



# Magma Evolution of the Mineral Lake Intrusive Complex, Mellen WI

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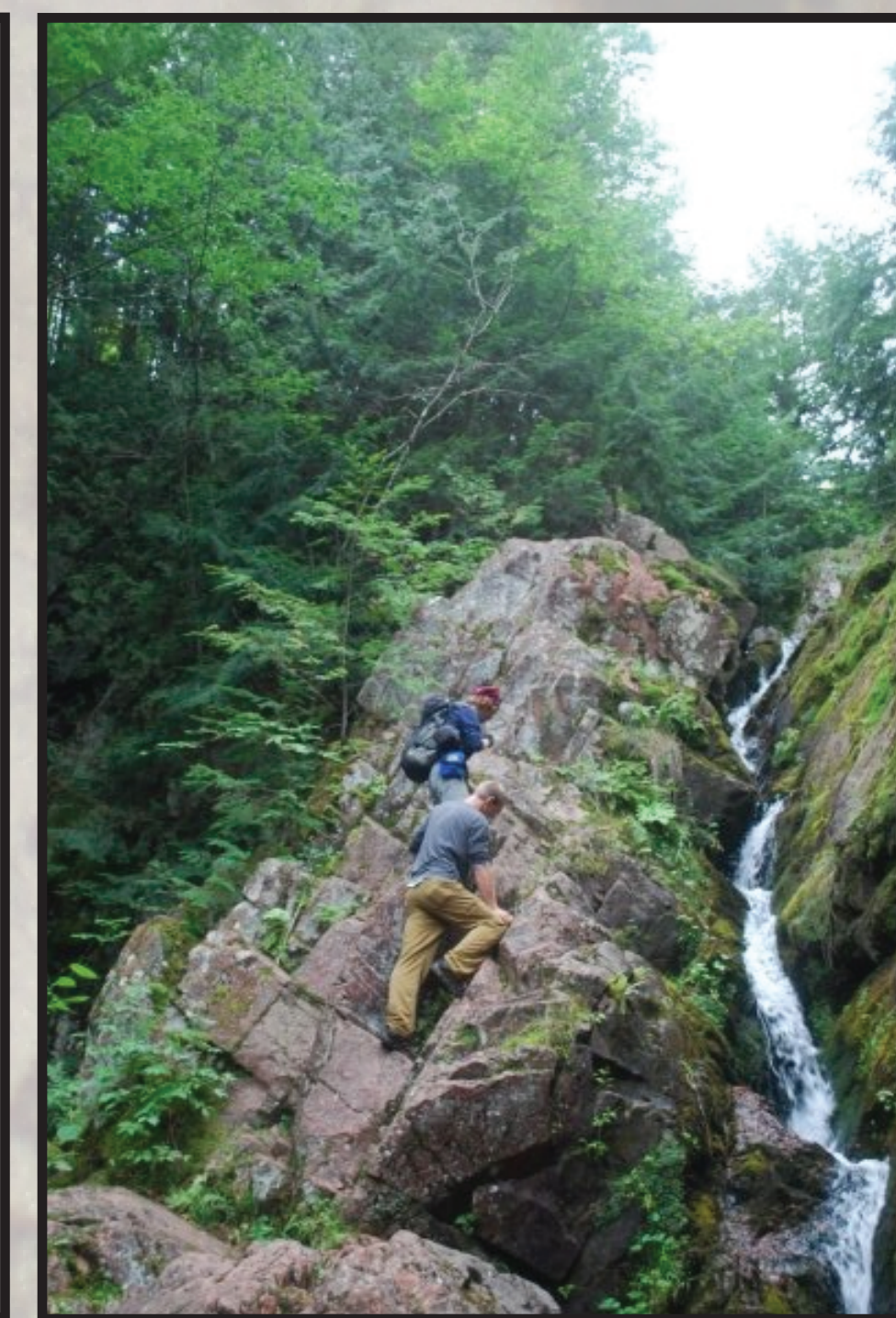
## Abstract

The Mineral Lake Intrusive Complex (MLIC) of northern Wisconsin is a well-exposed and well-preserved fossil magmatic system of the Mid-Continent Rift at 1.1 Ga. The MLIC is composed of a bimodal suite of compositions that include gabbro and granite. Surprisingly, the intrusive complex has largely escaped careful geochemical analysis. We present new field, geochemical, and petrographic analyses of the MLIC that further constrain its magmatic evolution. In particular, we provide a test of our hypothesis that the felsic magmas were produced by liquid immiscibility from highly evolved residual liquids. Our model holds that the residual liquids were trapped within a mafic crystalline framework located just behind the advancing crystallization front within the evolving chamber. Our alternative theory for the origin of granite offers an exciting new explanation for a series of paradoxes observed in the evolution of igneous rocks, including the cause of the extreme Fe-enrichment observed in samples from the classic Skaergaard and Bushveld Layered Mafic Intrusions that define the 'Tholeiitic Trend' on AFM diagrams.



