ADVANCES IN METAMORPHIC STUDIES

PROGRESS TOWARDS A STATE METAMORPHIC MAP

Over the last few decades, methods have been refined to unravel the depth, thermal, temporal and deformational history of geological terranes. Detailed observations at the map, hand sample and thin section scales can now be integrated with elemental and isotope data, and inverse and forward phase equilibria modelling, to retrieve more precise pressure (*P*)–temperature (*T*)–time (*t*) data from rock samples. We are applying this integrated approach using modern methods of metamorphic petrology to enhance our understanding of the tectono-metamorphic evolution of Western Australia. Our aim is ultimately to produce a statewide metamorphic map, with robust *P*–*T*–*t* constraints providing critical data points.

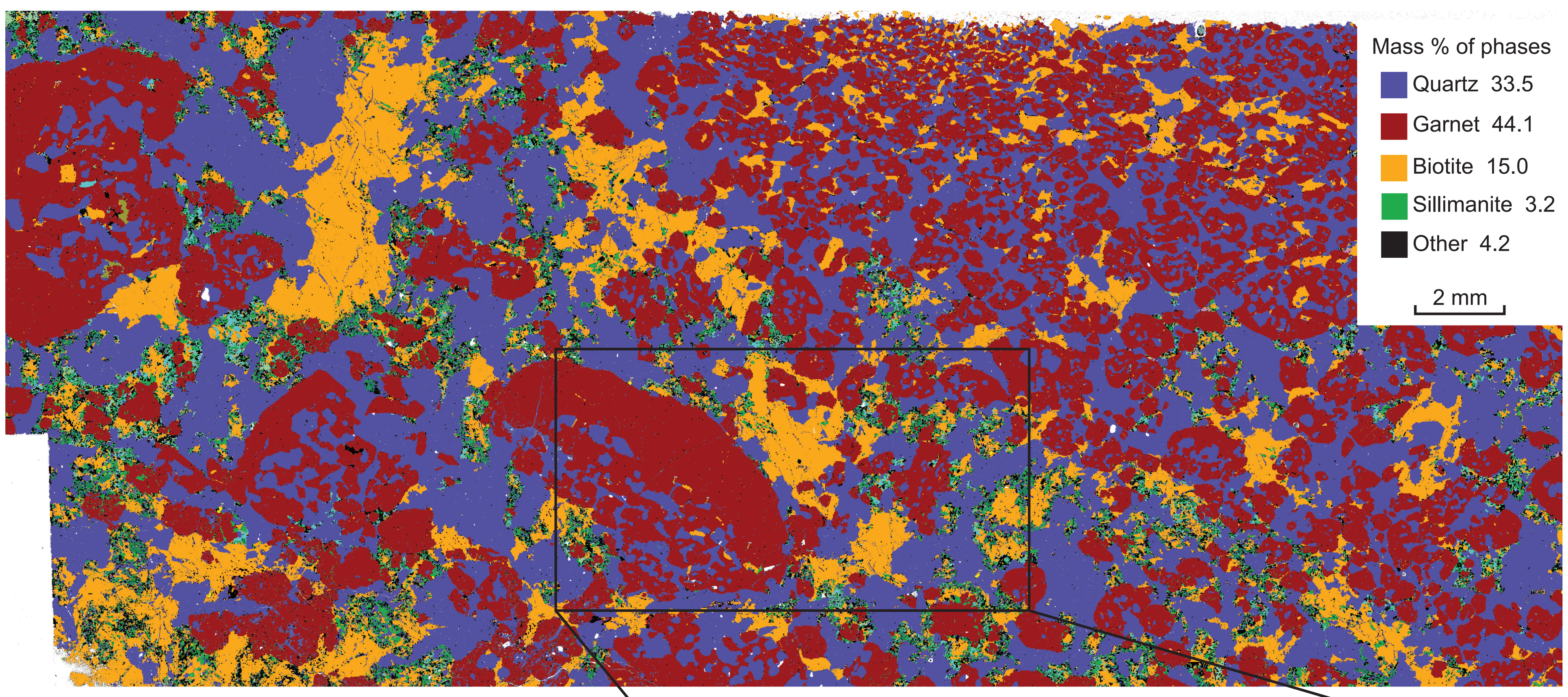
Methodology for metamorphic studies

- Field observations and sample collection*
- Petrography **
- In situ geochronology **
- Bulk composition
- Mineral chemistry** and thermobarometry*
- Phase equilibria modelling
- *P*–*T*–*t* path and interpretation*
- Data capture and Records

