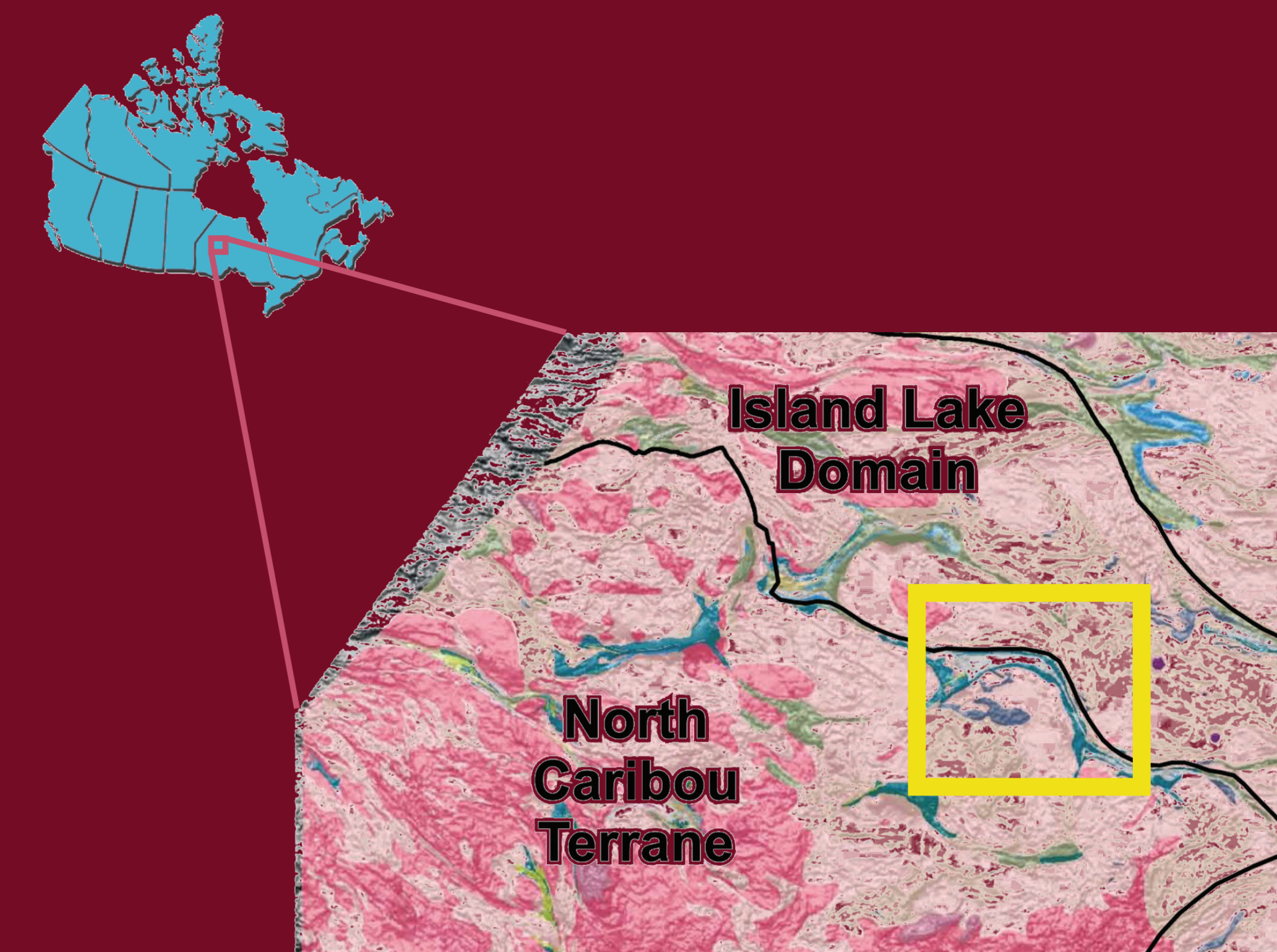


Garnets as petrogenetic witnesses

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Introduction

The mineral garnet ($\text{Ca}^{2+}, \text{Mg}^{2+}, \text{Fe}^{2+}, \text{Al}^{3+}, \text{Fe}^{3+}, \text{Cr}^{3+}, \text{SiO}_4$) commonly forms under both igneous and metamorphic conditions, or during the consequent interaction with hydrothermal fluids. In an attempt to characterize garnet from the Archean North Caribou granite-greenstone belt (N. Ontario), rocks were collected that sample each of these three environments and the garnets were studied for their major and trace element composition. The North Caribou belt hosts notable gold deposits, but the genesis

of the gold is ambiguous: originating from igneous magmatic activity, high-temperature metamorphic mineral reaction, or hydrothermal fluid circulation related to either process. Thus, geochemical analyses of the garnet may lend insight into the process that generated the gold deposit. Six rocks were selected: two igneous (pegmatitic granite, mica granite), three metamorphic rocks (schist, 2-mica schist, amphibolite) and one rock containing probably hydrothermal garnet (metaconglomerate).

