

Metal Enrichments During Magma-Carbonate Interactions in the Jurassic Bonanza Arc

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1. PURPOSE OF THE STUDY

The purpose of this thesis is to characterize magma-carbonate interactions on meter-scale basaltic dikes in the Earth's crust. Rock samples were collected at the Merry Widow Mountain region (Fig 1). Basaltic dikes cutting through limestone (LST) wallrock is observed in outcrop (Fig 2). The central questions for study are:

- 1) How does trace element geochemistry vary by mixing LST in basalt?
- 2) Why do reacted dikes show anomalously high concentrations in some elements?
- 3) How does magma-carbonate interactions affect sulfide mineralization and ore metal deposition?

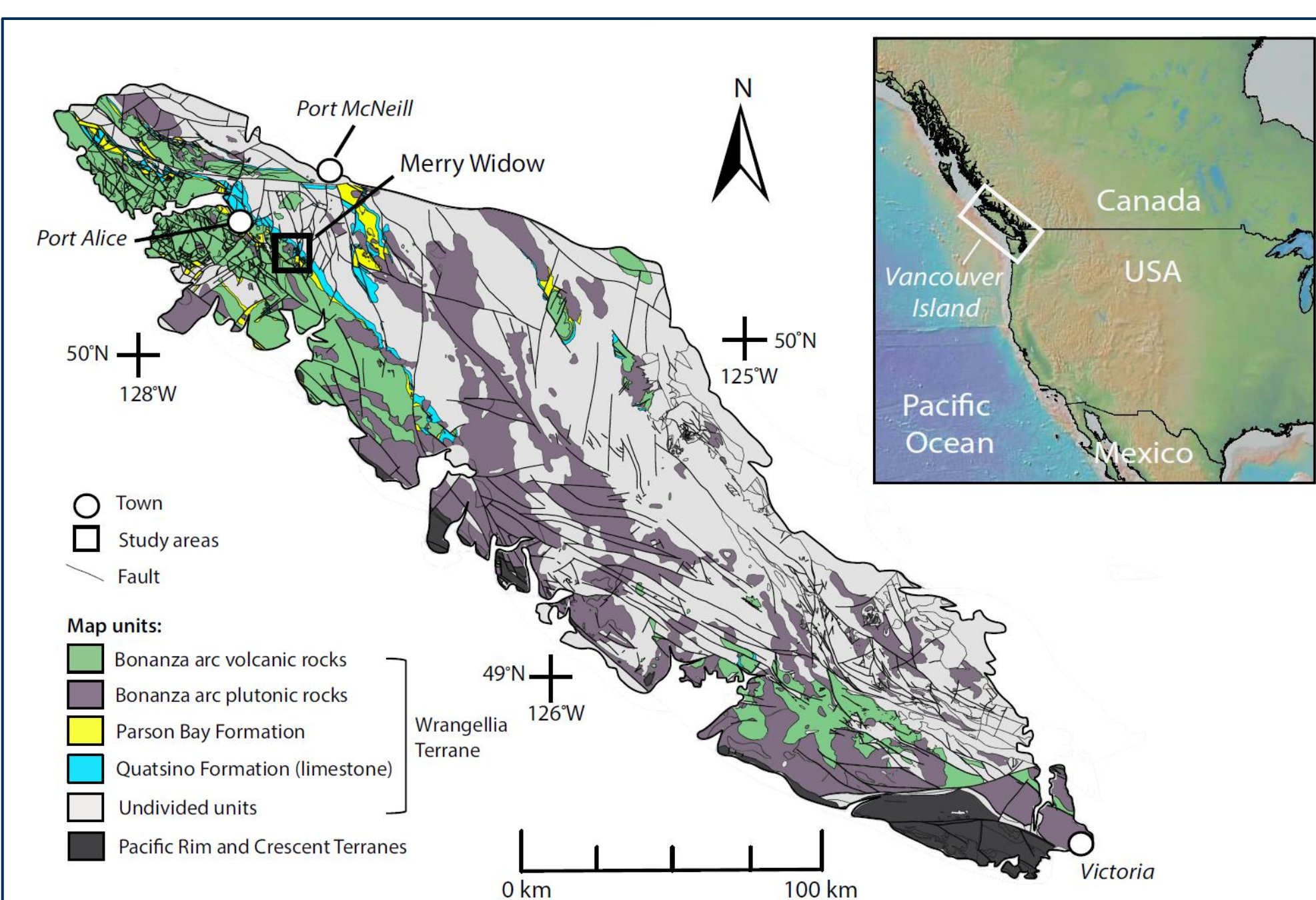


Figure 1: Regional geology of Vancouver Island, Canada (modified from Morris et al., 2023). Study area is Merry Widow Mountain region.

