The Distribution of Indium among Minerals in a Granitic Suite of Rocks

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Objective and Project Overview

Goal: Evaluate the distribution of indium among select minerals from four samples of granitic rocks

- My hypothesis: The highest concentrations of Indium will be found among the ferromagnesian minerals

EPMA analysis was used to identify the chemical composition of the samples and to characterize the needed standards for use with the LA-ICP-MS analysis

LA-ICP-MS analysis was used to evaluate this hypothesis and measure indium concentrations.

The scope of analyses included samples from each of the four discrete, intrusions known collectively as the Tuolumne Intrusive Suite (TIS), Sierra Nevada Batholith, California

Geology

The four samples used in this study represent the TIS members (in order of emplacement and increasing felsic composition) the Kuna Crest (May Lake Granodiorite; MLG), the Half Dome Granodiorite (HDG), the Cathedral Peak Granodiorite, and the Johnson Granite Porphyry, thought to be associated with volcanic activity. The TIS formed between 95 and 85 Ma, by incremental, pulsed volcanic activity. The TIS formed between 95 and 85 Ma, by incremental, pulsed intrusive eruptions inherited from there same magma source (Coleman et. al, 2009)

LA-ICP-MS Analysis

LA-ICP-MS analysis was used to measure the trace concentrations of indium found in the granitic samples, but without complications. Indium is the only element to have no isopes free from isotopic inferences. The mass spectrometer cannot differentiate isotopes of similar mass; detected signal intensities for indium overlap with both 113mSn and 113mCd, requiring corrections.

Limit of Detection

- LOD[In] = \(\text{C}_{\text{LOD}} = (C_{\text{IPM}} \times P_{\text{B}} \times P_{\text{IS}}) \times (P_{\text{SN}} - P_{\text{LOD}}) \)

\(A = \text{IS standard internal, } P_{\text{B}} = \text{biotite, } \text{Bd} = \text{background signal, } \text{In} = \text{indium, } C = \text{concentration, } I = \text{signal intensity} \)

115 Indium Concentration Comparisons (before and after corrections)

Both 113mSn and 113mIn have isotopic inferences caused by the 113mCd and 113mSn respectively. Using isotopic ratios in the following calculations were required to remove these inferences from the measured indium signal intensities.

- Corrected 113mSn = 113mIn (total uncorrected cps) / (Sn/In ratio) (113mSn cps)
- Corrected 113mCd = 113mIn (total uncorrected cps) - (113mCd cps / Cd 113mSn)

Calculating the concentrations of indium (example shown with biotite)

- \(C_{\text{In}} = (C_{\text{LOD}} \times I_{\text{SN}} / I_{\text{LOD}}) \times (P_{\text{SN}} - P_{\text{LOD}}) \times (P_{\text{IPM}} / P_{\text{LOD}}) \)

Data and Results

<table>
<thead>
<tr>
<th>Sample</th>
<th>Biotite</th>
<th>Hornblende</th>
<th>Titanite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vol. %</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quartz</td>
<td>18.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Biotite</td>
<td>10.6%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Hornblende</td>
<td>10.5%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Plagioclase</td>
<td>48.4%</td>
<td>2.5%</td>
<td>3.0%</td>
</tr>
<tr>
<td>Alkali Feldspar</td>
<td>10.6%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Titanite</td>
<td>0.4%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Magnetite</td>
<td>0.5%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Chlorite</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
</tbody>
</table>

Table 2 Summary of mineralogy and concentrations of indium measured among each sample from the TIS.

Project Conclusions

As the abundance of ferromagnesian minerals decreased, their concentrations of indium increased; most notably with the hornblende in the first 3 TIS members. The first TIS intrusion (MLG) had indium concentration averages in biotite 3 less than biotite in proceeding emplacement (HDG). The last TIS member to form (JGP) had no observed hornblende and was the only sample to successfully measure indium in the magnetite at 0.04 ppm. All the biotite sampled from the JGP had undergone chloritization with indium concentrations in some samples between 0.17 - 0.23 ppm (similar to levels found in the biotite from HDG and CDG), while others were below detection (therefore not in data averages). The later stages of crystallization had few ferromagnesian minerals left hosting high concentrations of indium; this might result from the incompatible nature of indium with quartz, plagioclase and alkali feldspar and the decreasing melt phase as opposed to any appreciable increases with the concentration of indium.

References:


Coleman, D. G., Gray, W., & Glazner, A. F. (2004). Rethinking the emplacement and evolution of zoned plutons; geochemistry evidence for incremental assembly of the Tuolumne Intrusive Suite, California. Geology


Low concentrations of indium require low limits of detection (LOD) and sufficient signal counts (cps) to obtain measurements; increasing the ablation spot size and laser / time parameters can increase signal intensities and decrease LOD settings but only within limitations determined by the mineralogy and/or grain size of the sample.

Internal and external standards are used for reference, enabling both accuracy and precision when properly matched with the samples (external standards: NIST7610 and BHVO2G, internal standard (IS): used was aluminum).

Project Conclusions

Calculation corrections

Both 113mSn and 113mIn have isotopic interference caused by the 113mCd and 113mSn respectively. Using isotopic ratios in the following calculations were required to remove these inferences from the measured indium signal intensities.