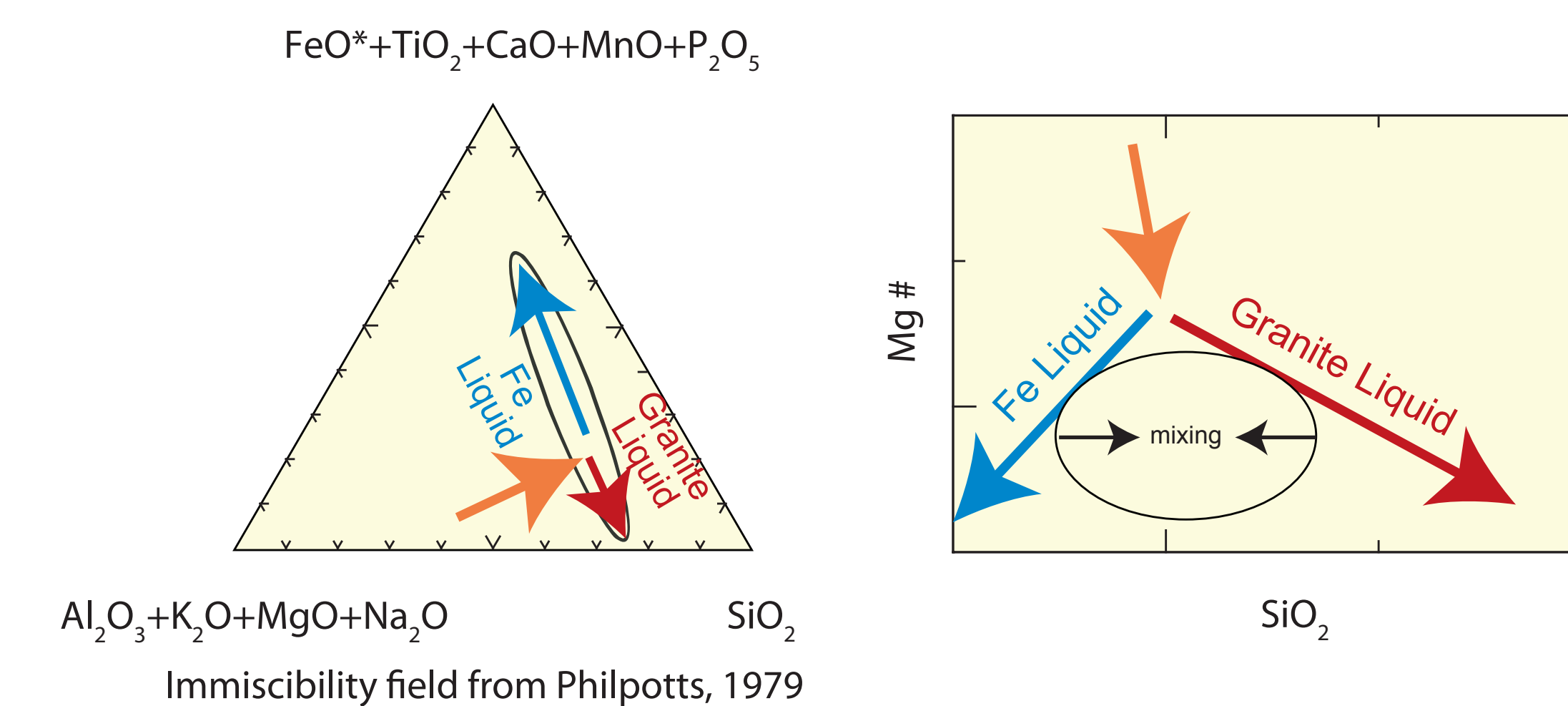
## Why Study the Mineral Lake Complex?

