

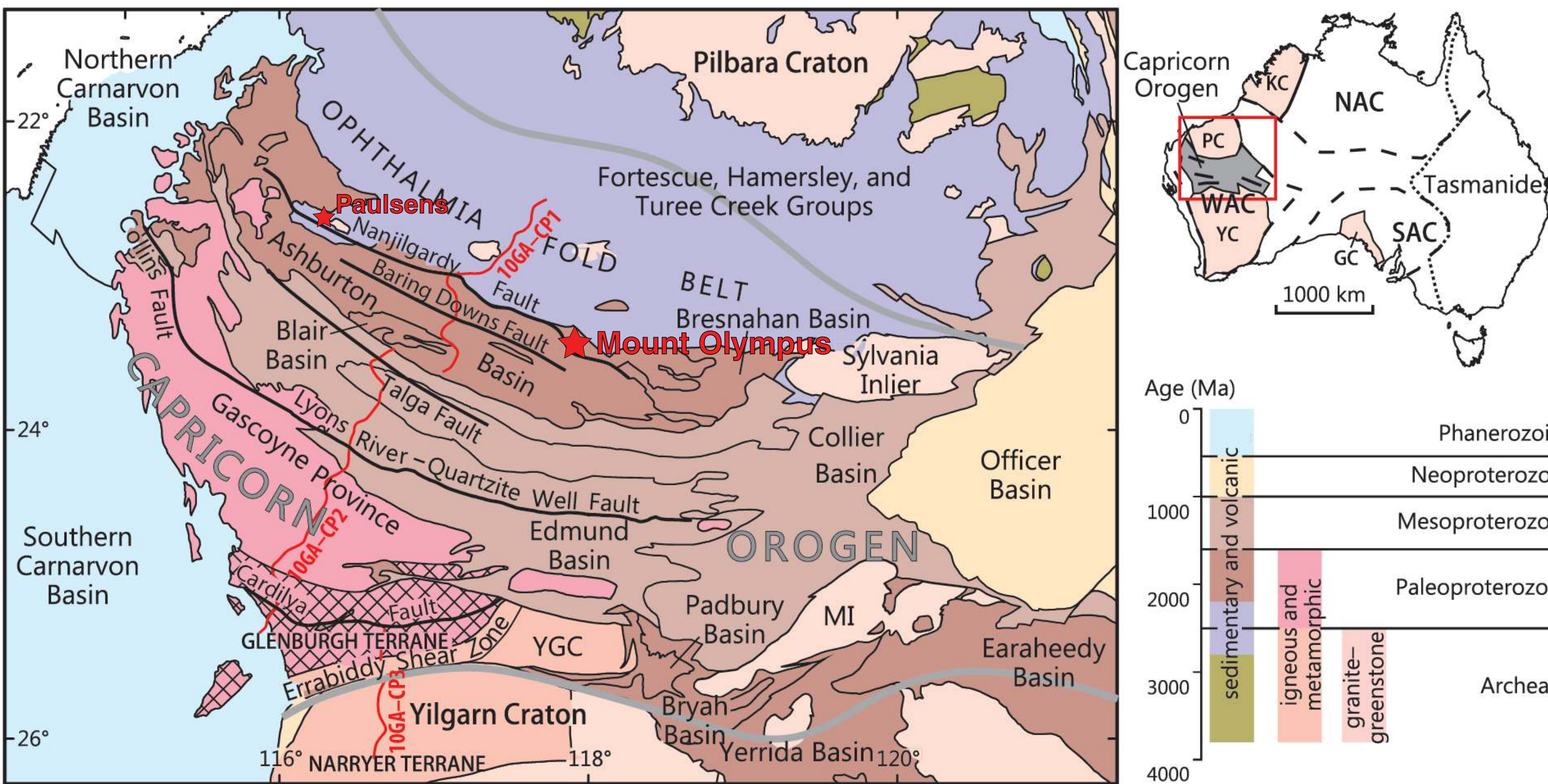
LINKING GOLD MINERALIZATION TO TECTONOTHERMAL EVENTS USING IN SITU XENOTIME U–Pb GEOCHRONOLOGY

Introduction

Understanding controls on gold mineralization involves determining the class of deposit, and the ability to link the timing of mineralization to the tectonothermal framework. The Mount Olympus gold mine in the northern Capricorn Orogen of Western Australia, is classified as an orogenic gold deposit despite having the physical characteristics of a Carlin-type gold deposit. A previously determined age of ca. 1740 Ma for mineralization was thought to be associated with an Australia-wide orogenic event at 1750–1720 Ma (Şener et al., 2005). However, more recent work shows that there is no evidence for accretionary or collisional orogenic events at this time, either in the Capricorn Orogen or across Australia.