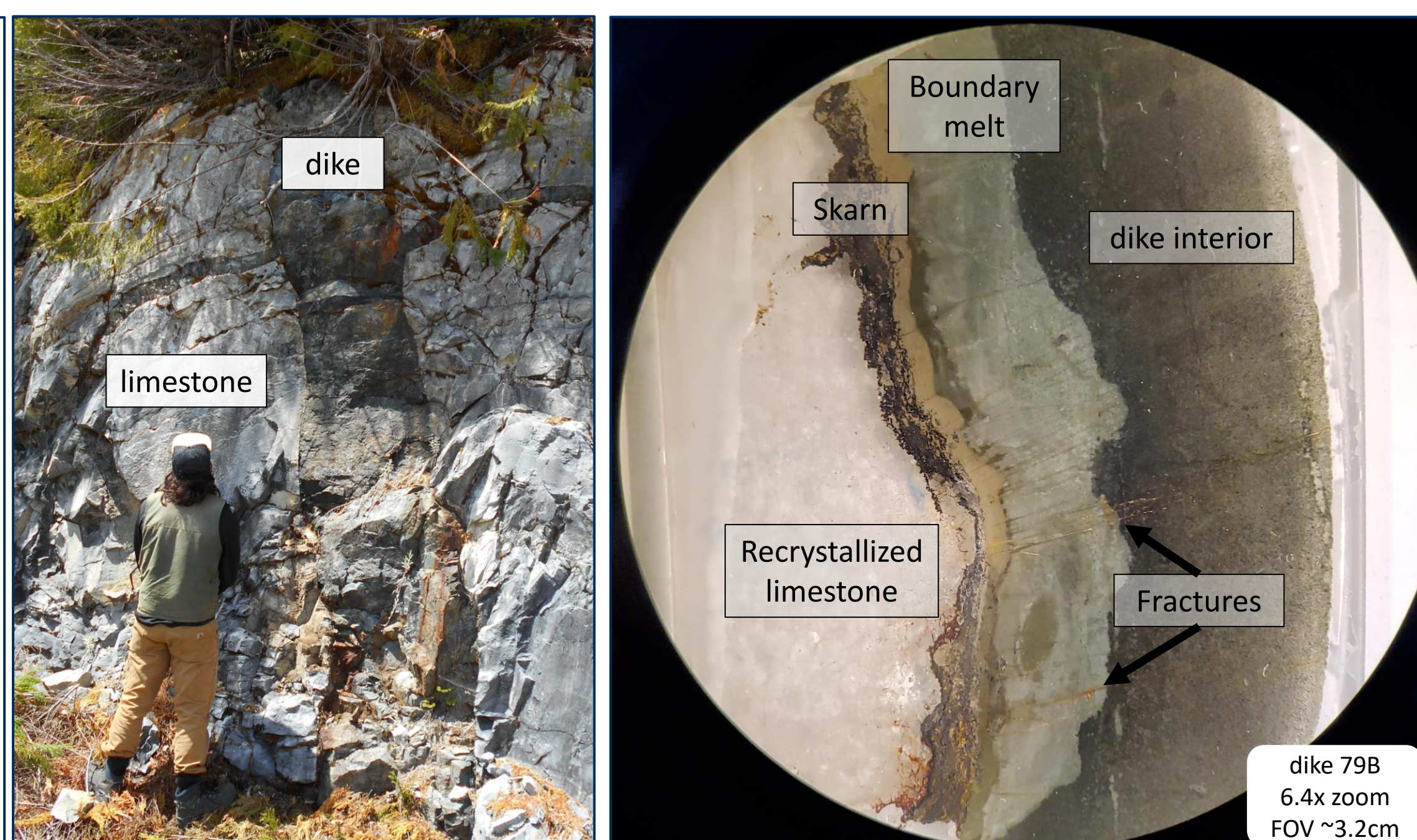


Figure 2: Outcrop image of the dike in the field (left). Photo on the right is a thin section cut-out of dike 79B, showing the dike-limestone contact (Morris and Canil, 2019).

2. APPROACH TO PROBLEM

Outcrop dikes were sub-sampled to study the chemical reactions as depicted in Fig 2. The dike-carbonate contact shows distinct layering which was caused from very hot magma partially melting the limestone. The two rock units began to mix to produce the skarn and boundary melt layers. In my thesis, two types of samples were investigated: (1) hand samples of dike margins and interiors and (2) 14 milli-slices cut from a single 25 cm cross-section of dike 79B (Fig 3). Rock samples were melted into glass beads and analyzed using Laser Ablation Inductively Coupled Plasma Mass Spectrometer (LA-ICP-MS) to collect major and trace element chemistry data on 42 elements.



Figure 3: Rectangular profile of dike 79B with micro-slice samples labelled.

3. GEOCHEMICAL PROFILE OF THE DIKES

Enrichment vs distance plots were constructed for selected elements and were plotted along the dike profile.

The represented data suggests,

- Strong variations in concentration throughout the dike profiles.
- Near the dike interior, some elements appear very enriched while others depleted.
- Strontium (Sr) which is high in LST, shows two locations where its concentration was greatest in basalt dikes.

Acknowledgements

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References

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- Morris, R. A., Canil, D., 2019. Field photos collect at Merry Widow Mine.
- O'Neill, H.St.C., 2021. The Thermodynamic Controls on Sulfide Saturation in Silicate Melts with Application to Ocean Floor Basalts, in: *Magma Redox Geochemistry*. American Geophysical Union (AGU), pp. 177–213. <https://doi.org/10.1002/9781119473206.ch10>.