Layered Mafic Intrusions (LMI) world-wide all have associations with silica-rich (felsic) magmas. The exact nature of the relationship between these two vastly different magma types is not fully understood. For reasons that have not always been clear, many geologists have concluded that the two magma types were derived from distinctly different sources. However, from the time of N.L. Bowen (1931), geologists have fully appreciated that felsic magmas form as a consequence of the crystallization of mafic minerals from a basaltic melt. However, only the felsic material found in the thin 'sandwich horizon' has been attributed to derivation from the mafic body. The abundant felsic pods, sheets, and dikes littered throughout these intrusions are written off as secondary and unrelated to the evolution of the mafic magma. The Mineral Lake Intrusive Complex is a relatively unaltered LMI with rock types that range in composition from gabbro to granite. The complex, located in northern Wisconsin, is easily accessible to sample collection. The location is ideal for testing out hypotheses for the crystallization of tholeiitic magma. Here, we present a test of a recent model for granite production within an evolving basaltic magma chamber. Our model is bolstered by the observation that every major LMI is associated with voluminous granitic and rhyolitic magmatism of equivalent age.

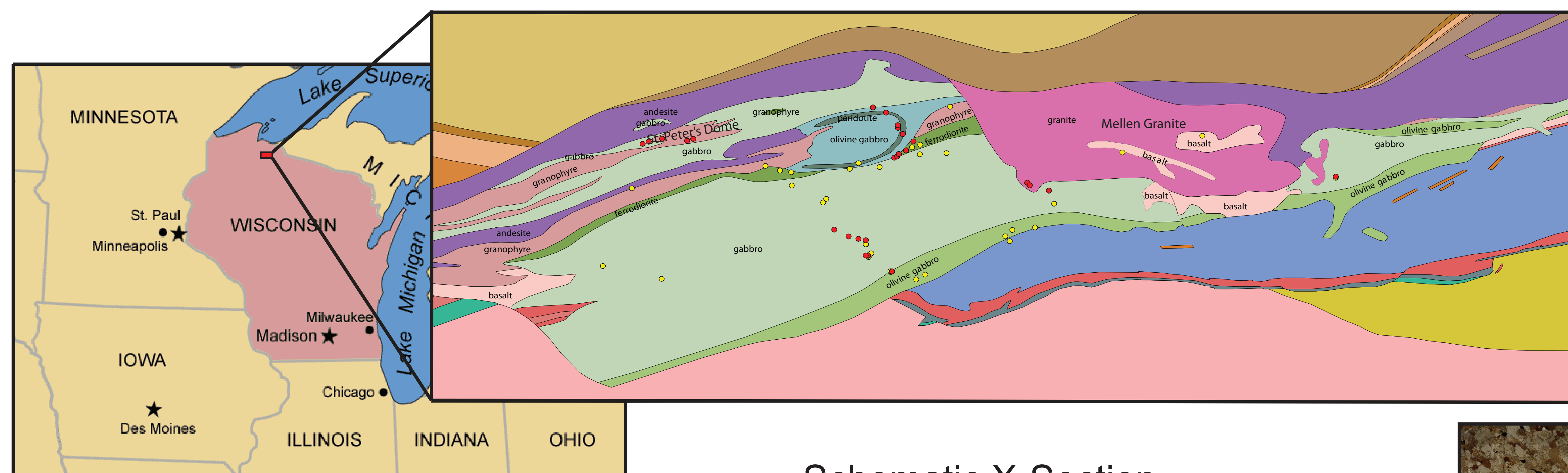


## The Model

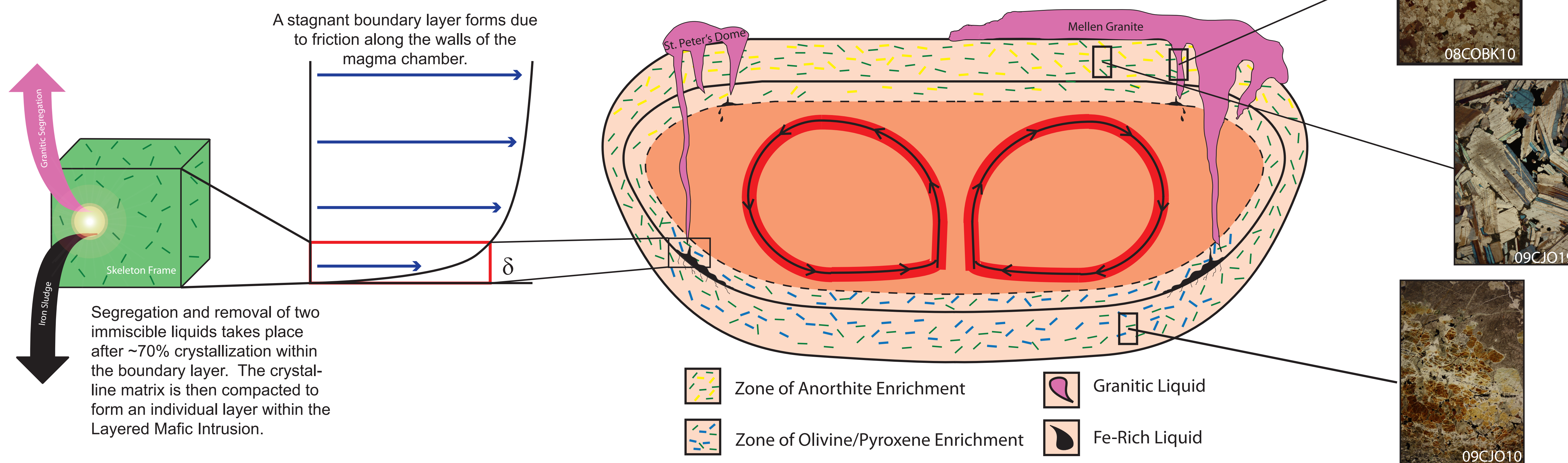
Over the last few years, we have been developing a new model for the origin of granitic magma that involves the sequential extraction of buoyant, felsic residual liquids generated within mafic magma chambers. LMIs do not show the expected changes in composition from margin to core. Our proposed model invokes the removal of evolved felsic liquids from within a crystal mush zone located behind the advancing crystallization front. The crystal mush zone is segregated from the main body of the chamber due to the formation of a boundary layer at the margins of the convecting chamber. After ~70% has crystallized, the composition of the interstitial liquid crosses into a field of immiscibility such that an Fe-rich liquid separates from a Si-rich liquid. The felsic liquids migrate up, first through the host crystal mush and subsequently through the overlying basaltic magma. Their evolved composition prevents them from mixing