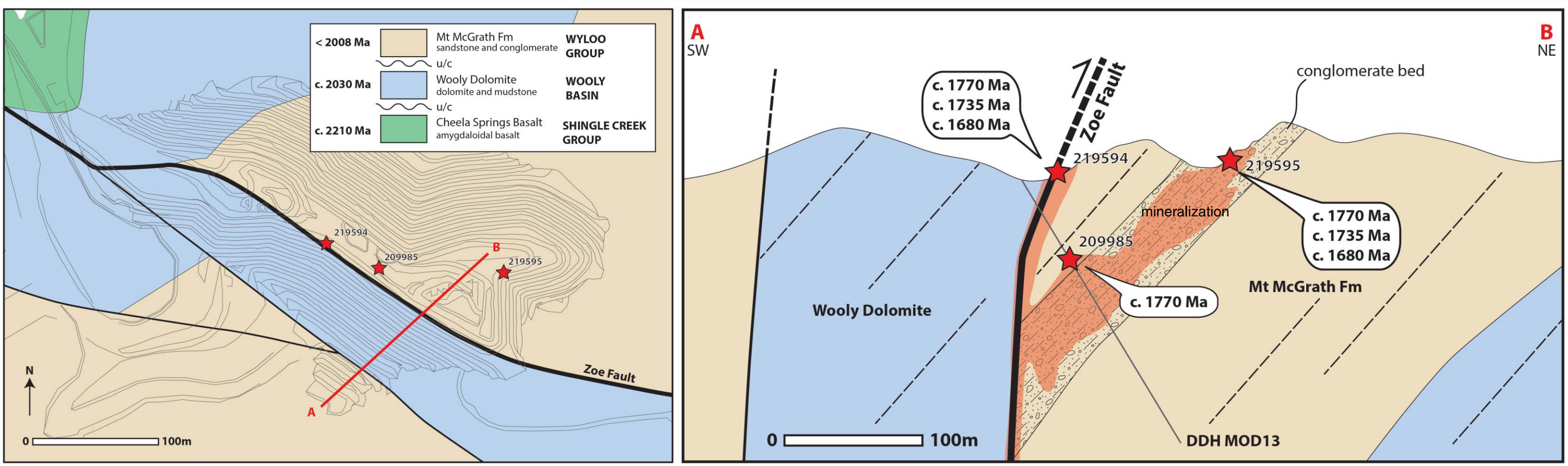
The presence of hydrothermal xenotime in the deposit makes it an ideal example in which to examine the processes responsible for ore formation. Here we present in situ U–Pb xenotime geochronological data obtained using the Sensitive High Resolution Ion Microprobe (SHRIMP) to determine the timing of multiple hydrothermal events, including gold mineralization, at Mount Olympus. We then integrate this age information with the record of well-established tectonothermal events in the West Australian Craton.

Geological Setting



The Capricorn Orogen is a zone of variably deformed rocks between the Pilbara and Yilgarn Cratons of Western Australia. The orogen records the two-stage assembly of the West Australian Craton by ca. 1950 Ma, as well as at least five younger episodes of intracratonic reworking. In the northern part of the Capricorn Orogen, Paleoproterozoic siliciclastic, carbonate and volcanic rocks of the Wyloo and Shingle Creek Groups were deformed during the 1820–1770 Ma Capricorn Orogeny.