Analytical procedure

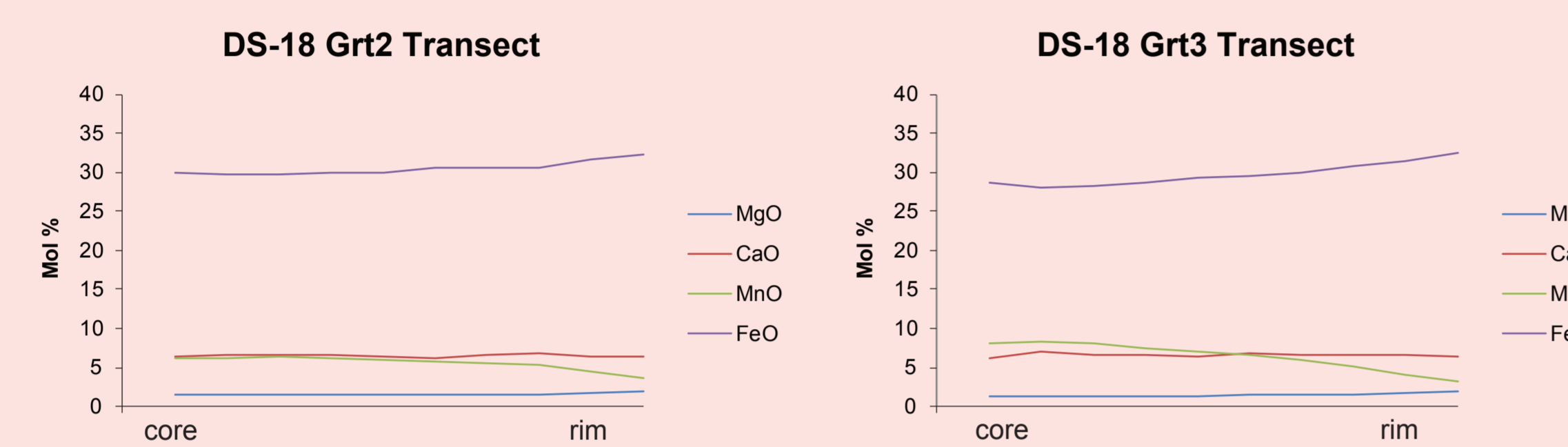
- Major elements concentrations have been analyzed with an Electron Microprobe, for several points on individual garnet crystals: transects were conducted traversing the grain's core to rim. Important major elements displayed in figures include Fe, Mg, Mn and Ca, represented as oxides in the mineral. The samples were analyzed at New Mexico Tech (Socorro).

- Trace elements data has been collected using the Laser Ablation Inductively Coupled Plasma Mass Spectrometry analysis (LA-ICP-MS). We analyzed precise points on the garnet, again sampling both core and rim material. Trace elements that have been studied are the lanthanides Rare Earth Elements (REE); concentrations are normalized to chondrite values and plotted on a logarithmic scale. This technique was conducted at the Geological Survey of Canada's ICP-MS Facility (Ottawa).

