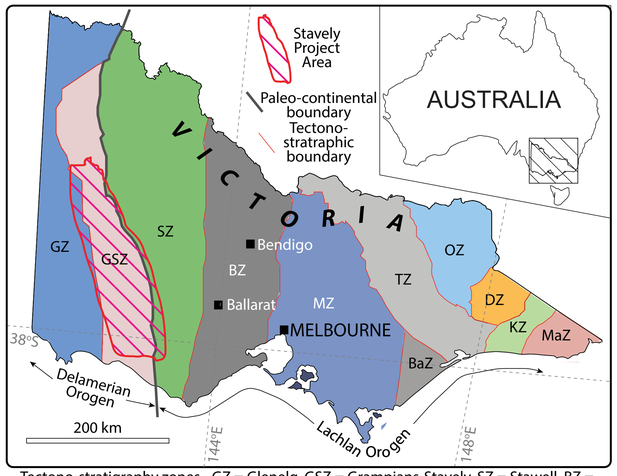
It's not easy being green – detecting arc-related mineral system fingerprints using mineral chemistry in 'propylitic alteration' in a Cambrian arc terrane, Victoria, Australia

Rob Duncan*, David Taylor
The Geological Survey of Victoria, Melbourne, Victoria Australia

Sebastien Meffre, Ivan Belousov, Leonid Danyushevsky, David Cooke
Centre for Ore Deposit and Earth Sciences, University of Tasmania, Hobart, Australia

** corresponding author - rob.duncan@ecodev.vic.gov.au*



Tectono-stratigraphy zones - GZ = Glenelg, GSZ = Grampians-Stavely, SZ = Stawell, BZ = Bendigo, MZ = Melbourne, TZ = Tabberabbera, OZ = Omeo, DZ = Deddick, KZ = Kuark, MaZ = Mallacoota, BaZ = Bass

Figure 1. Location of Stavely Project Area which forms part of the Delamerian Orogen and is distinct from the younger Lachlan Orogen.

Overview

Cambrian rocks of the Stavely Arc **(Fig. 1)** have demonstrated potential for a range of arc-related mineral systems. Mineral chemistry data from 'green rock' mineral assemblages were collected with the aim of identifying fertility and prospectivity indicators that have been developed for mineralised systems elsewhere (e.g., Wilkinson et al. 2015; Cooke et al. 2017). This project was completed as part of a wider collaborative program between The Geological Survey of Victoria and Geoscience Australia to de-risk mineral exploration programs in a largely covered terrane. More details on the program can be found at https://earthresources.vic.gov.au/projects/stavely/geological-data-and-information.

Sample material

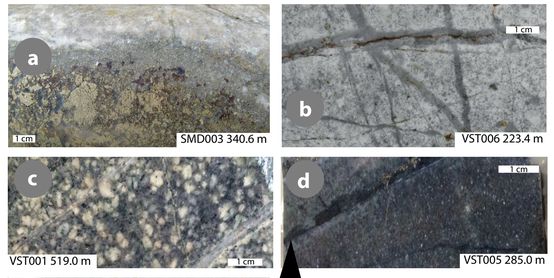


Figure 3. Thursday's Gossan - samples of (a) chalcopyrite-bornite-pyrite D vein, (b) quartz-chalcopyrite-pyrite B vein, (c to e) chlorite-bearing green rock assemblages analysed.

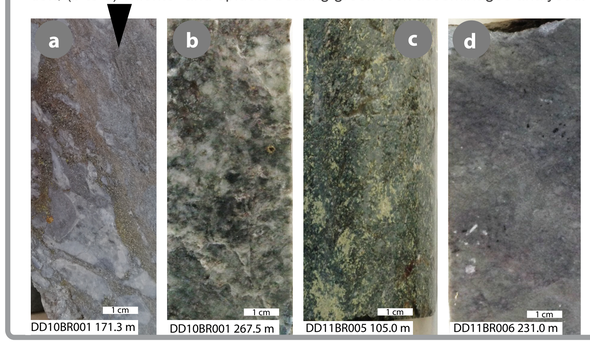


Figure 4. Eclipse - samples of (a) sphalerite-chalcopyrite-pyrite mineralisation, (b to d) chlorite- and epidote-bearing green rock assemblages analysed.

Geodynamic Context

Stavely Arc rocks are contained within a series of volcanic belts that formed above thinned continental crust in response to west-dipping subduction from 525 and 500 Ma - some arc-related rocks may be as old as 540 Ma. The volcanic belts are 3 to 8 km wide and fault bound **(Fig. 2a)**. The volcanic belts are separated by Cambrian marine sedimentary rocks and transition to a largely intact volcanic rock in the mid-crust.