Local Geology

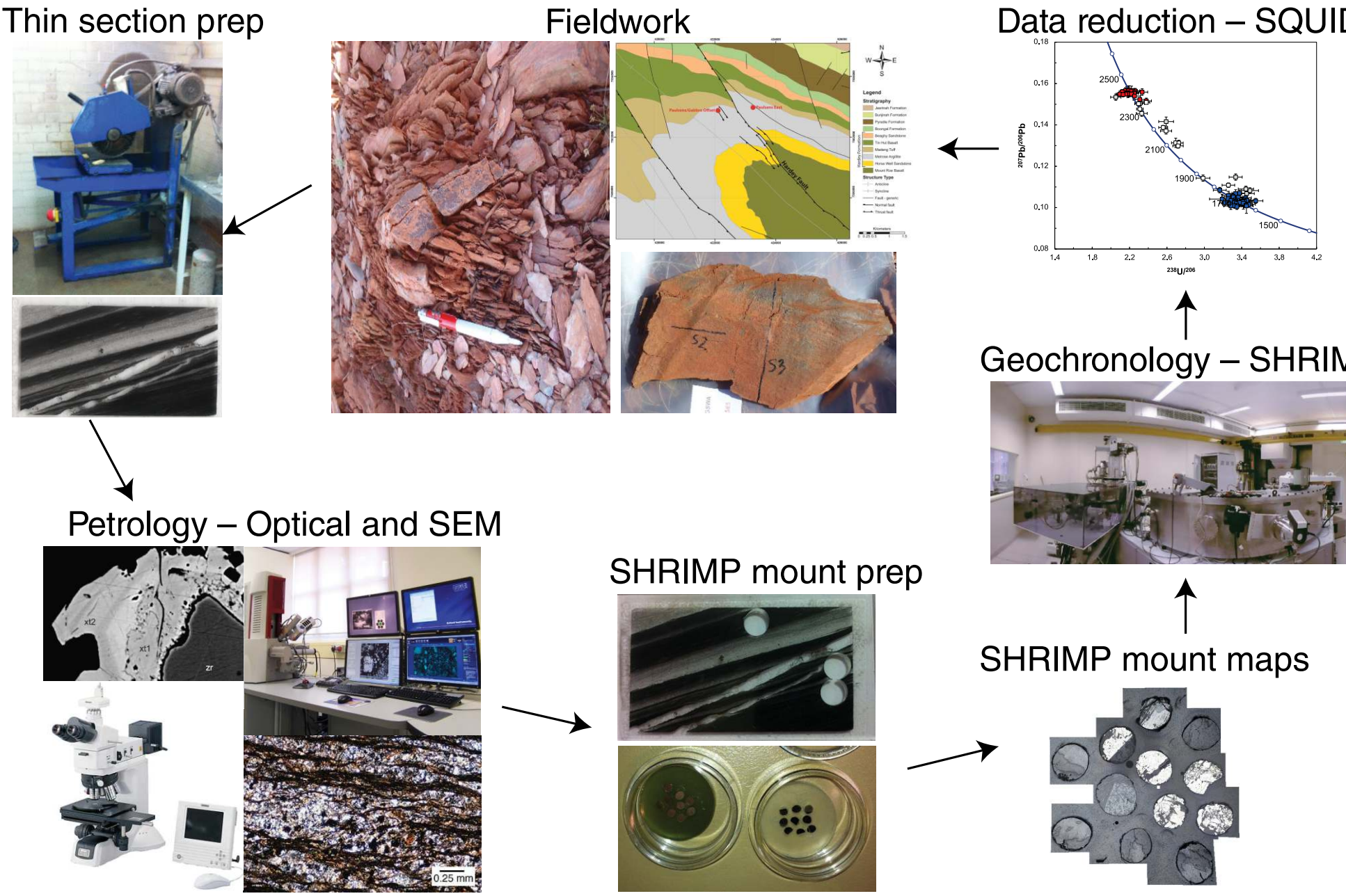


Mount Olympus is a Carlin-type gold deposit with a total remaining resource of 15 million tons at 2.2 g/t containing 1 million oz of gold. Mineralization occurs where the Zoe Fault, a second-order splay of the Nanjilgardy Fault, juxtaposes conglomerate and coarse-grained sandstone of the Mount McGrath Formation from dolomitic mudstone of the Woolly Dolomite. The Zoe Fault is a dextral transpressional fault which has a strong control on the location of gold mineralization and is likely to have been the primary conduit for mineralizing fluids.