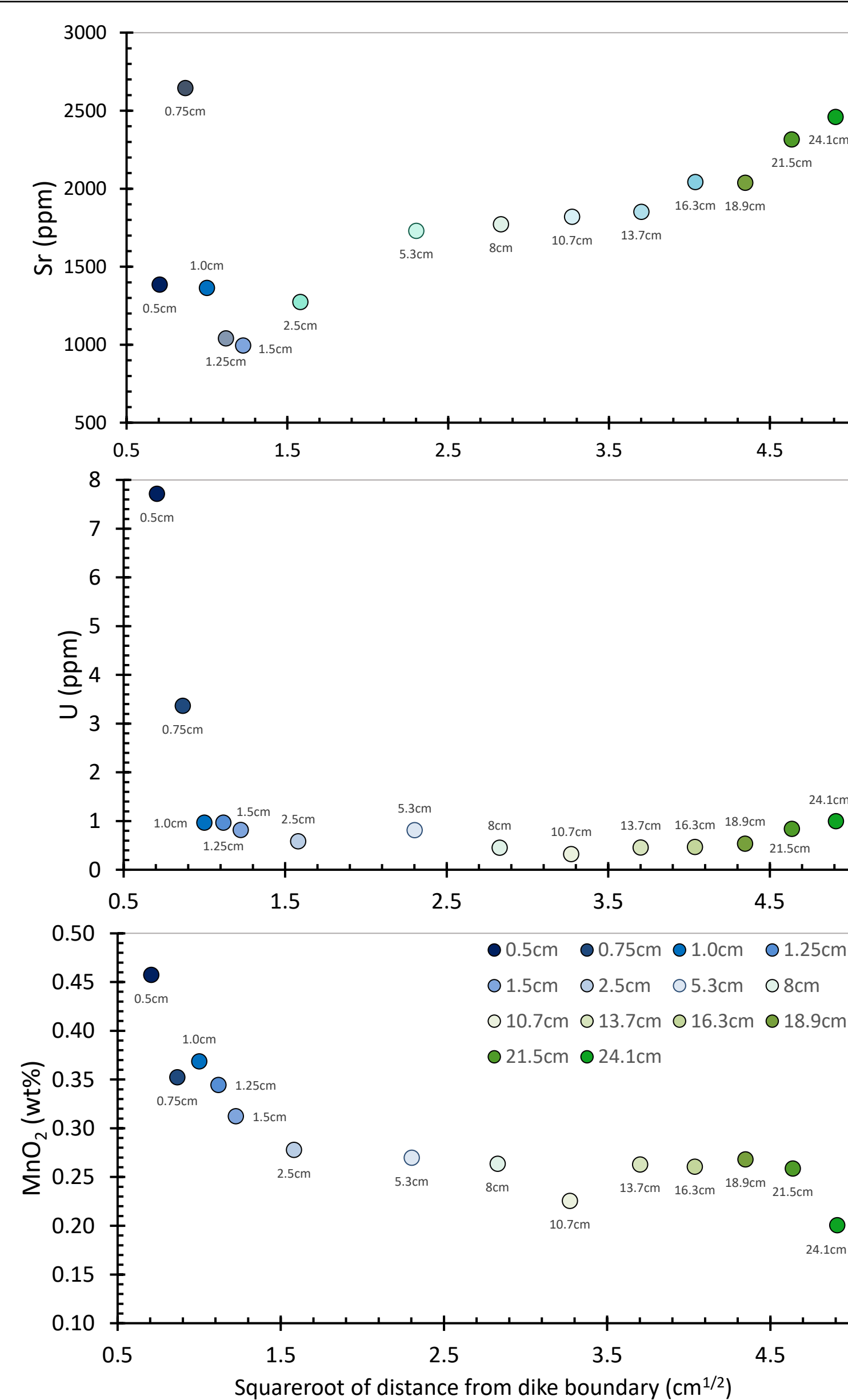


Figure 4: Enrichment vs distance along the dike profile.

4. USING THE STRONTIUM ANOMALY TO INFER PROCESS

The observed Sr enrichment was compared against europium (Eu) to study the source of the enrichment pattern.

- Dike samples that plot along the black arrow follow the enrichment pattern associated with plagioclase crystals.
- Dike samples that plot along the red line follow enrichment associated with limestone assimilation.