The effects of post-arc magmatism deformation resulting from the ~400 Ma Bindian Orogeny (and so also post-the timing of arc-related mineral systems) can be removed and the volcanic belts restore to three major sub-parallel belts that have a cumulative strike length of over 1,100 km **(Fig. 2b,c)**. Preservation potential for arc-related mineral systems in relatively high because the arc has undergone little tectonic uplift since 380 Ma.

Case study areas

Materials were collected from two prospects in exposed portions of volcanic belts. At **Thursday's Gossan** (Stavely Belt) calc-alkaline andesitic to rhyolitic volcanic, volcaniclastic and sedimentary rocks have been intruded by dacitic to tonalitic sub-volcanic porphyry stocks. An ~8 km^2 propylitic alteration zone **(Fig. 3)** is roughly coincident with a small supergene resource (inferred 28.1 Mt at 0.4 % Cu at 0.2 % cut-off grade). Hypogene mineralisation associated with porphyry-like veins **(Fig. 3)** (and phyllic and potassic hydrothermal alteration assemblages) have returned encouraging exploration intercepts (e.g., 952 m at 0.23% Cu from 11 m) (Stavely Minerals, 2019).

At **Eclipse** (Black Range Belt) calc-alkaline dacitic to rhyolitic volcanic and volcaniclastic rocks host massive Cu-Zn mineralisation that appears to be of VHMS affinity. Phyllic hydrothermal alteration is associated with a quartz-carbonate-sulphide mineralisation transitions to a propylitic assemblage (**Fig. 4**). No resource has been estimated. Significant intercepts include 267.1 m at 0.3 % Zn, 2 g/t Ag and 0.1 g/t Au from 1.3 m (Navarre Minerals, 2014).

Eight polished samples mounts were prepared and imaged using scanning electron microscopy. Epidote and chlorite were analysed for major, minor and trace elements using the laser ablation ICP-MS facility at CODES, University of Tasmania. **Fig. 5** shows selected results.

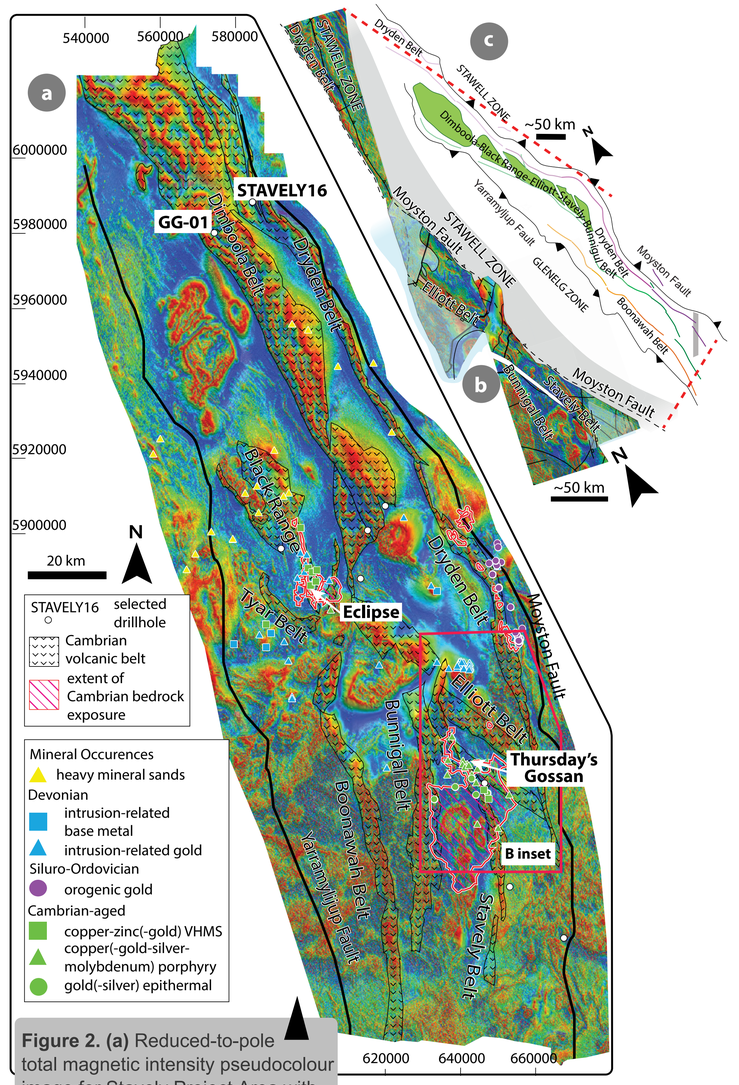


Figure 2. (a) Reduced-to-pole total magnetic intensity pseudocolour image for Stavely Project Area with extent of Cambrian rock exposure, distribution of Cambrian volcanic belts and location of mineral occurrences. **(b)** Inset of restored Stavely and Elliott belts by removal the effects of faulting and rotation associated with the Bindian Orogeny to show original distribution of volcanic belts. **(c)** Restoration of original volcanic belts across the entire arc resolves to three sub-parallel belts.