Methods

Precise dating of hydrothermal gold mineralization is inherently difficult due to a lack of minerals suitable for geochronology, and the ease of isotopic resetting of common chronometers during subsequent metamorphism and deformation. However, in situ Sensitive High-Resolution Ion Microprobe (SHRIMP) U–Pb analysis of hydrothermal monazite and xenotime is an effective way to date hydrothermal and mineralizing events. These phosphate minerals are robust chronometers that commonly form during hydrothermal activity, yield precise ages, and are resistant to isotopic resetting over a range of temperature and pressure conditions.

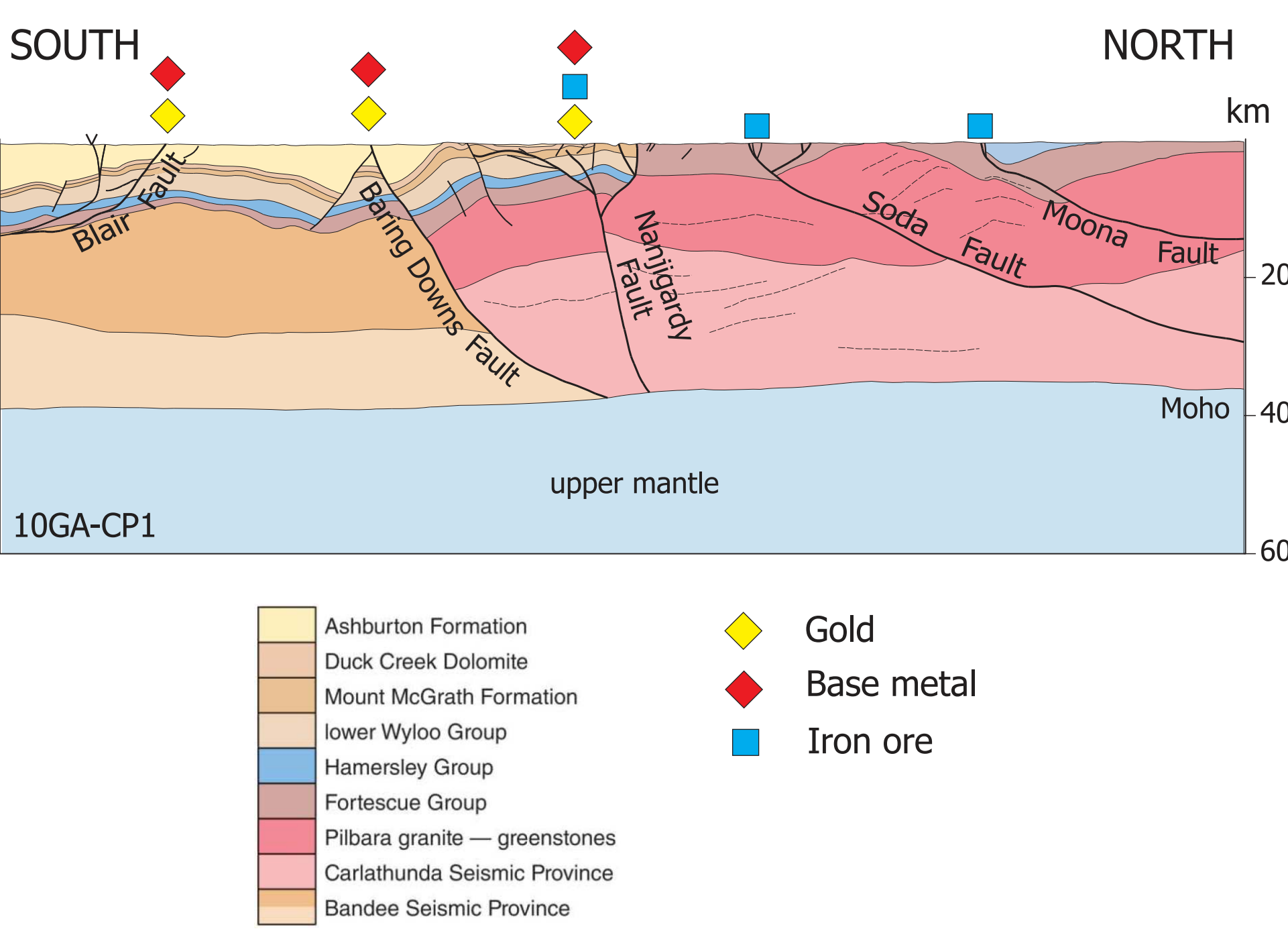
In situ geochronology is a method where textural relationships are retained by drilling the minerals to be dated and the surrounding minerals, out of a polished thin section. By using in situ geochronology we can directly date phosphate minerals and, hence, provide ages for hydrothermal activity and associated gold mineralization and then link this back to what is observed on an outcrop scale.