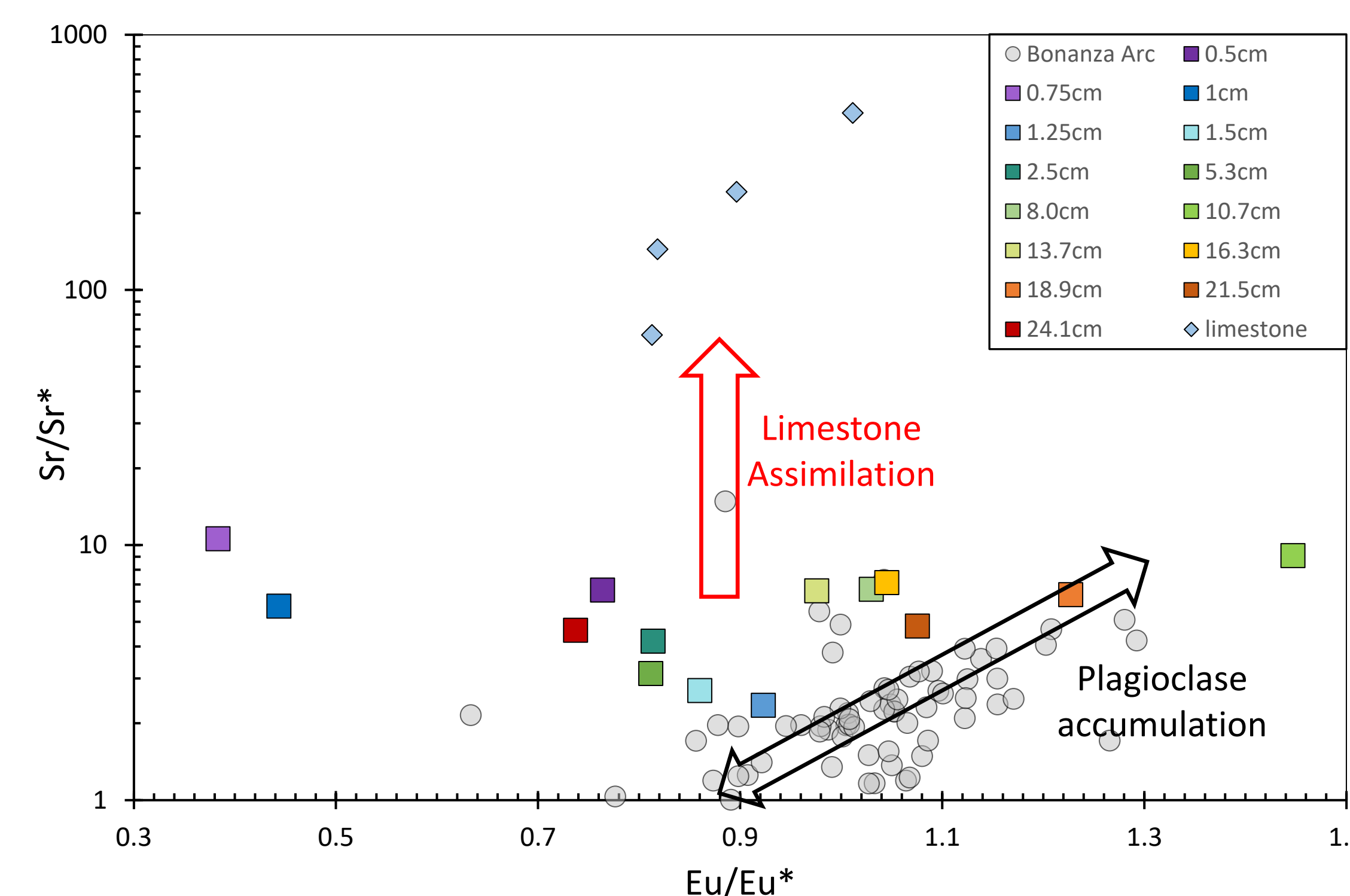


Figure 5: Strontium vs Europium anomaly within milli-slices. Sample data is plotted against standard volcanic rock data.

5. HOW MUCH ASSIMILATION?

Using a mixing equation, I was able to reverse calculate the Sr value for a "theoretical limestone." The data suggests that the reacted dike samples have Sr values much greater than typical basalt. Up to 80% of limestone mixing (>80%) is required to explain the anomalously high Sr (Fig 6). This data suggests either:

- 1) The wallrock limestone lost Sr during lithification.
- 2) Binary mixing model isn't the process to explain the data.