* not presented on this poster
** see companion poster for techniques

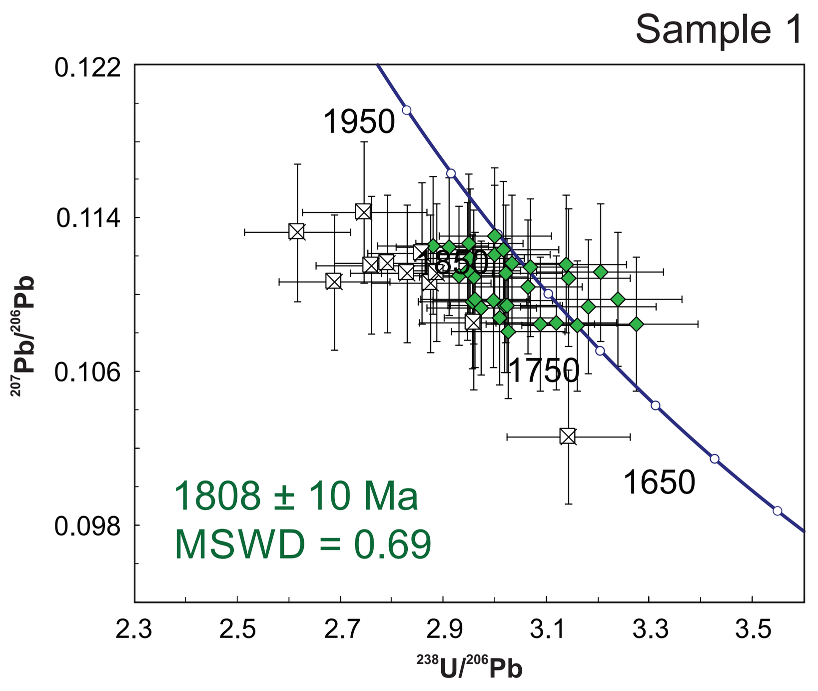
Petrography

In combination with standard optical petrography, we are also utilizing analytical scanning electron microscopy to map at the thin section- or grain size scale, and resolve small-scale features that are difficult to see with an optical microscope. These techniques can be used to quickly identify minerals, assess variations in mineral chemistry, and quantify mineral abundances.