Crustal Architecture

Mineralization through the region has a spatial association with crustal-scale faults identified by a deep-crustal seismic survey. The Nanjilgardy Fault has experienced multiple reactivations that led to deposition and remobilization of various styles of gold mineralization throughout the northern Capricorn Orogen.

The Mount Olympus gold deposit is located on the Zoe Fault which is a second-order splay of the Nanjilgardy Fault.

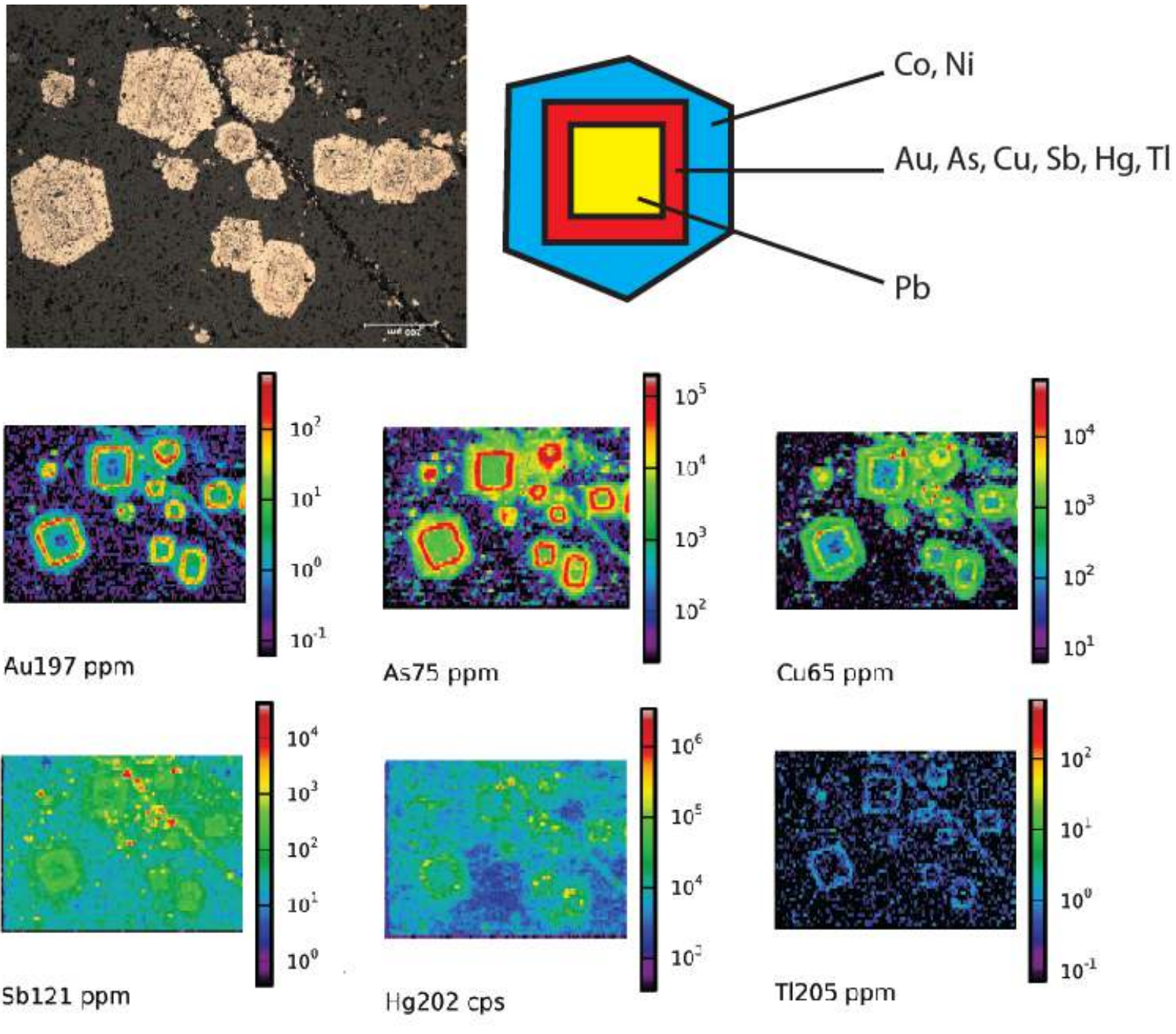


Ore Body Classification