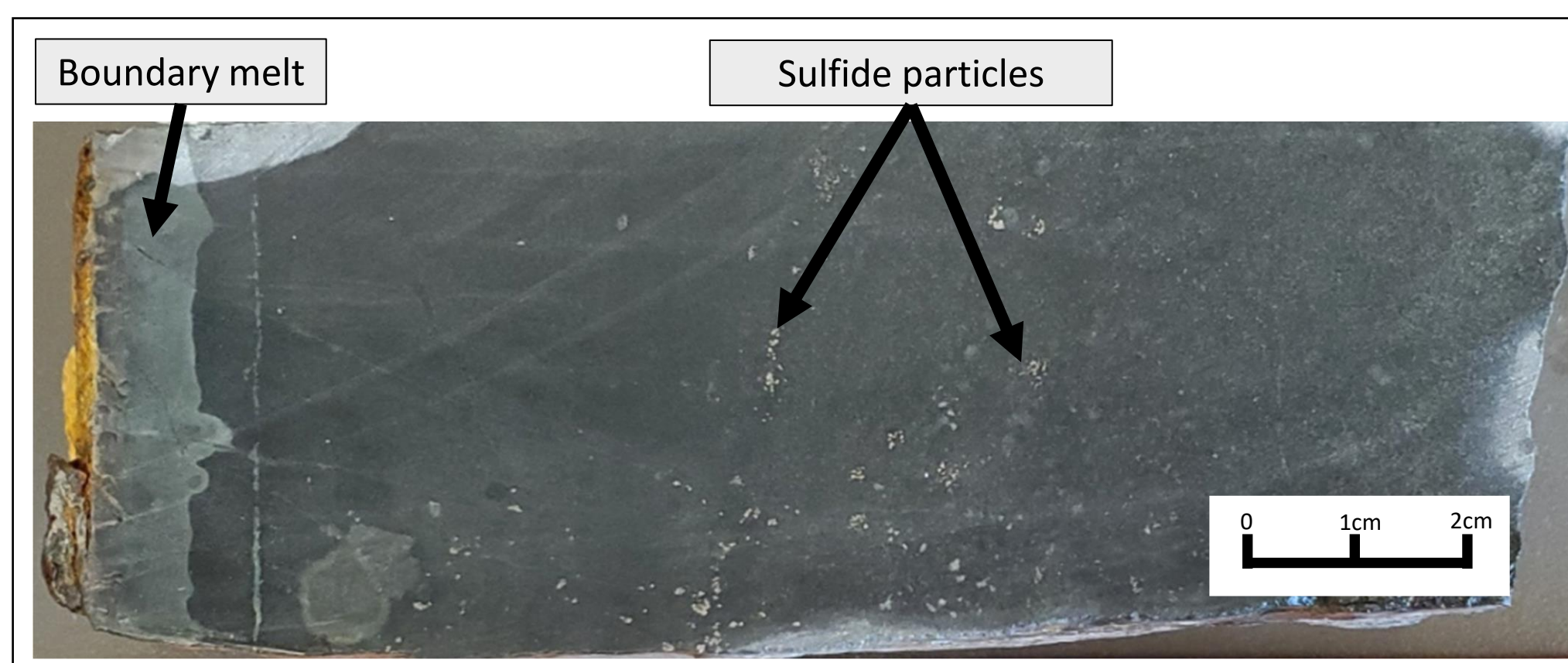


Figure 7: Polished sill showing the distribution of sulfides.

