Skarn deposits represent an important global resource of base and precious metals. These mineral deposits form via the metasomatic alteration of calc-silicate rocks due to interactions with magmatic fluids from nearby intrusive bodies. The pressure and temperature at which this alteration occurs serve as fundamental controls on the size, style, and extent of mineralization. However, whereas the temperatures of skarn formation can be directly constrained using information from fluid inclusions, pressures are commonly limited to imprecise estimates based upon assumed stratigraphic thickness or geochemical proxies that are commonly complicated by extensive fluid alteration accompanying mineralization. In contrast, Raman spectroscopic analysis of quartz inclusions in garnet—a common alteration mineral assemblage in skarns provides pressure estimates that are independent of chemical equilibrium and thus represents a potential method for precisely and accurately determining the pressure of skarn mineralization.

Quartz-in-garnet (or QuiG) inclusion barometry is rooted in the observation that at the instant a garnet envelops a grain of quartz, both minerals are in mechanical equilibrium with no pressure differential between them. A residual pressure may eventually develop between the inclusion and host, however, due the different thermoelastic responses of the two phases during exhumation and cooling. Raman spectroscopy of the enclosed quartz grain enables the measurement of the remnant pressure, which may then be inverted to iteratively solve for the pressure of garnet growth.

A recent study of the conditions of garnet growth in the Yerington mining district in northwestern Nevada (Barkoff et al., 2019) demonstrates the utility of this method. By combining the results of spectroscopic
analysis of both apatite and quartz trapped in skarn garnet, Barkoff et al. derive accurate paleodepths of garnet growth with significantly improved precision (≤ 1 km) to that estimated from stratigraphic constraints (~1-2 km). This study, however, highlighted one of the other significant complexities in the study of skarn formation—determination of the timing of mineralization relative to garnet growth.

Within the Yerington district, skarn formation followed the intrusion of at least two generations of granitic bodies between ~233-232 and ~169-165 Ma (Dilles and Wright, 1988). Although base metal mineralization is generally interpreted to have primarily occurred during the latter plutonic event (e.g., Dilles and Proffett, 1995), it is possible that initial garnet growth may have occurred during the initial magmatic period. If garnet growth and mineralization occurred at separate times, the results from garnet inclusion thermobarometry may record metasomatic conditions significantly older that those responsible for base metal deposition. Laser-ablation U-Pb geochronology of skarn garnets represents one possible method for resolving this complexity (e.g., Seman et al., 2017; Gevedon et al., 2018), and when combined with QuiG barometry, may allow for the determination of both the age and conditions of skarn formation using a single mineral phase.

AU-SKARNS OF EASTERN AUSTRALIA

Gold-bearing skarns occur across a broad geographic range within eastern Australia, from northeast Queensland to central Tasmania (Fig. 1). These skarn systems formed at various times in the mid-late Paleozoic in association with the intrusion of a series of granitic bodies related to the Tabberabbean and Kanimblan orogenies (e.g., Oversby, 1971; Morrison and Beams, 1995; Kovacs, 2000). Skarns within this geologically complex region formed at different pressures and temperatures and are characterized by multiple mineral assemblages representing either (1) distinct metasomatic events or (2) progressive changes in mineralization conditions during a single period of alteration (e.g., Morrison and Treacy, 2001; Cockerton and Tomkins, 2012; Illig and Chang, 2017). As such these rocks present a rare opportunity to examine the utility of combining U-Pb garnet geochronology with quartz-in-garnet barometry.

RESEARCH PROGRESS TO DATE

The ERI summer research fellowship was used to begin work on a suite of garnet-bearing tactites collected from several well-studied Au-skarn deposits in eastern Australia. The studied samples include four garnet-pyroxene skarns from the Chillagoe mining district in northeastern Queensland, a massive garnet skarn from the Brown’s Creek mine in New South Wales, and a garnet-chlorite skarn from the Stormont mine in northwest Tasmania. To augment the garnet-bearing specimens, a sample of intrusive granodiorite from Brown’s Creek was also obtained to provide additional geochronologic constraints on the timing of ore formation. All samples were previously part of the Washington State University Economic Geology Collection and were provided by Dr. Peter Larson.

As referenced in the previous section, the various samples used in this study were formed at different dates and conditions and as such provide an unrivaled chance for
combining the insights provided by combined U-Pb garnet geochronology and QuiG geobarometry. In preparation for the implementation of these two methods, the ERI summer fellowship was used to (1) prepare doubly-polished petrographic thick sections for geochronologic and thermobarometric analysis and (2) to begin the assembly of a set of reliable mineral U-Pb standards. To date, billets cut from the various samples were sent to Spectrum Petrographics in Vancouver, WA for sectioning with a tentative return date of November 15th. Moreover, multiple garnet standards were obtained for later U-Pb analysis. These include several samples previously analyzed by McFarlane and Massawe (2017) and Yan et al. (2019), as well as multiple garnet crystals analogous to those dated by Seman et al. (2017).

In the future, each of the obtained garnet standards will be analyzed for their major element chemistries and U-Pb isotope ratios using combined electron probe micro-analysis and laser-ablation mass spectrometry. Those samples that appear compositionally and isotopically homogenous will be further analyzed by thermal ionization mass spectrometry (TIMS) to establish reference isotope values for use in later U-Pb analysis of the Australian skarns. Furthermore, upon receipt of the finished thin sections entrapment pressures of quartz crystals within garnets in the Australian skarns will be determined by Raman spectrographic analysis. The resultant dates and pressures will then be combined with formation temperatures taken from the literature to reconstruct the timing and conditions of skarn mineralization and hydrothermal alteration.
REFERENCES


Kovacs, N.J., 2000, Magmatic and hydrothermal evolution of the Brown’s Creek Intrusive Complex and associated gold mineralisation: Unpublished Master’s Thesis, Australian National University,