The classification of the Mount Olympus deposit has been reported as having features similar to both Carlin-type and orogenic gold deposits (Şener et al., 2005). However, results indicate that Mount Olympus is more similar to a Carlin-type deposit than an orogenic deposit. Two distinct types of mineralized lodes are evident at Mount Olympus and are typical of Carlin-type ores:

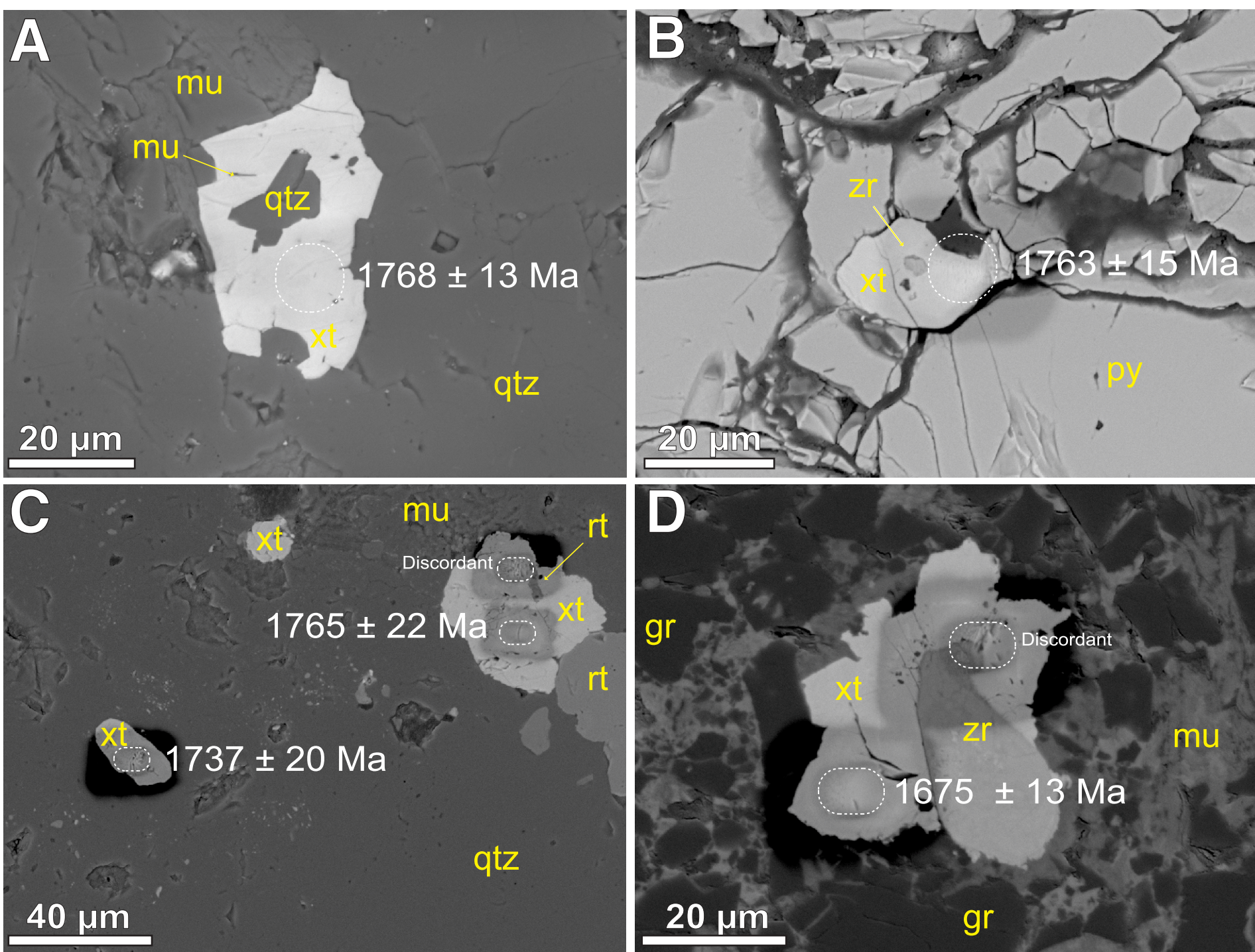
- 1) strata-bound ore where pyrite crystals up to 2 mm in diameter are disseminated within carbonaceous and ferruginous conglomerate and sandstone of the Mount McGrath Formation, and
- 2) fault-hosted mineralization associated with pyrite or graphite along the Zoe Fault.

