

1. Rationale

Cold, stable and refractory mantle lithosphere represents an unconventional source region for metal-rich magmas. However, the behaviour of ore elements and their host mineral phases within these deep mantle roots remain poorly understood. Mantle fragments (e.g., xenoliths/xenocrysts) entrained within Kimberlites sample the cratonic mantle and allow us to address some of these knowledge gaps (Figs. 1-2).

Herein we present electron probe microanalysis (EPMA) and laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) geochemical datasets for olivine (Figs. 3-4) and clinopyroxene (Figs. 5-6) mantle xenocrysts from the Jurassic Kirkland Lake kimberlite field, Abitibi greenstone belt, Canada. We specifically focus on the trace elements (Fig. 7-8)

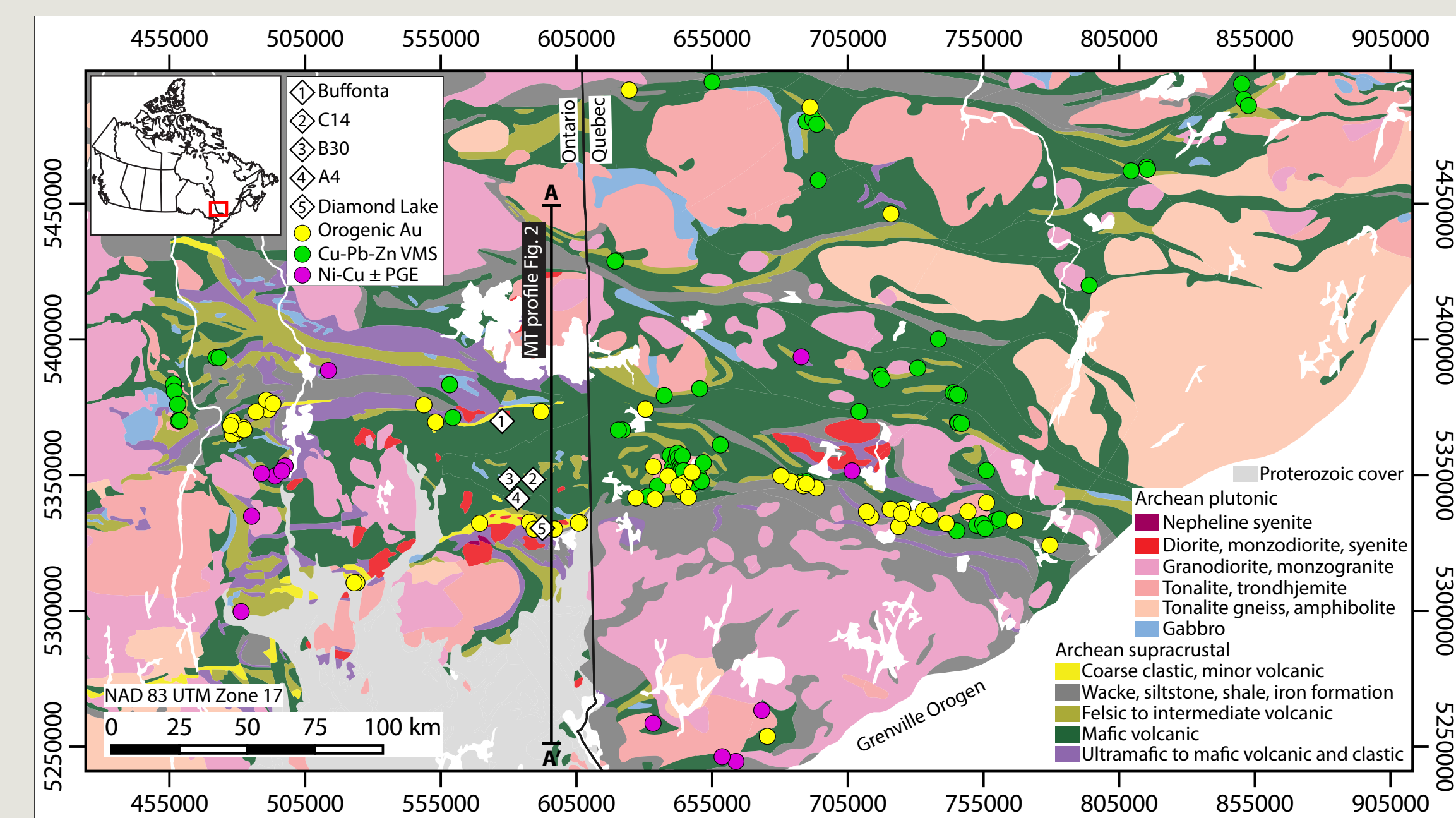


Figure 1 – Regional geological map of the southern Abitibi greenstone belt showing the locations of ore deposits and kimberlites. Map modified after Percival et al. (2012).