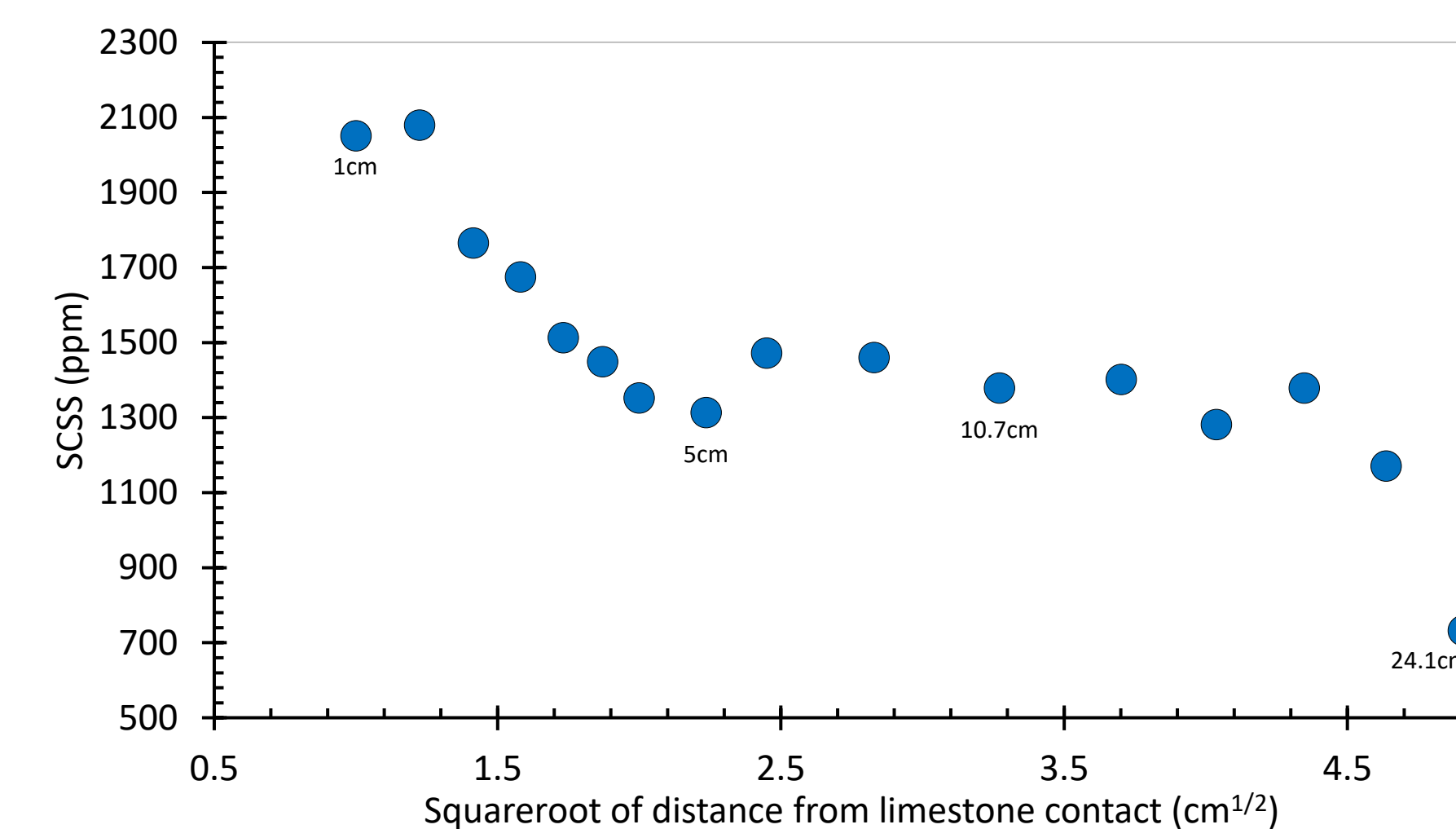


Figure 8: Sulfur saturation vs distance for milli-slice samples.