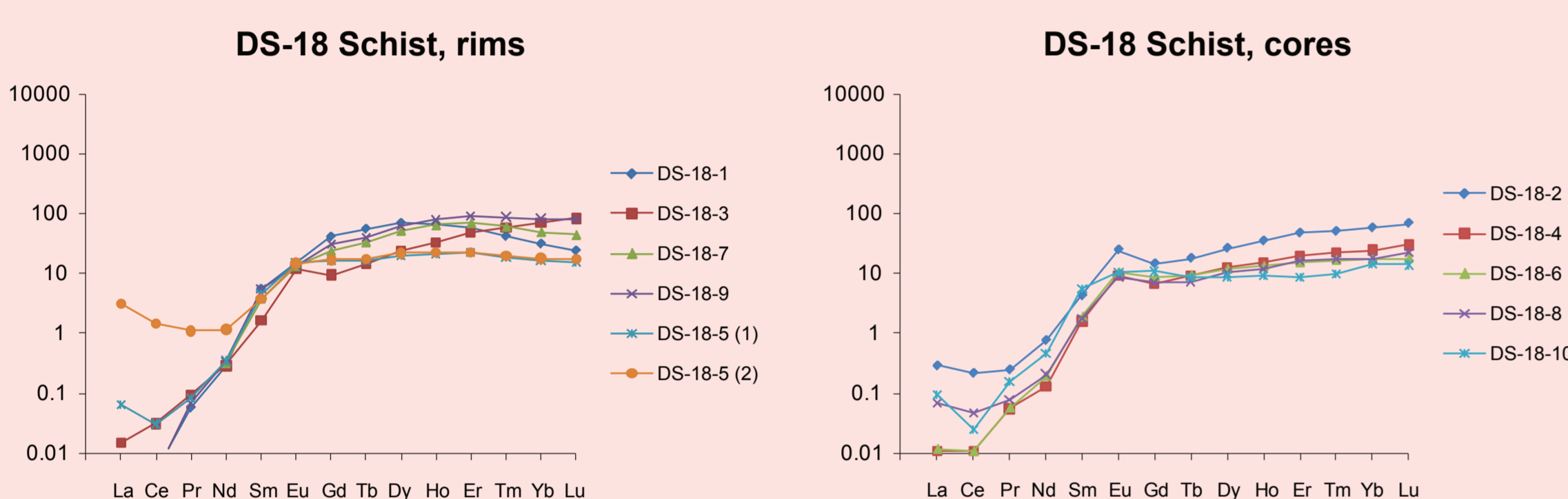
Metamorphic garnets

DS-18 Schist

Major elements



Trace elements normalized to chondrite



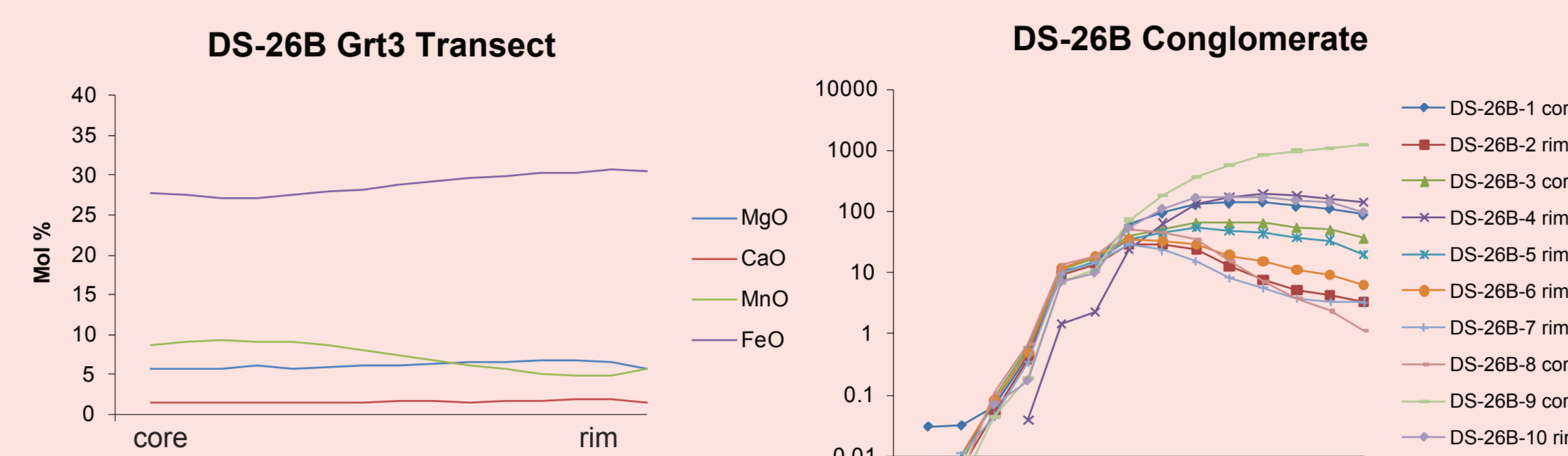
- Major elements patterns fairly flat for most samples, suggesting homogenous chemistry
- Variable LREE concentrations
- Weak negative Eu anomaly in both rims and cores, except for the schist that displays a small positive Eu anomaly
- Possibly a small negative Ce anomaly in the schist
- Garnets' rims in the schist enriched in HREE relative to cores

The amphibolite and the 2-mica schist display only a weak Eu anomaly, which may indicate an igneous protolith, or slight igneous inheritance. In the schist, the 2-mica schist and the amphibolite, LREE display a wide range of concentrations of about three orders of magnitude. It may be possible, then, that some fluid interacted with these samples. We typically assume here a closed system in which the fluid is metamorphic in origin and has been released during prograde metamorphism, but a magmatic fluid is also possible.