with the mafic liquid, and their enhanced buoyancy allows them to penetrate through the overlying roof into the country rocks to eventually crystallize as granitic bodies or erupt as rhyolitic lavas. The dense, Fe-rich liquid sinks and infiltrates the underlying layer, while the remaining crystal mush is compacted to form a 'layer' in the Layered Mafic Intrusion.



## The Mineral Lake Intrusive Complex



## Schematic X-Section of the Magmatic System



## Acknowledgements

We thank the UWEC Office of Research and Sponsored Programs for their financial support of our fieldwork and for our preliminary geochemical analyses. Connie Dicken, of the USGS, spent two hours helping us import and modify the USGS' existing geologic map. Also, Jill Ferguson, J. Brian Mahoney, and Geoffrey Pignotta provided invaluable expertise in preparing and analyzing the major and trace element contents of our samples. Thanks are due to Tom Bruckner, the proprietor of the Cayuga Hotel where we lodged, and Brennan Kadulski who assisted with sample analysis. Lastly, we thank Lorilie Steinke, our department secretary, whose work behind the scenes allows us to do all this.

## Conclusions

Sampling traverses across the MLIC have identified a suite of mafic through felsic rocks.

XRF analysis of major element geochemistry exhibits four distinct trends in MLIC rocks:

- Pyroxene and olivine accumulation in the lower portion of the chamber
- Accumulation of buoyant plagioclase in the upper portion of the chamber
- Enrichment in K and Si from addition of Si-rich immiscible liquid
- Enrichment in Fe, Ca, P, and Ti from addition of Fe-rich immiscible liquid

Rock textures in thin section show evidence of crystal compaction and segregation of Si-rich and Fe-rich liquids.

## References

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## Future Research

- Electron Microprobe analysis of plagioclase and mafic mineral chemistry will be done at the University of Minnesota. This will allow us to examine how Mg# and An content of the mafic and felsic phases changes with stratigraphic height throughout the MLIC.
- Mineral chemistry will also help shed light on the relationship between the Rearing Pond and Mineral Lake Intrusions.
- Continued field mapping and sample collection will allow us to edit and improve upon the existing USGS map of the MLIC.

## Major Element Geochemistry of the Mineral Lake Intrusive Complex