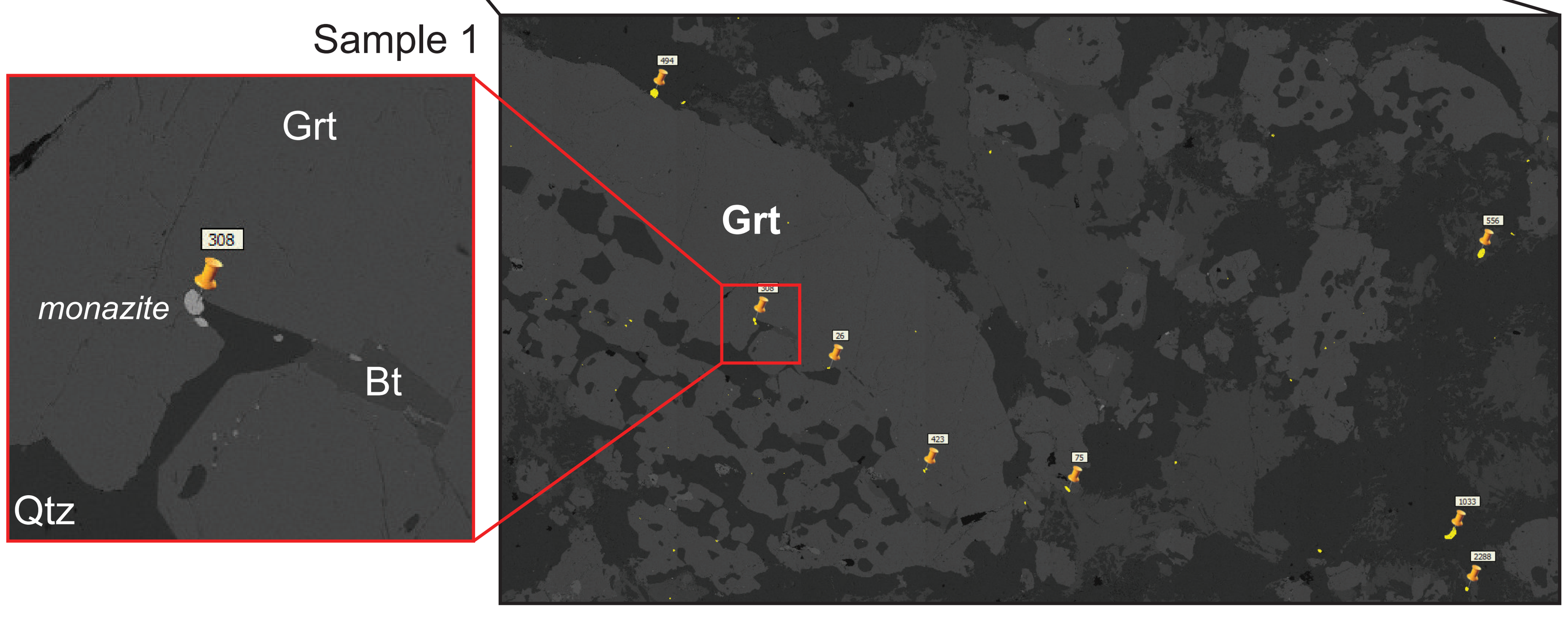


In situ geochronology

Accessory phases, such as monazite, can be analysed in situ to preserve their microstructural setting, so that age results can potentially be linked with the stability of specific major rock-forming minerals. Monazite chemistry may also be used to assess the behaviour of other minerals, which may reveal important information about the *P*–*T*–*t* path.