Hydrothermal garnet

DS-26B Metaconglomerate

Major elements

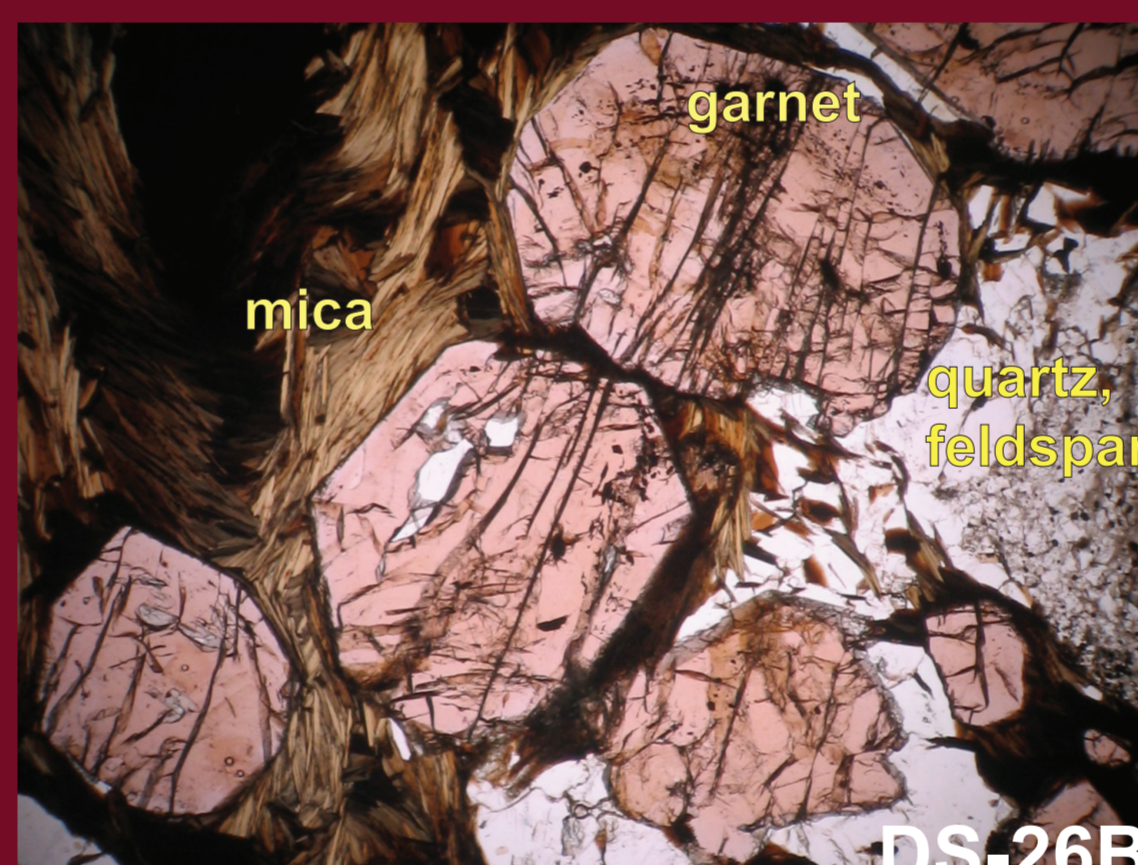


- Small decrease in MnO approaching the rim
- Notable enrichment in FeO relative to other major elements
- No differentiated cores and rims
- HREE concentrations variable across four orders of magnitude
- Weak negative Eu anomaly