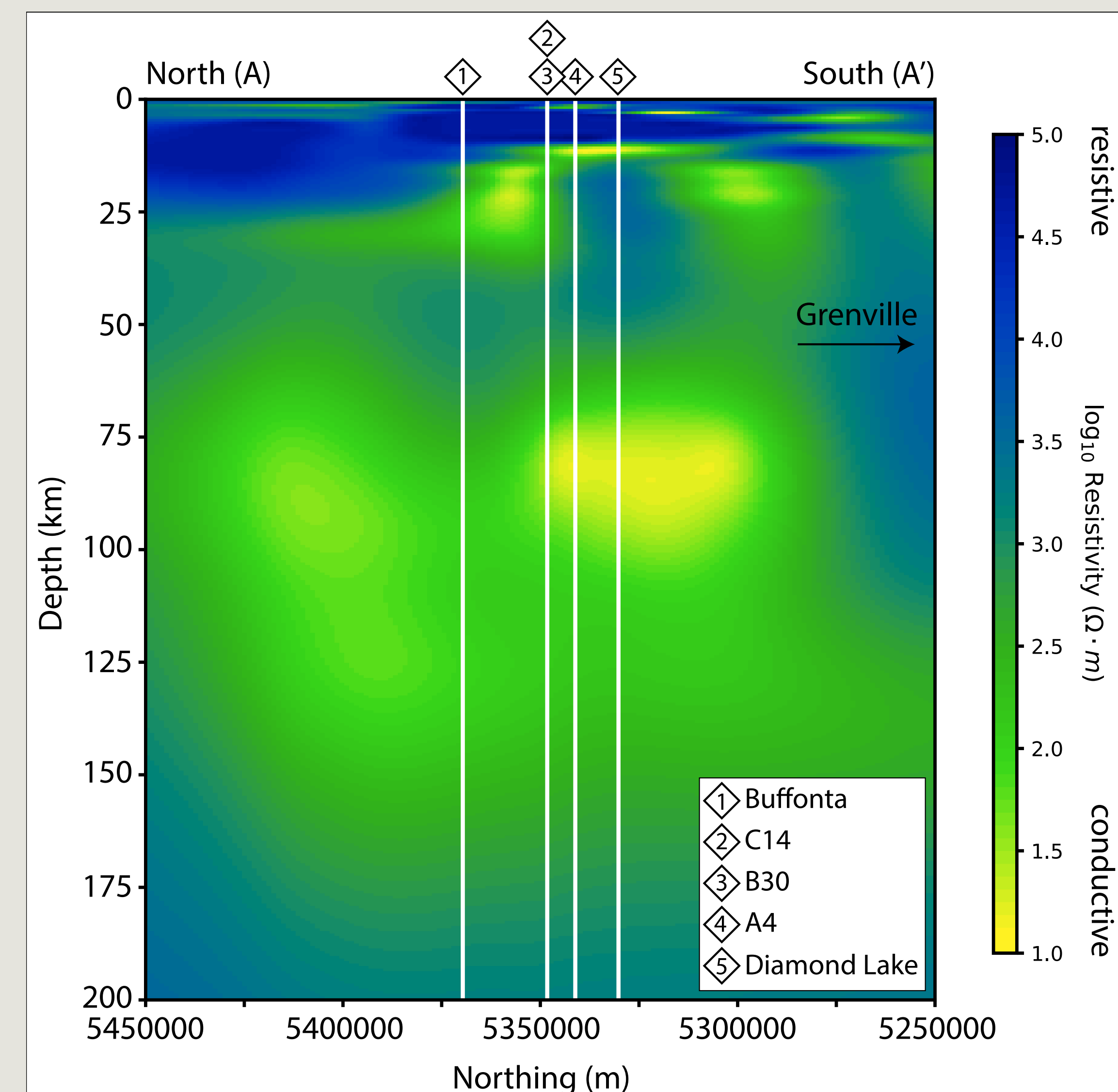


Figure 2 – Interpolated section through 3D magnetotelluric inversion model (Roots and Craven, 2017). Vertical lines represent the trace of kimberlites included as part of this study projected to 200 km depth.