Chlorite results

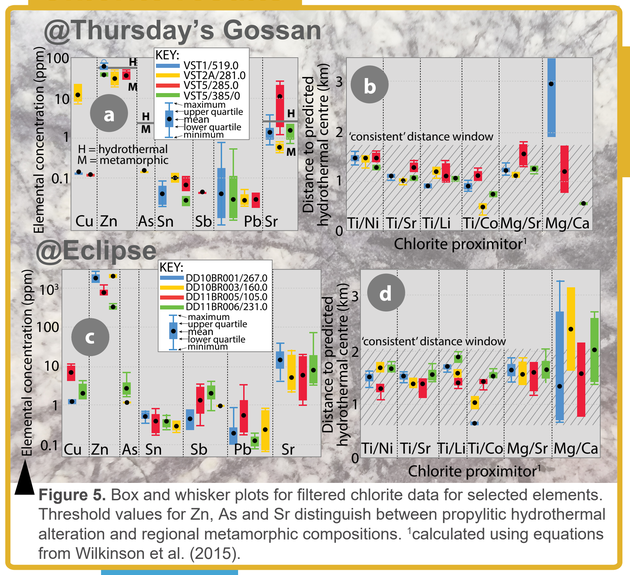


Figure 5. Box and whisker plots for filtered chlorite data for selected elements. Threshold values for Zn, As and Sr distinguish between propylitic hydrothermal alteration and regional metamorphic compositions. ¹calculated using equations from Wilkinson et al. (2015).

Epidote @Eclipse

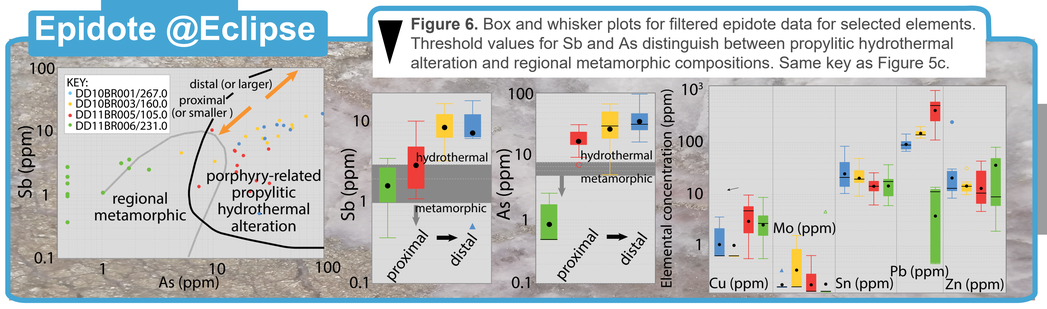


Figure 6. Box and whisker plots for filtered epidote data for selected elements. Threshold values for Sb and As distinguish between propylitic hydrothermal alteration and regional metamorphic compositions. Same key as Figure 5c.

Key outcomes

At Thursday Gossan Prospect elevated Sr and Zn in chlorite are indicative of hydrothermal alteration associated with pyropylitic hydrothermal alteration. Chlorite proximitors demonstrate a vertical temperature gradient to the hydrothermal system.

At Eclipse elevated As and Sb in epidote and elevated Zn, Cu, and Pb in chlorite are indicative of hydrothermal alteration associated with propylitic hydrothermal alteration. Systematic variations in chlorite Cu -Pb and As-Cu in epidote at Eclipse identify an untested area for follow-up mineral exploration.

This study demonstrates that even a small green rock mineral chemistry dataset may assist in mineral exploration programs. These data are consistent with whole rock geochemistry fertility data (e.g., Sr/Y and V/Sc) and geodynamic models that demonstrate prospectivity for arc-related mineral systems in the Stavely Arc.

REFERENCES: COOKE, DR et al. (2017) Porphyry indicator minerals (PIMS) and porphyry vectoring and fertility tools (PVFTS) – Indicators of mineralization styles and recorders of hypogene geochemical dispersion halos. Proceedings of Exploration 17: p. 457–470.
NAVARRE MINERALS, 2014, Navarre extends copper zone at Eclipse prospect, western Victoria. ASX Release 6 August 2014.
STAVELY MINERALS, 2018, Thursday's Gossan Copper- Gold Porphyry – Diamond Drilling Update. ASX Release 20 April 2018.
WILKINSON, JJ et al. (2015) The chlorite proximitor: A new tool for detecting porphyry ore deposits. Journal of Geochemical Exploration 152: 10–26.

VICTORIA State Government