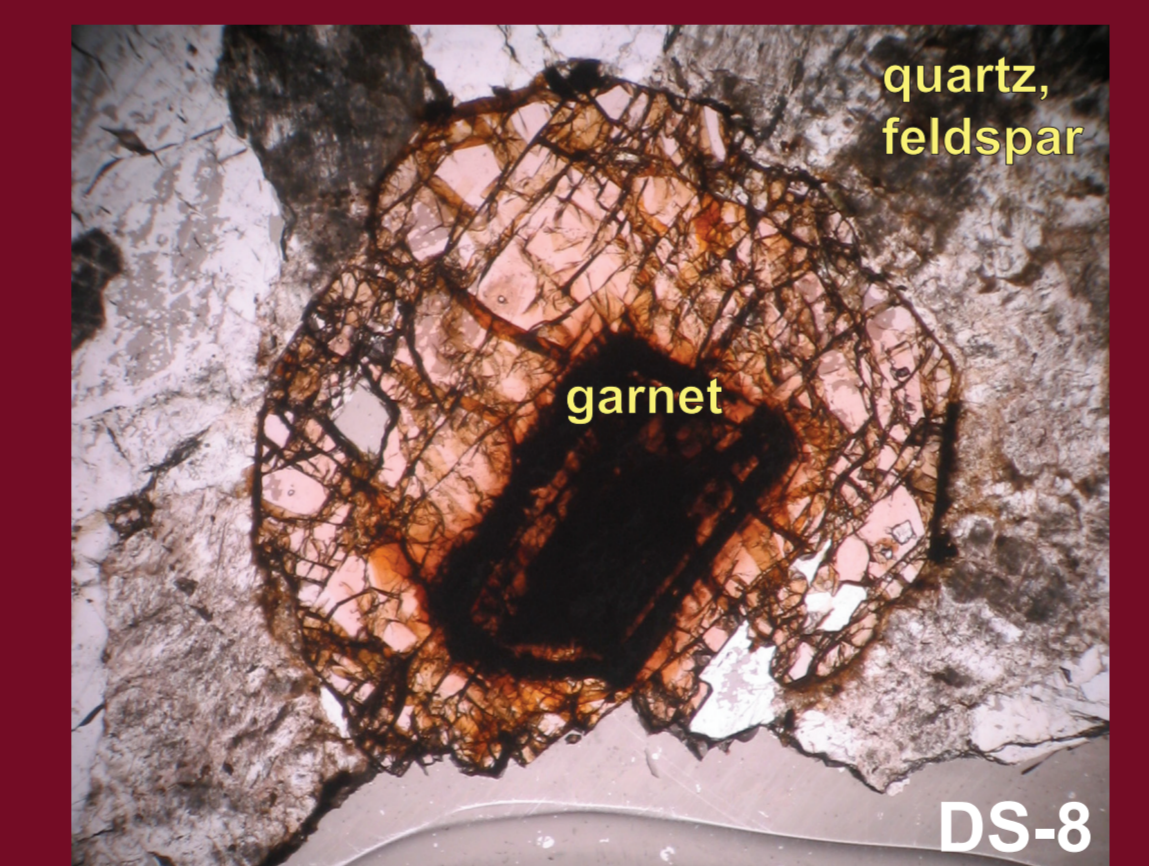
The metaconglomerate's REE pattern is typical of hydrothermal garnet with the variable concentrations of elements across the mineral, since the composition of the fluids is likely evolving over the garnet's crystallization history.