2. Olivine mantle xenocryst results

Olivine depth profiles were calculated using the Al-thermometer (Bussweiler et al., 2017), with olivine pressure (i.e., depth) determined by calculating the intersection of each temperature with the xenolith-based geotherm (re-calculated after Vicker, 1997). We adopt the geochemical classification of Bussweiler et al. (2017) to focus on least-altered mantle xenocrysts (Fig. 3-4). Some trace metals (e.g., Cu; Fig. 4) yield concentrations that tend to correlate with depth, consistent with PT-partitioning during sub-solidus equilibration.

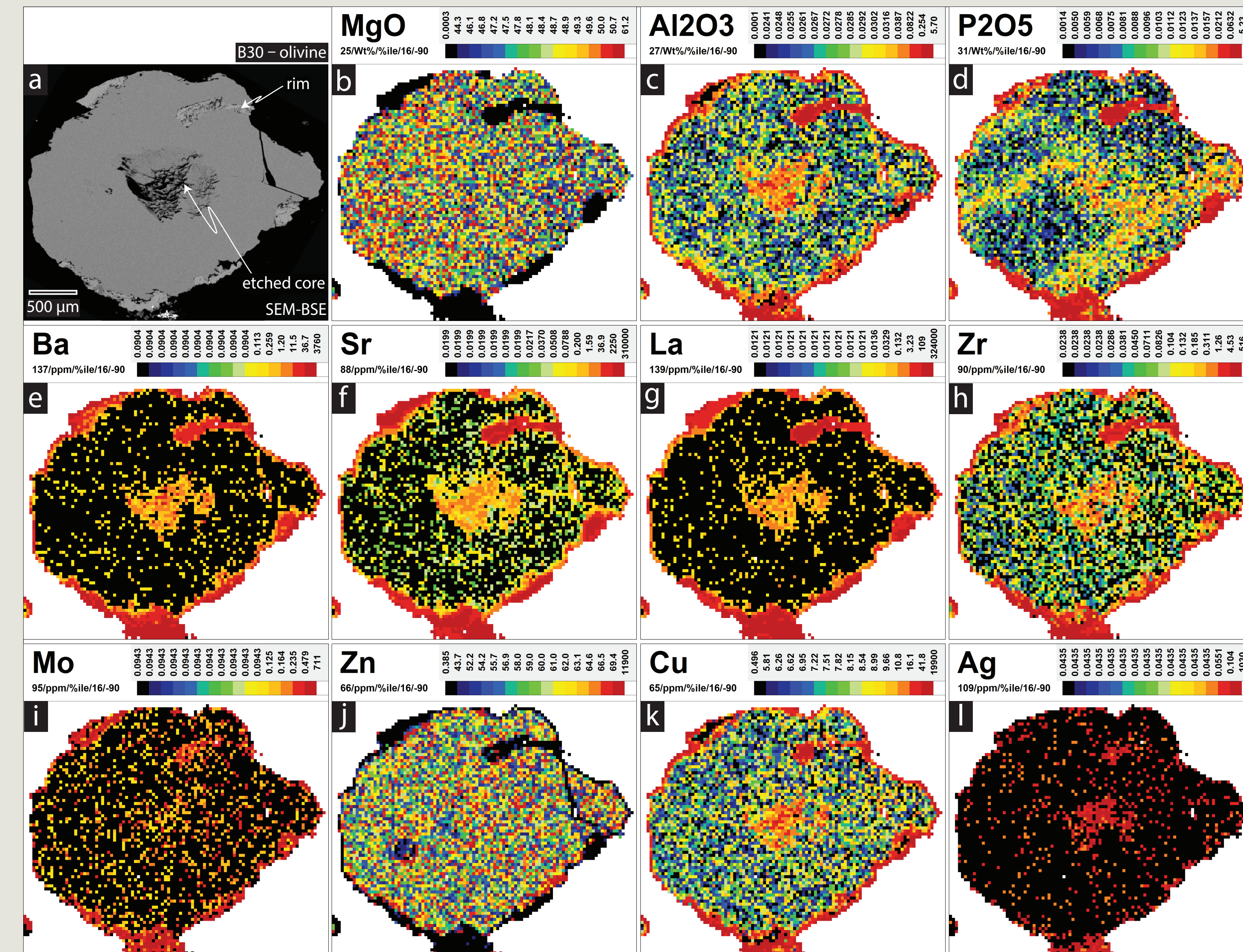


Figure 3 – LA-ICP-MS element mapping results for a complex olivine xenocryst from B30. Olivine scanning electron microscope (SEM) backscatter-electron (BSE) image (a) shows bright rim and etched olivine core. Each olivine type (i.e., narrow rim, homogenous interior and etched core) yield a distinct major and trace element signature (b–l).