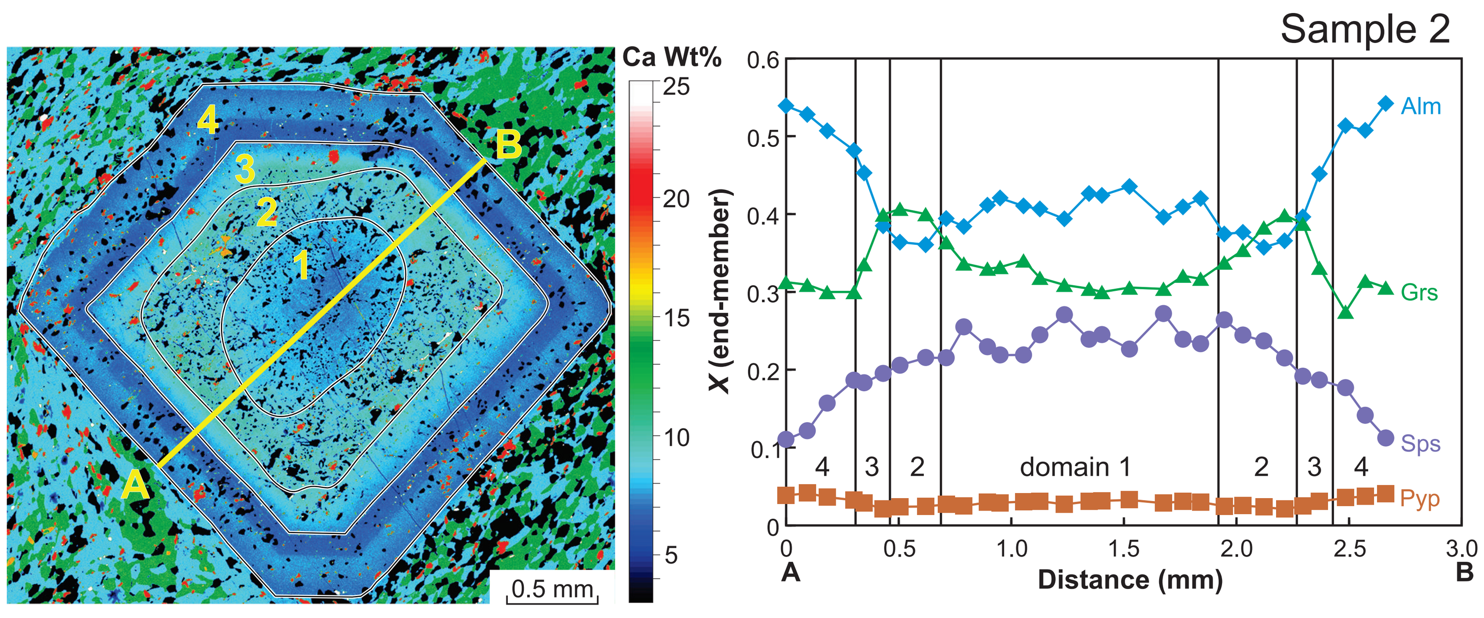


Sample 1 is a garnet–sillimanite-bearing restite from the west Kimberley. This full thin section scan was collected with the Tescan Integrated Mineral Analyser (TIMA) at the John de Laeter Centre, Curtin University. Accessory phases, such as monazite, can be quickly identified in situ, as highlighted in yellow on the backscattered electron (BSE) image on the right. These monazite grains were analysed using the laser ablation split steam at Curtin University (age results shown on left). See companion poster for Y data