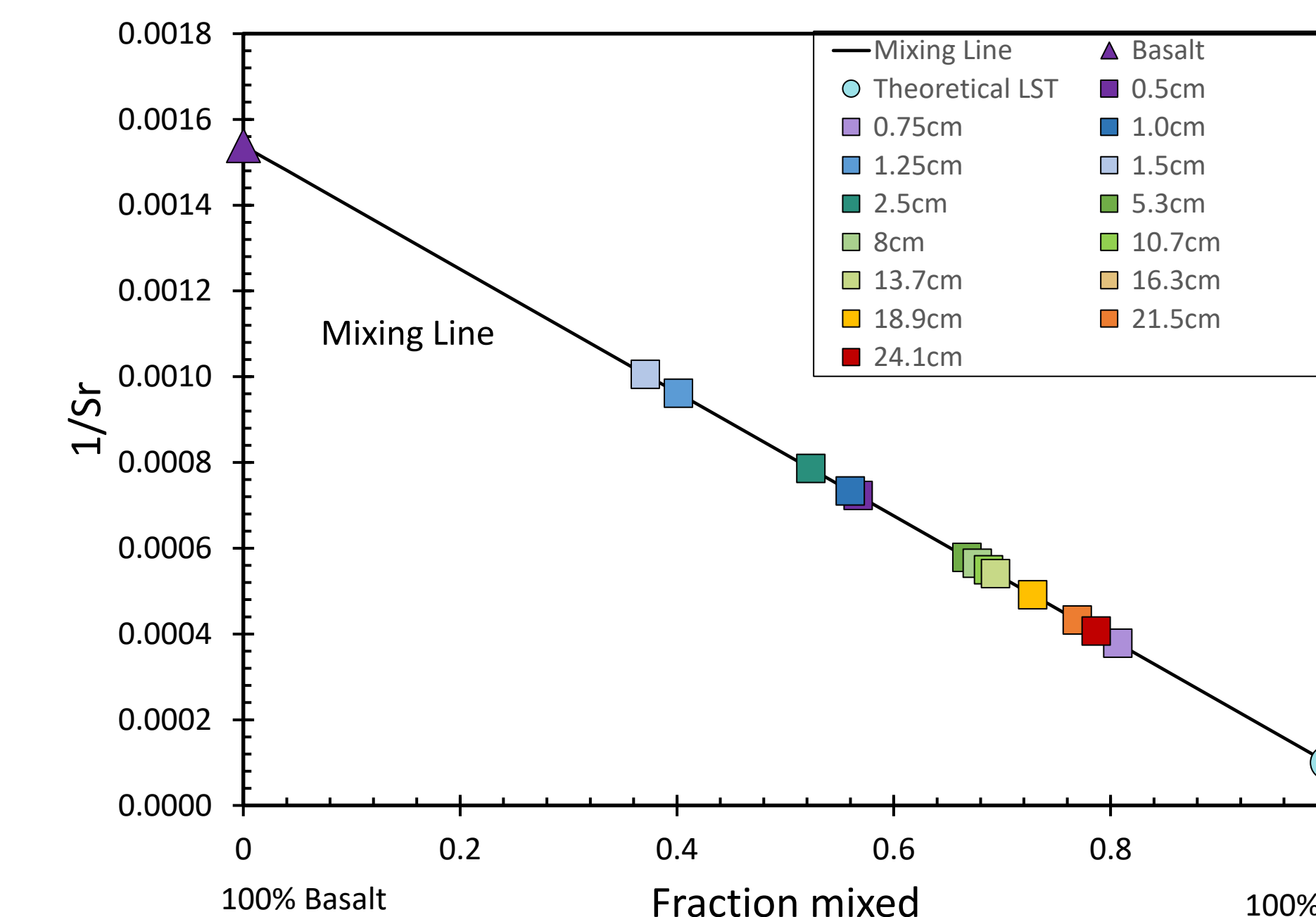


Figure 6: Binary Mixing model for the Sr values observed in the milli-slice samples.

6. ROLE FOR METAL ENRICHMENT

We can examine the dike's capacity to transport sulfur. The abundance of sulfur is very important for: (1) sulfur degassing into the atmosphere as a greenhouse gas and (2) a trigger for precious mineral deposition (O'Neill, 2021).

Calculations of the sulfur solubility show,

- Boundary melts adjacent to the limestone are rich in calcium and low in silica relative to the dike interior. Therefore, the boundary melts can transport much more sulfur species.
- The calculated data mirrors the observations seen in hand sample (Fig 7).

7. CONCLUDING STATEMENTS

- The micro-sliced dike 79B reports complex trace element distribution from the chemical reaction with limestone.
- The anomalously high Sr content in the dikes could be explained using a mixing model.
- Future research could explore →
 1. The process that explains element enrichment within the center of the dike compared to the contact.
 2. What methods causes Sr to be higher in the reacted basalt opposed to the reacted limestone.
 3. The mineralization within the skarn layer.