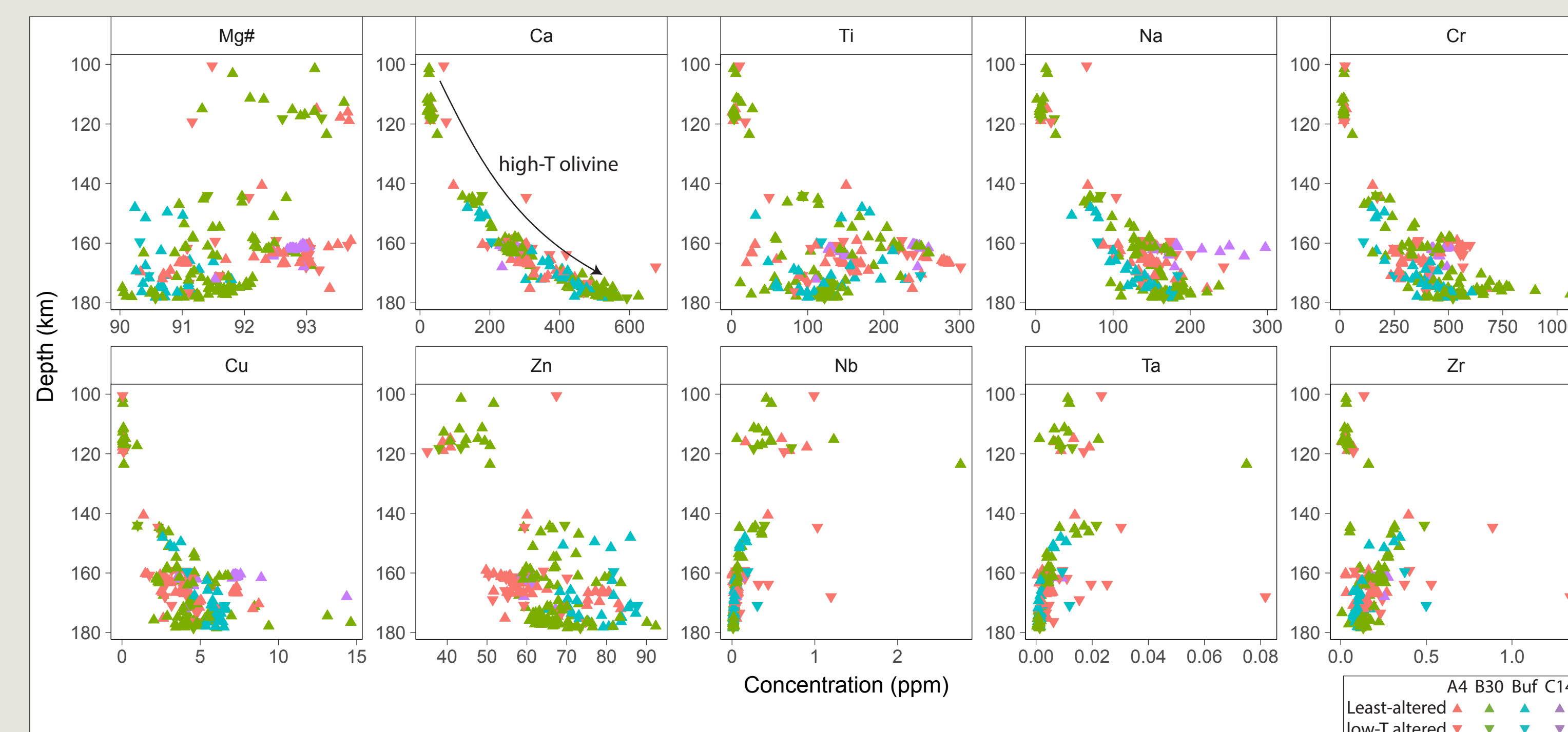


Figure 4 – Olivine depth profiles for select elements. PT-dependent elements yield coherent depth profiles. Elements that occupy olivine's M-site typically increase in concentrations with depth. High-field-strength-element (HFSE; Nb-Ta-Zr) yield contrasting depth profiles that probably reflect PT-dependent, coupled substitution reactions with elements occupying olivine's T-site. Elements (e.g. Ti, Na) that are divorced from coherent depth profiles, within otherwise equilibrated xenocrysts (based on good agreement between major elements such as Al-Ca), likely reflect metasomatic processes operating at depth. Given the high diffusion rates for olivine at these elevated-T, we suggest that metasomatism likely occurred during, and/or immediately preceding, kimberlite volcanism.

3. Clinopyroxene mantle xenocryst results

Clinopyroxene depth profiles were constructed using single-grain clinopyroxene PT determinations (calculated using enstatite-in-clinopyroxene thermometer and Cr-in-clinopyroxene geobarometer, respectively; Nimis and Taylor, 2000). Based on the depth profiles for least-altered clinopyroxene xenocrysts, we suggest that even some so-called chalcophile and siderophile elements participate in PT-dependent substitution reactions during sub-solidus equilibration (Fig. 6).