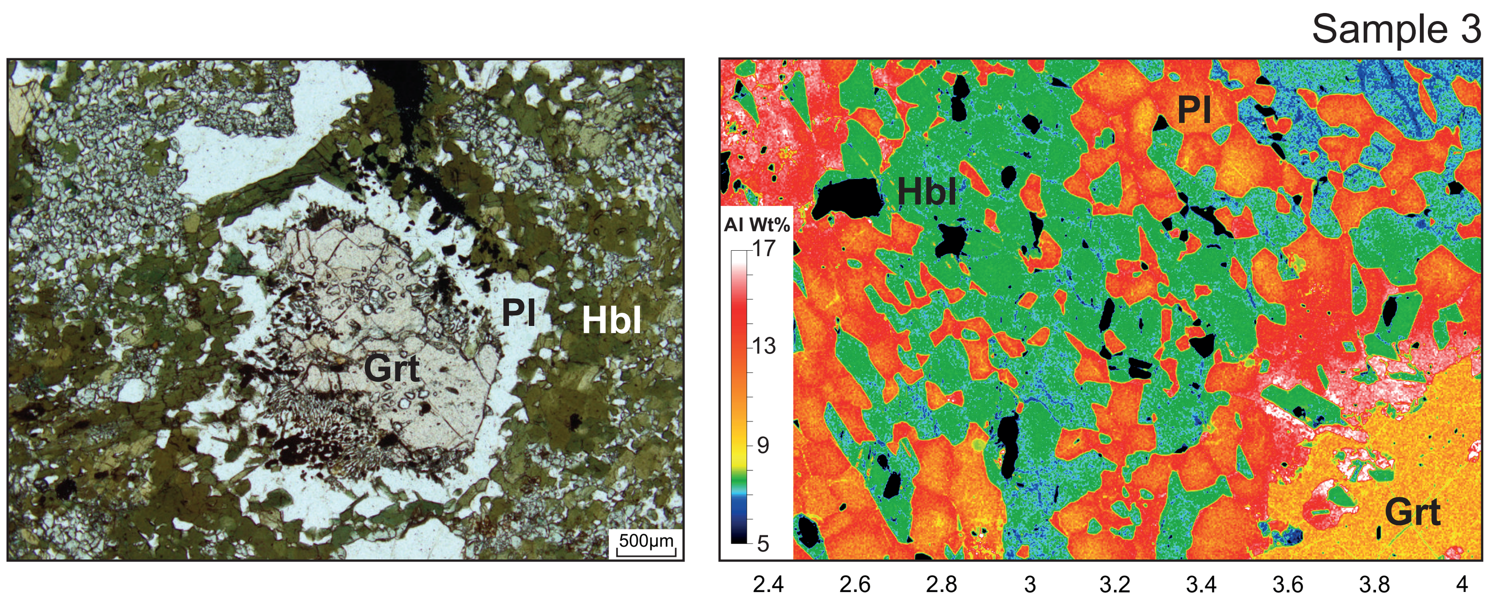


Bulk composition and mineral chemistry

The mineral assemblage preserved in a rock is primarily a function of the *P*–*T* conditions and the composition (*X*) of the equilibration volume. Therefore bulk composition is a fundamental variable. For many samples, particularly at higher metamorphic grade, the bulk composition can be measured by X-ray fluorescence (XRF) of the rock sample. However, some samples require a domainal composition of a specific microstructure to be calculated. Mineral chemistry is also a function of *P*–*T*–*X* conditions and may provide insight into the metamorphic evolution.



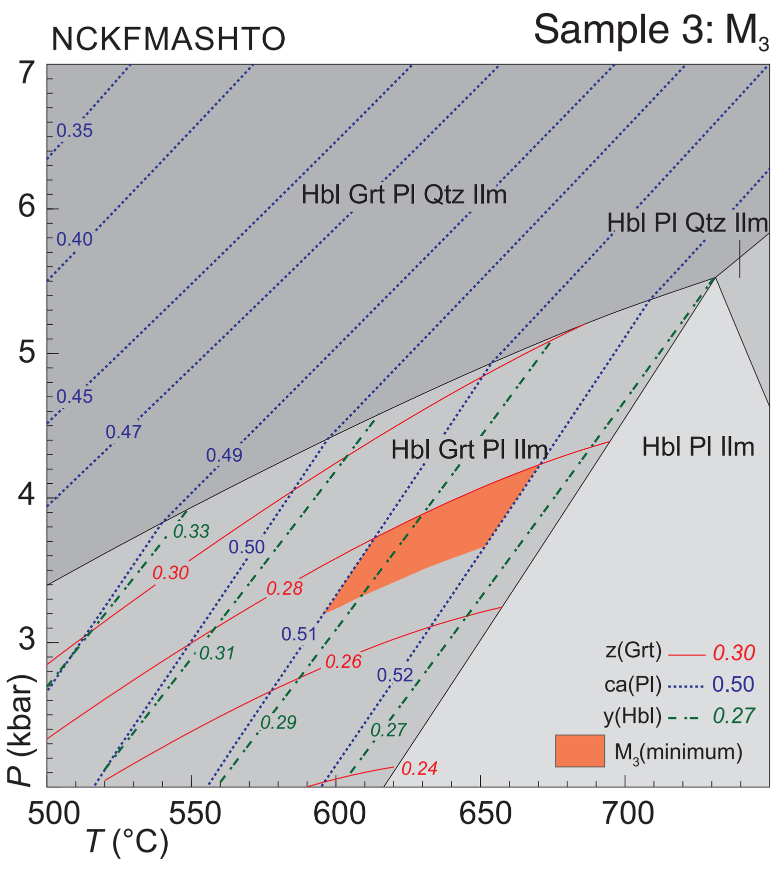
Ca elemental map and line traverse of a garnet grain from an amphibolite in the Gascoyne Province. The garnet preserves four distinct compositional domains that record different *P*–*T* conditions