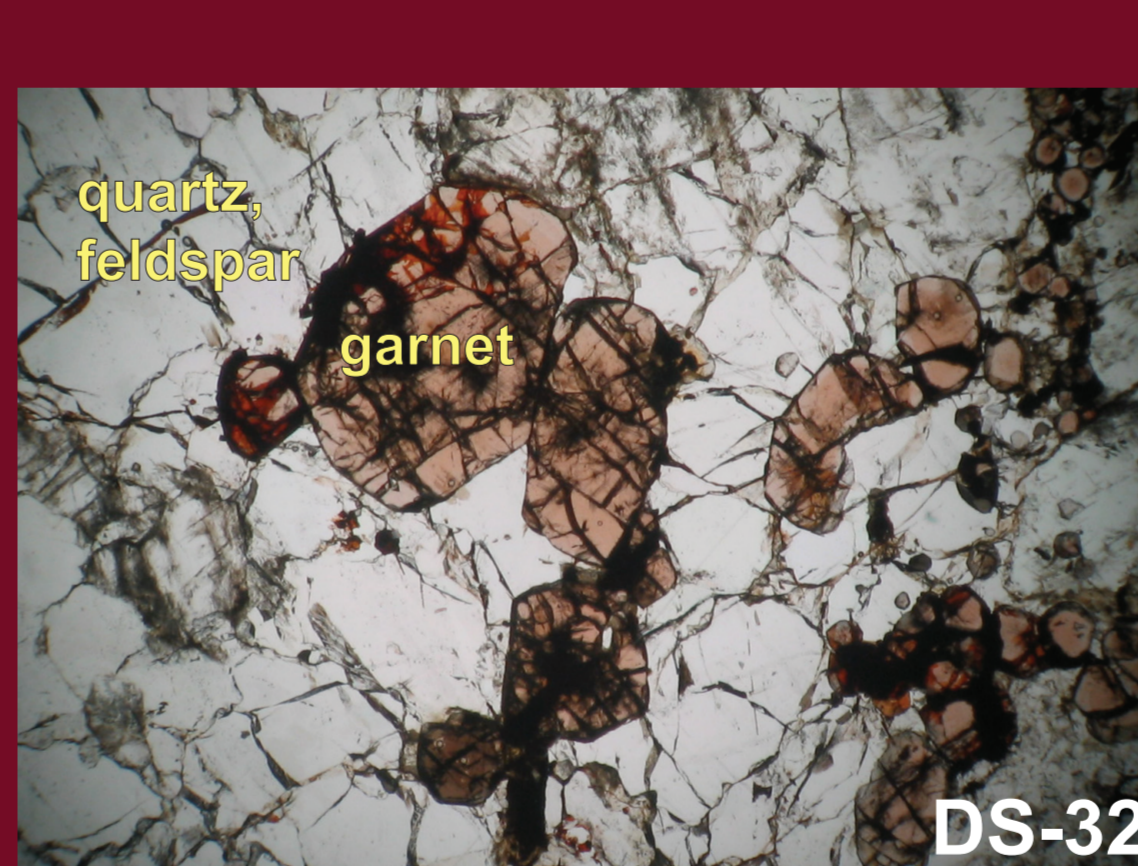
Photomicrograph of garnets in a schist; image taken in plane light.



Photomicrograph of garnets in a metaconglomerate; image taken in plane light. Note the euhedral crystals.



Photomicrograph of garnet in a pegmatitic granite; image taken in plane light. Note the zoning.



Photomicrograph of garnets in a mica granite; image taken in plane light.



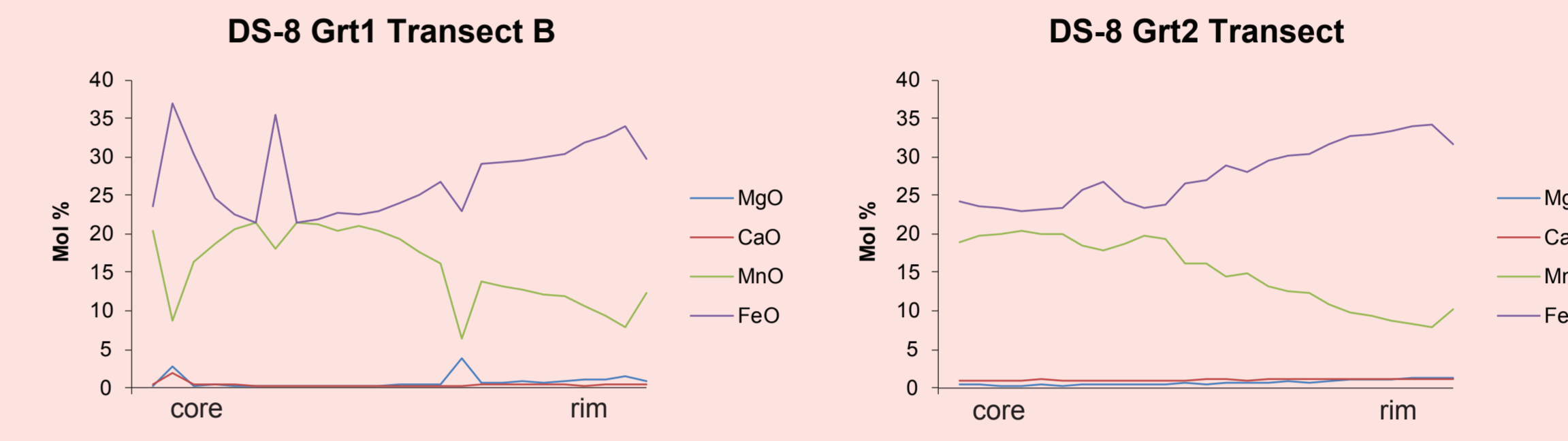
Field photograph of garnet nests visible in an outcrop of the 2-mica schist