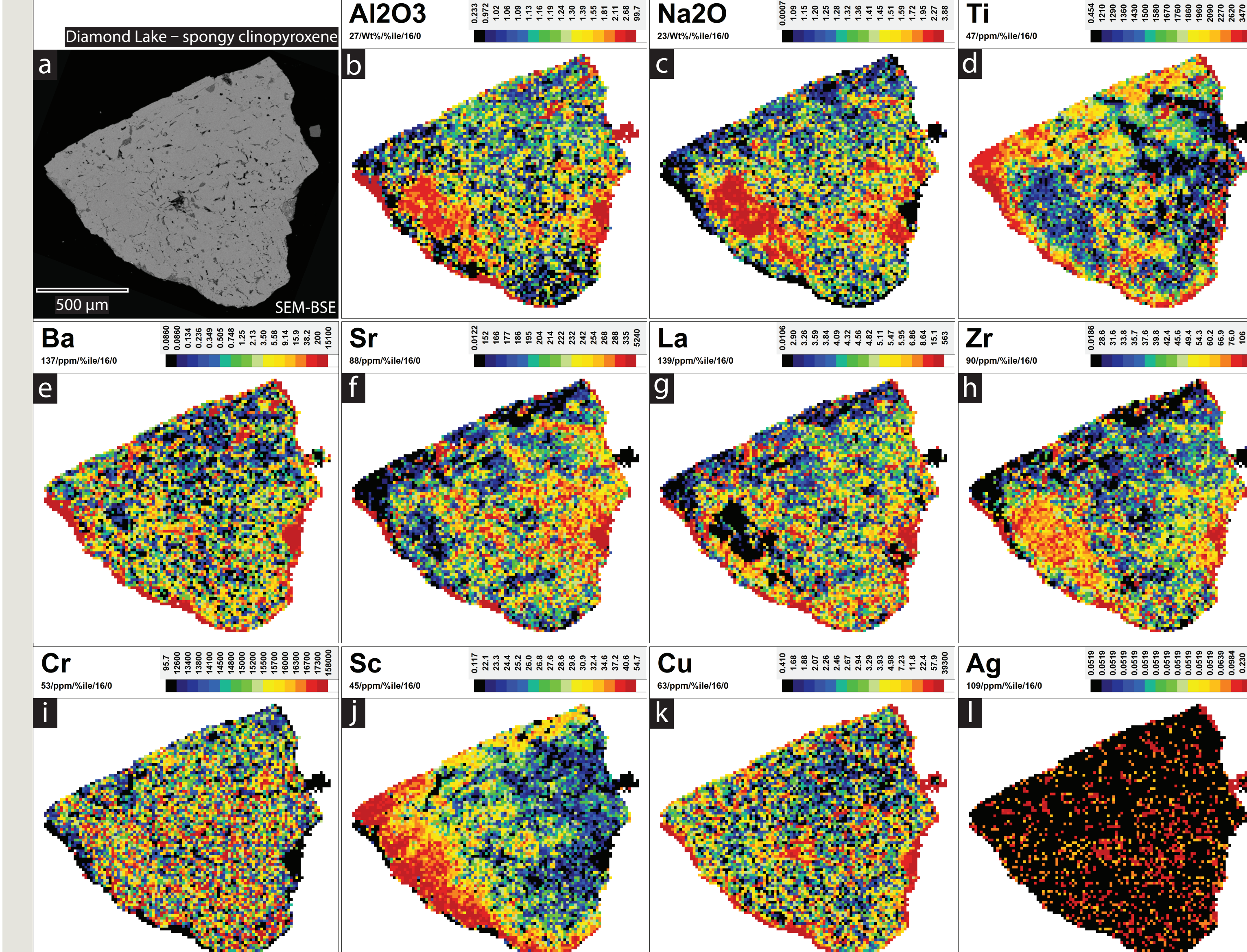


Figure 5 – LA-ICP-MS clinopyroxene mapping results for a spongy clinopyroxene xenocryst from Diamond Lake. SEM-BSE image (a) shows the pitted clinopyroxene and thin rim. Inclusions and rims yield anomalous compositions that infiltrate the xenocryst (b–l).