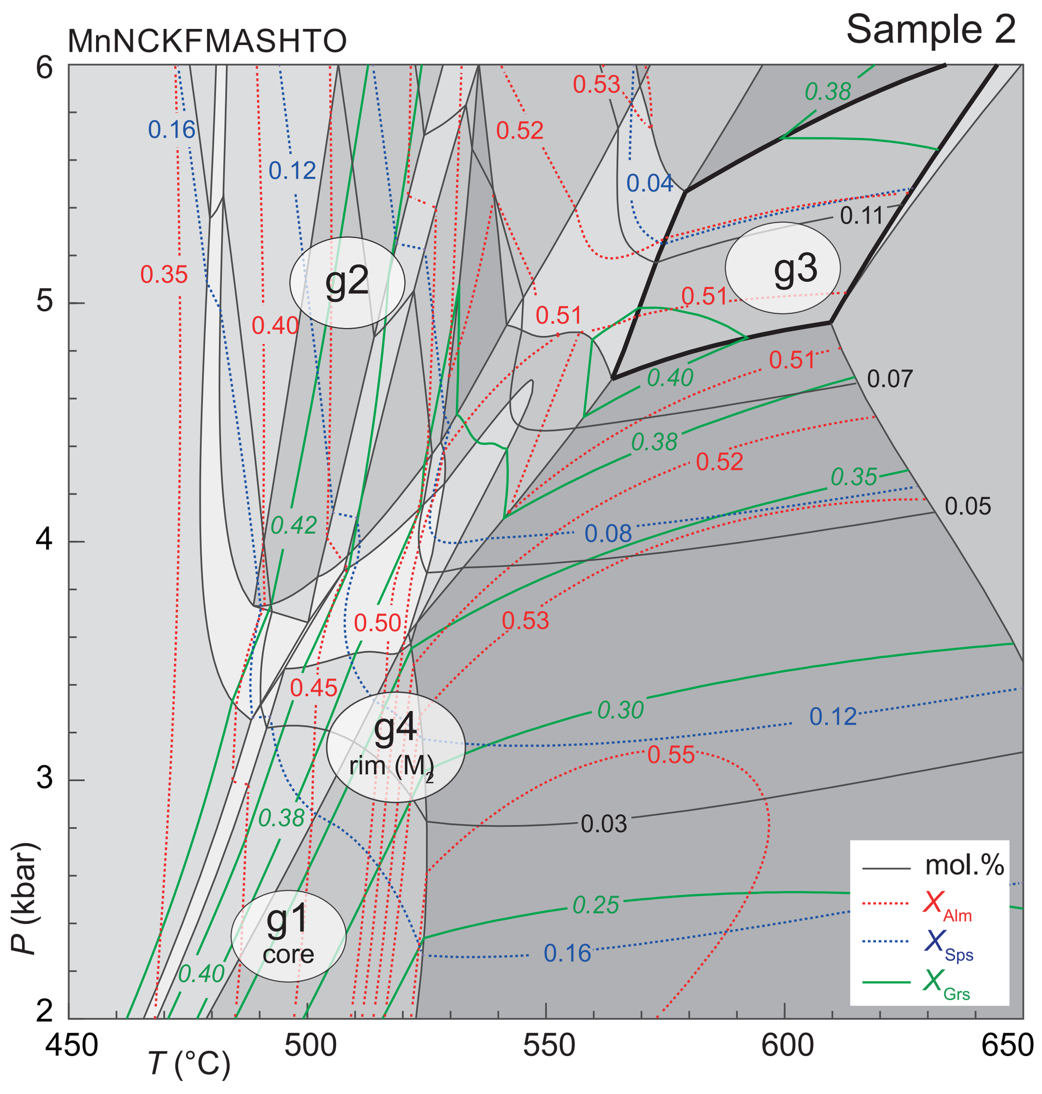
This garnet-bearing amphibolite from the Waroonga Shear Zone in the Yilgarn Craton preserves a Hbl–Pl–Ilm symplectite around garnet that is associated with a late metamorphic overprint (M_3). To determine the *P*–*T* conditions for M_3, the domainal composition of the symplectite was calculated using the area shown on the Al elemental map on the right

Phase equilbria modelling

The use of phase diagrams is an extremely powerful tool to quantify *P*–*T* conditions and understand the metamorphic evolution of a rock. These diagrams use internally consistent datasets of the thermodynamic properties of minerals, fluids and melts with activity–composition models for these phases. A major advance in applying phase equilibria modelling to natural rocks is using isochemical phase diagrams ('pseudosections') to explore the assemblages and reaction sequences applicable for a particular composition.