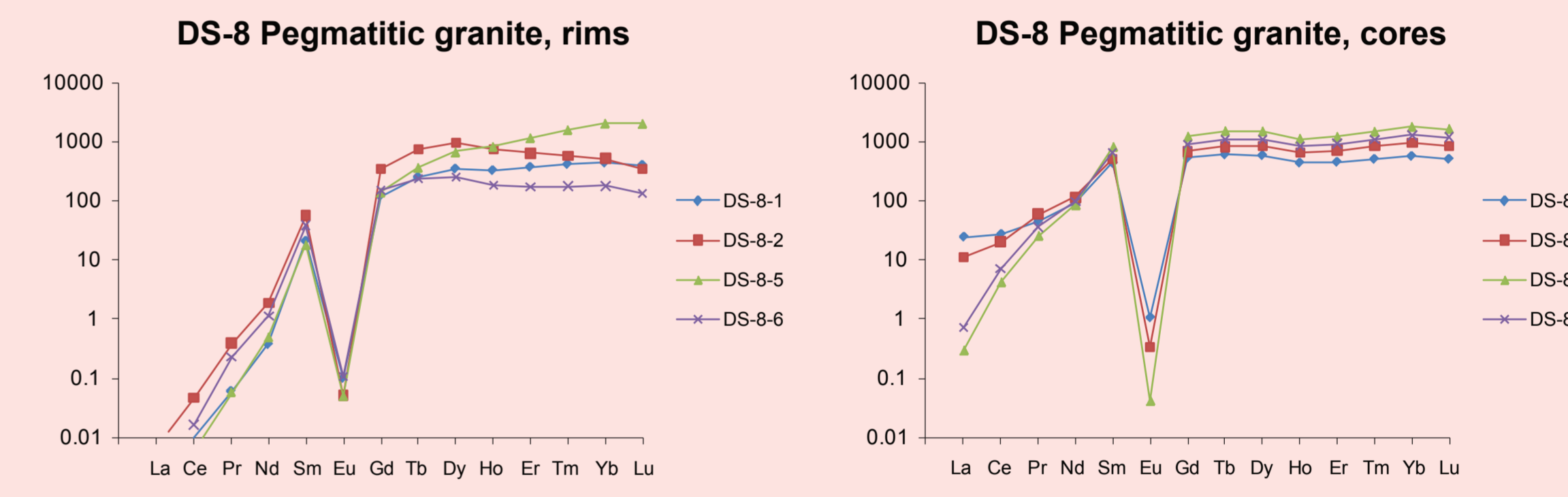
Igneous garnets

DS-8 Pegmatitic granite

Major elements



Trace elements normalized to chondrite

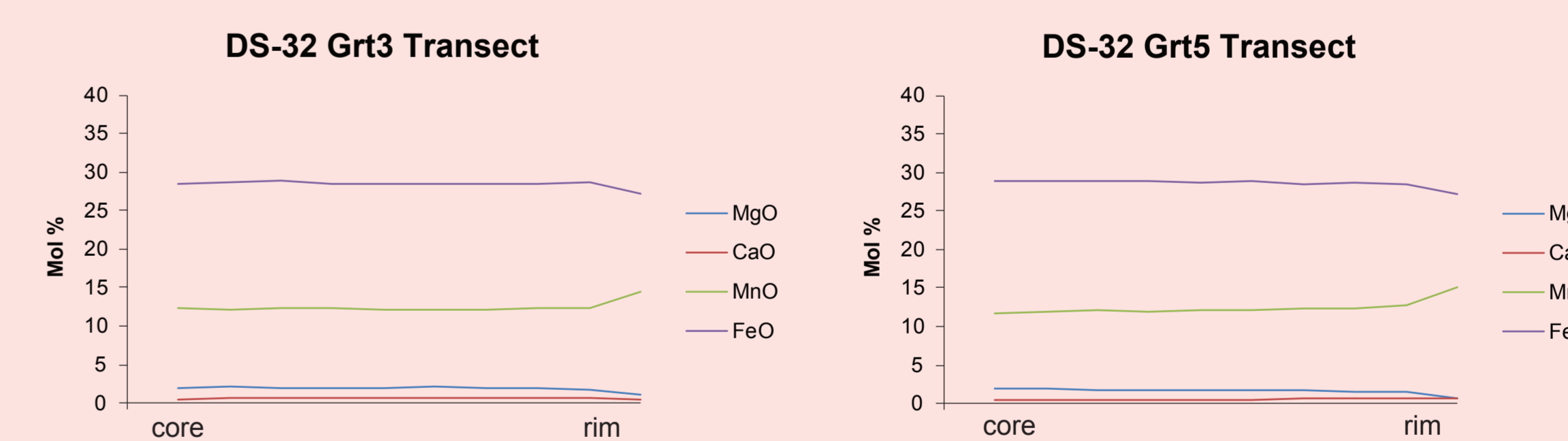


- Depletion in MnO and enrichment in FeO from core to rim in pegmatitic granite
- Antithetic geochemical pattern in pegmatitic granite
- High concentrations of MnO relative to other rocks
- Significant negative Eu anomaly
- Cores enriched in LREE relative to the rims
- Cores enriched in HREE relative to the rims in mica granite