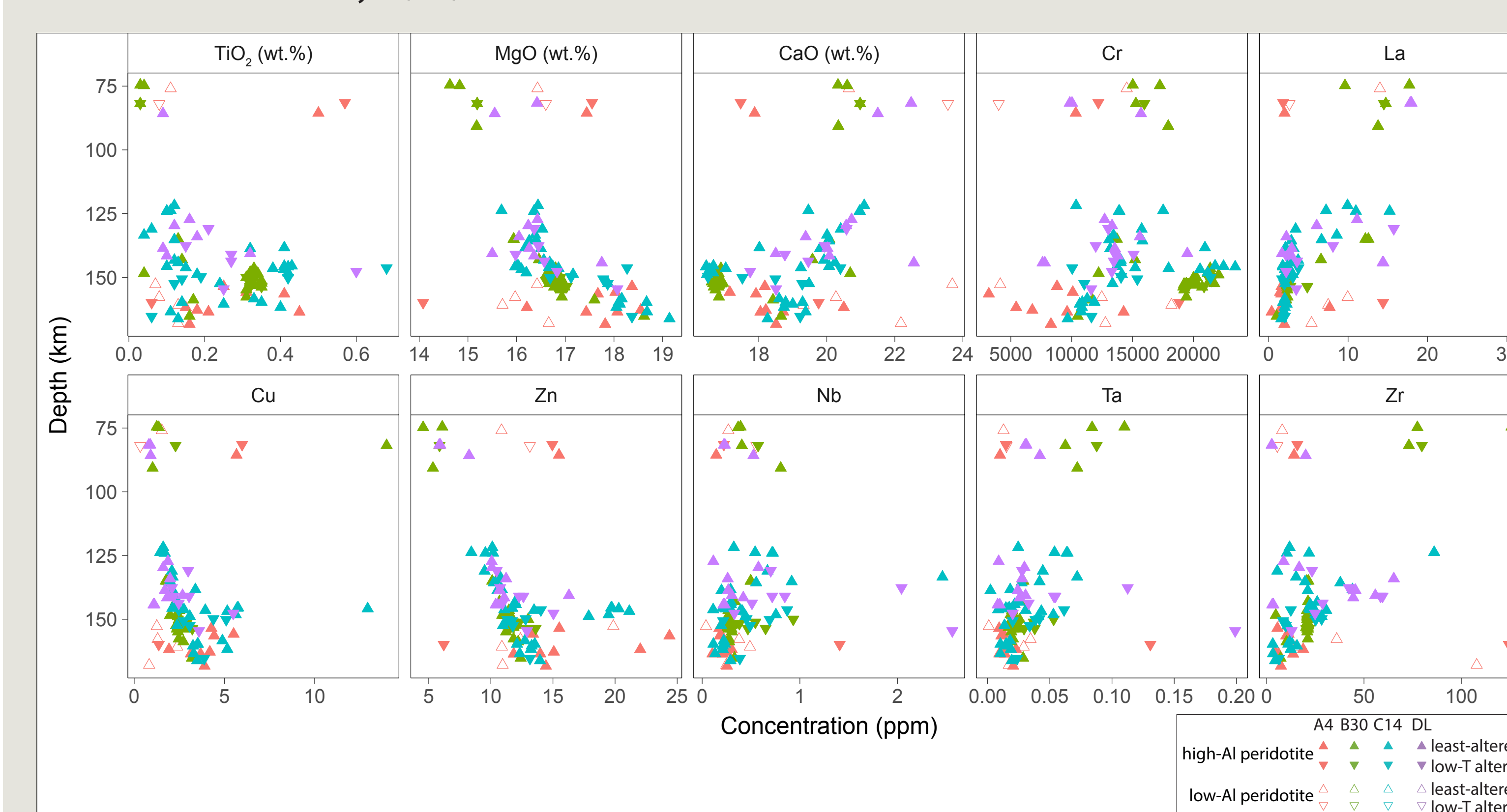


Figure 6 – Clinopyroxene depth profiles for select elements. PT-dependent elements yield coherent depth profiles. Elements that occupy clinopyroxene's M1-site typically increase in concentration with depth along with Mg. Elements that occupy clinopyroxene's M2-site typically decrease in concentrations with depth along with Ca. Trace element analyses that are divorced from coherent depth profiles, within otherwise equilibrated xenocrysts, likely reflect a metasomatic processes operating at depth.

4. Controls on mantle xenocryst chemistry

Robust principal component analysis (PCA) suggests that low-T, large-ion lithophile element alteration (PC1; 57% and 50% of variability for olivine and clinopyroxene, respectively; Fig. 7a, c), which likely occurred during kimberlite emplacement, represents the largest source of variance for the xenocryst dataset. PT-dependent, sub-solidus partitioning represents the second most important control on olivine and clinopyroxene chemistry (PC2; 17% of variability for olivine and clinopyroxene; Fig. 7b, d).

Sub-solidus PT-partitioning document a depth-dependent shift in the mineral phases controlling ore elements within equilibrated garnet peridotite. The role of silicate-hosted metals may impact the fertility of mantle-derived melts. Kimberlites also sampled PGE and Au modified cratonic mantle underlying the Abitibi (Fig. 8), corresponding to the lithosphere-asthenosphere boundary (180-200 km) and a conductive feature of the mid-lithosphere (75-100 km; Fig. 2). All results are reported in Lawley et al. (2018).

