolution ion microprobe (SHRIMP) U–Pb zircon dates. Ongoing work (represented by 133 results obtained in 2005–06) supports current regional mapping and geophysical interpretations in the Murchison Domain and Burtville Terrane of the Yilgarn Craton, the Gascoyne and Musgrave Complexes, the Albany–Fraser Orogen, the Edmund and Collier Basins, and the Perth, Carnarvon, and Canning Basins. Some of the diverse applications of geochronology to GSWA's regional programs are illustrated in the examples below.

Tectono-metamorphic histories from Musgrave Complex zircons

Zircon structure, chemistry, and geochronology data have been integrated with whole-rock Sm–Nd isotopic data to elucidate spatial patterns in the tectono-metamorphism of granulite-facies supracrustal rocks that form basement to the Musgrave Complex. In the south, these rocks have Sm–Nd model ages of c. 2800 Ma, are intruded by the 1330–1290 Ma Wankanki Supersuite, and contain detrital zircon cores (with U–Pb ages in the range 1800–1370 Ma) that are overgrown by 1220–1200 Ma rims with high uranium contents and low Th/U ratios. In contrast, northern Musgrave supracrustal rocks have Sm–Nd model ages of 2000–1800 Ma, lack evidence for Wankanki plutonism, and contain detrital zircon cores (with U–Pb ages in the range 1650–1290 Ma) that are rimmed by 1180–1170 Ma overgrowths with low uranium contents and high Th/U ratios. These data support the existence of two basement terranes with disparate tectono-metamorphic histories. Clues to the nature of their interrelationship are provided by rocks in the central Musgrave Complex, where both types of zircon rims have been identified at single-grain scale. These rocks are proximal to the crustal-scale Mann Fault, along which the two terranes may have been juxtaposed during the latter stages of the 1220–1160 Ma Musgravian Orogeny.

Reservoir sandstone provenance from Canning Basin zircons

Detrital zircons have been dated from potential reservoir sandstones in the Ordovician Willara (Acacia Sandstone Member), Gap Creek, and Carranya Formations, with the aim of testing the proposed continuity of sand bodies between control points (wells and outcrops), establishing sediment provenance and likely sediment pathways, and constraining the paleogeography of reservoir units by linking them to possible sediment input points along the basin margin. Two of the four dated samples yielded identical provenance spectra dominated by 1880–1840 Ma zircons derived from the North Australian Craton to the northeast. However, two other proposed correlatives are characterized by more diverse age spectra and much higher Meso- and Neoproterozoic inputs derived from the Centralian Superbasin (or directly from its source terrains) to the southeast. This suggests that either the Acacia Member represents several discrete sand bodies of similar age derived from different sediment input points, or that provenance switching during deposition has led to provenance stratification within the unit. Both possibilities have important implications for predicting reservoir distribution and lateral facies changes.

Baddeleyite dating of Proterozoic dolerite in the central Yilgarn Craton

Baddeleyite (ZrO_2) has considerable potential as a U–Pb chronometer in mafic intrusive rocks such as dolerite and gabbro, which usually do not contain magmatic zircon and have previously been considered difficult to date. The mineral separation procedure is complicated by the small size and fragility of baddeleyite and by the high proportion of high-density and magnetic minerals in mafic rocks. However, GSWA's Carlisle Laboratory has successfully implemented crushing, washing, and magnetic separation protocols designed to maximize baddeleyite yield. Consequently, several hundred crystals of baddeleyite (and a small number of zircons) were obtained from a dolerite sill in the central Yilgarn Craton, southeast of Sandstone. The baddeleyite yielded a SHRIMP U–Pb date of 1070 ± 18 Ma that is interpreted as the crystallization age of the sill. Two of 13 zircons furnished dates within uncertainty of the baddeleyite result, whereas the remainder yielded dates in the range 2460–1200 Ma, and are interpreted as xenocrysts acquired from older rocks. This new result confirms that the dolerite sill is part of the Warakurna large igneous province (LIP), and indicates that the Warakurna LIP extends well into the central Yilgarn Craton, with a newly recognized areal extent of some 1.7×10^6 km^2.

Laser Ar–Ar muscovite dating of Neoproterozoic deformation in the Gascoyne Complex

The Chalba Shear Zone is a crustal-scale structure separating the 1840–1620 Ma northern-central Gascoyne Complex from the 2005–1970 Ma southern Gascoyne Complex (Glenburgh Terrane). Within the shear zone, well-developed S–C fabrics in strongly deformed granites were widely regarded as the product of Paleoproterozoic deformation, overprinted and reactivated during the 1030–950 Ma Edmundian Orogeny. White micas in different textural associations were dated in situ (via infra-red laser) using the $^{40}Ar/^{39}Ar$ method. Five analyses of coarse-grained C-plane crystals yielded widely variable ages (2790–630 Ma), and probably reflect a combination of heterogeneously distributed excess Ar, and partial resetting of the Ar–Ar systematics. However, the fine-grained S-plane material indicated a single age of 570 ± 10 Ma. This suggests that at least some of the observed structural reactivation may be associated with the development of dextral shear zones that transect the 755 Ma Mundine Well dolerite dyke swarm elsewhere in the Gascoyne Complex. This terminal Proterozoic deformation event may reflect either a far-field response to Petermann Orogeny tectonism in central Australia, or a more northeasterly manifestation of deformation in the Pinjarra Orogen, west of the Darling Fault.