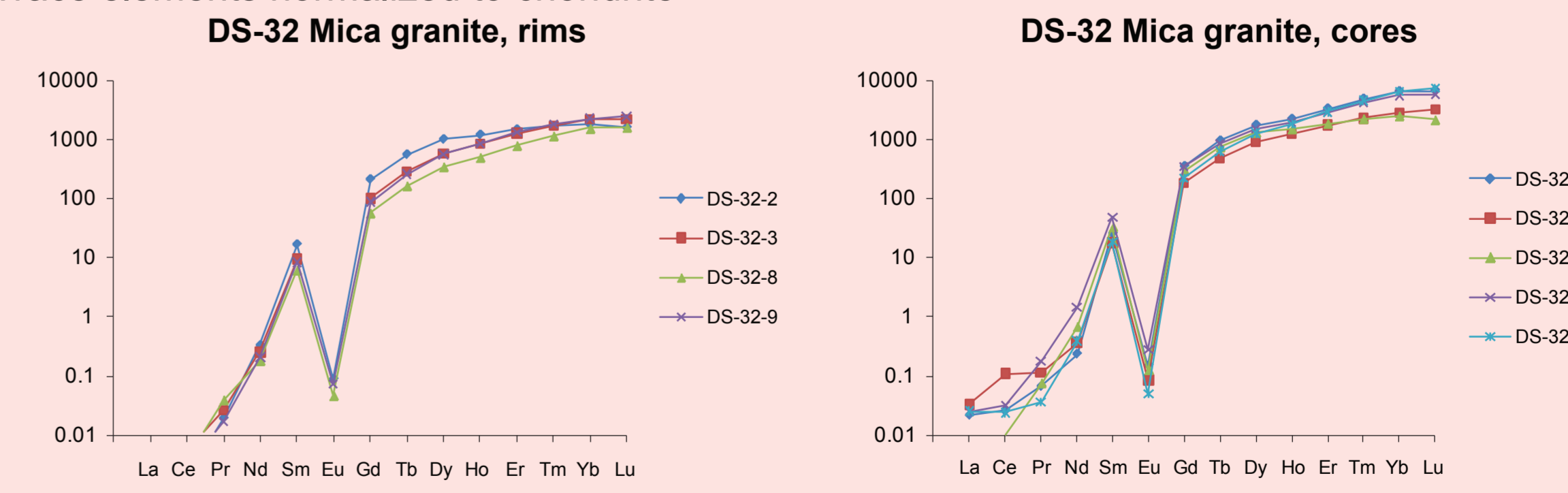
The Eu excursion in the REE pattern is a fractionation effect relative to the other REE and is related to Eu's atomic characteristics. In reducing conditions, Eu becomes divalent and is commonly incorporated into plagioclase by occupying Ca^{2+} sites. Once the plagioclase feldspar crystals are removed from the melt during crystallization, the remaining magma is depleted in Eu and the REE pattern displays a negative anomaly. Strong negative Eu anomalies are characteristic of igneous rocks. As the iron increases and the manganese decreases from core to rim, it is also noted that rims are depleted in LREE relative to cores. Zoning in garnets normally indicates changes in temperature and pressure during crystallization. Since the zoning is mostly present in the pegmatite, magmatic fluids present in the melt were probably quite variable during crystallization.

DS-32 Mica granite

Major elements



Trace elements normalized to chondrite



Conclusion

Major and trace element geochemistry of the six garnet samples lent some insight into the genesis of gold in the North Caribou granite-greenstone belt. Some garnets in the metamorphic rocks have negative Eu anomalies that suggest metamorphism of igneous protoliths. Moreover, garnets in metamorphic rocks, igneous rocks and in the

metaconglomerate suggest that there has been extensive hydrothermal fluid circulation during garnet crystallization. A likely model for the genesis of the gold deposit would be magmatic (igneous) fluids mobilizing the gold and precipitating during regional crustal thickening and metamorphism.