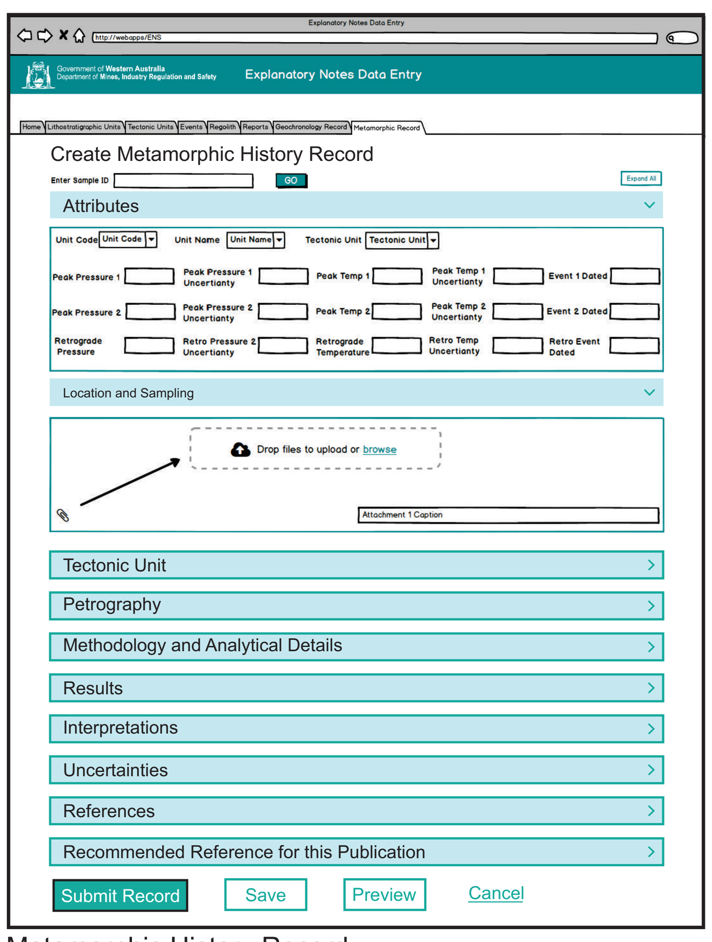
The *P*–*T* pseudosection for sample 3 is calculated for the Hbl–Pl–Ilm symplectite described above. The minerals and their compositions can be used to determine the conditions for the M_3 event in this sample, shown in the orange shaded field



The *P*–*T* pseudosection for sample 2 is shown above. Each of the shaded fields represents a mineral assemblage field (not labelled for clarity). The peak assemblage in this sample comprises hornblende, garnet, titanite, plagioclase, ilmenite and quartz (+ H_2O) with the stability field outlined in thick lines. The diagram is contoured for the mol.% garnet (~ vol.%) so that the growth and consumption of garnet can be assessed, as well as compositional isopleths. The four garnet growth domains shown above correspond to the *P*–*T* conditions shown in ellipses. This rock records late Paleoproterozoic contact metamorphism at low *P*, high *T* (g1), and Mesoproterozoic crustal thickening and subsequent thinning (g2–g4)

Data capture and Metamorphic History Records

History Record will be generated and published. These Records will include all the sample information, regional geology, the methods and analytical details, the results, interpretations, and uncertainties. Any data used to constrain *P*–*T*–*t* events, including geochronology, mineral chemistry, thermobarometry and phase equilibria modelling, will be included with the Record. At this time, these Records are written in a Word-based template, however, in future the Records will be compiled and generated through an interface in the Explanatory Notes System. A database to capture all the isotope and mineral chemistry data is in development, which will be linked with GeoVIEW.WA. This system will enable each Metamorphic History Record to be displayed and queried.



Metamorphic History Record

Summary

Protocols and a workflow have been developed for routine and standardized metamorphic studies within GSWA. These data will provide 'golden spikes' of robust metamorphic data across Western Australia in order to ultimately produce a statewide metamorphic map and database.

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FEBRUARY 2019

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