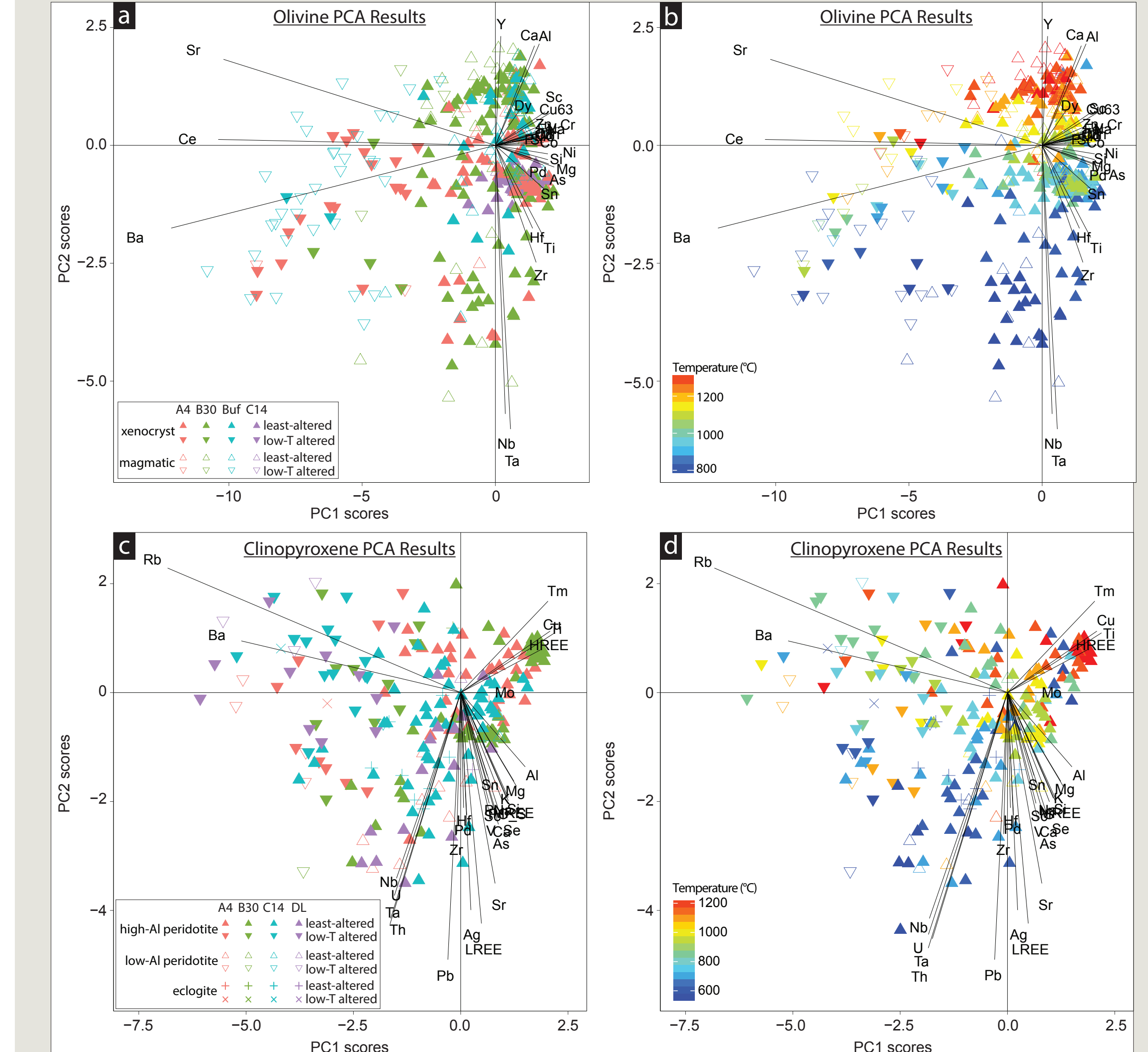


Figure 7 – PCA biplot for olivine analysis colour coded to olivine type (a) and temperature (b). PCA biplot for clinopyroxene analyses colour coded to clinopyroxene type (c) and Temperature (d).

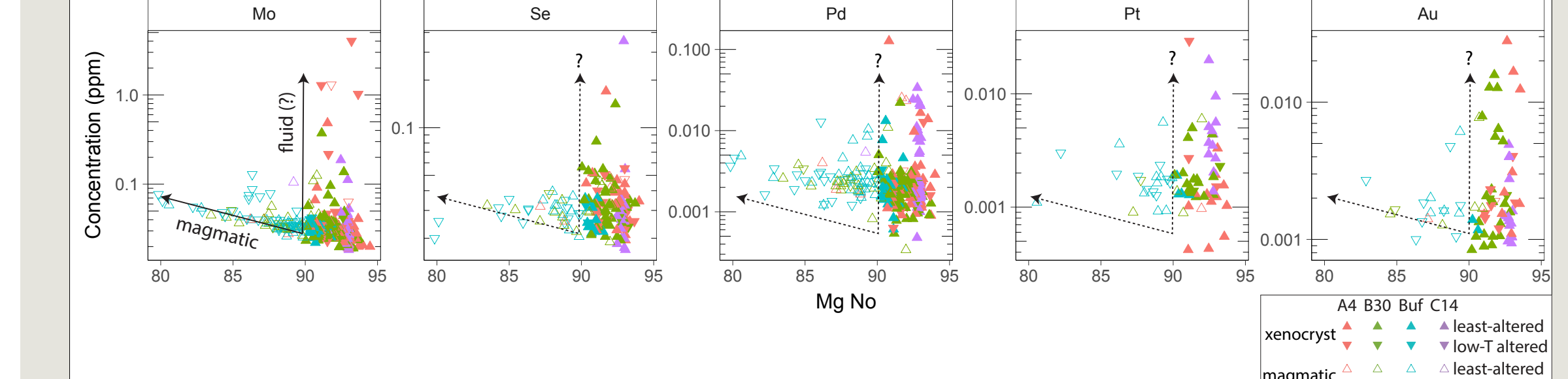


Figure 8 – Ore elements at trace (low ppm to ppb; Se and Mo) and ultratrace (low ppb; Pt, Pd, Au) concentrations yield two distinct signatures within magmatic and xenocryst olivine crystals. The ore element composition of magmatic olivine crystals are correlated with Mg# melt proxies; whereas ore element compositions of xenocrysts are independent of Mg# melt proxies. Ultratrace concentrations (Pt, Pd, Au) occur at, or slightly above, the detection limit and are subject to large analytical uncertainties due to counting statistics, but tend to be associated with mantle xenocrysts (i.e., metasomatized mantle lithosphere) rather than magmatic olivine.