Laser-ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) element distribution maps of pyrites from Mount Olympus show similar geochemistry to the Carlin-type ores of Nevada. Most of the gold forms a solid solution in Au–As internal bands on pyrite crystals in mineralization hosted in carbon rich ores hosted within the Zoe Fault or as rims in sericite altered strata-bound ores (see figure). However these zones are much thicker and of lower grade (up to 428.97 ppm Au) compared to those in the Carlin-type deposits (up to 2000 ppm Au). Trace elements associated with high grade gold mineralization at both deposits are the same with elevated Au, As, Cu, Sb, Hg and Tl (see figures).



Sample Details

Three mineralized samples were examined by optical and scanning electron microscope to identify xenotime suitable for geochronology. Strata-bound mineralization (GSWA 209985) from a pervasively altered siltstone with coarse pyrite and 2.67 g/t of Au, contained small xenotime (<25 µm diameter) crystals intergrown with ore-related alteration minerals, quartz and muscovite (Fig. A). Some xenotime crystals are fully contained within pyrite crystals (Fig. B).



A second sample of strata-bound mineralization (GSWA 219595) was collected from quartz–muscovite altered conglomerate in the Mount Olympus pit with pyrite crystals up to 2 cm. Xenotime crystals from this sample are up to 80 µm in diameter and commonly contain inclusions of quartz, zircon, rutile or muscovite (Fig. C).

From the Zoe Fault, a mineralized sample (GSWA 219594) comprising brecciated pyrite, graphite and quartz veins, contained small xenotime crystals (<20 µm diameter) in the brecciated parts of the sample. The xenotime commonly forms overgrowths on zircon crystals (Fig. D) and contains inclusions of quartz, muscovite and rutile.

Conclusions and Implications

The Mount Olympus gold deposit is located on the Zoe Fault, a second-order splay of the crustal-scale Nanjilgardy Fault. The timing of gold mineralization at ca. 1770 Ma, lies at the younger end of the age range for the intracratonic 1820–1770 Ma Capricorn Orogeny, a time that represents a distinct change in tectonic regime, from predominantly northeast compression to north–northwest stresses producing dextral strike-slip reactivation of the Nanjilgardy Fault. Xenotime growth dated at ca. 1730 Ma (from this study and by Şener et al. (2005)) and at ca. 1670 Ma is contemporaneous with hydrothermal monazite and xenotime growth at the Paulsens gold mine located 150 km to the northwest and during the early stages of the 1680–1620 Ma Mangaroon Orogeny. These events are also thought to reflect the timing of punctuated reactivation on the Nanjilgardy Fault and associated hydrothermal fluid flow.

Our results differ from those of Şener et al. (2005) who provided a ca. 1740 Ma age for mineralization which was thought to be associated with an Australia-wide orogenic event at 1750–1720 Ma. However, there is no evidence for accretionary or collisional orogenic events at this time, either in the Capricorn Orogen or across Australia.

Our results indicate that Mount Olympus is a Carlin-type deposit where mineralization occurred in an intracratonic setting, during low- to medium-grade metamorphism and was facilitated by the focusing of hydrothermal fluids along a major, crustal-scale structure.

