Schematic Illustration of Evolving Tholeiitic and Calc-Alkaline Magmatic Systems: New Models

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Abstract

The dramatic contrast in the geochemical evolution of tholeiitic and calc-alkaline magmatic systems has remained an enigma since their original characterization nearly a century ago. Recently, two new models that describe the evolution of each magma type have been developed that explain the enigmatic features observed in the classic intrusions of each magma type (Ihinger, 2015). The long-standing paradoxical observations within the tholeiitic Skaergaard (Greenland) and the calc-alkaline Shonkin Sag (Montana) intrusions are now understood to represent magma chambers wherein evolved felsic liquids have buoyantly segregated from a host residual crystal mush. Here, we present our efforts using Adobe Illustrator to schematically illustrate the processes that lead to the geochemical and textural variations observed in the crystallized intrusions. We support these illustrations with actual thin-section photomicrographs taken from the intrusions. Our images document the evolving geochemistry of both residual liquid and complementary crystal phases throughout the duration of crystallization. Our representations capture the details of the chemical evolution and show the roles that the processes of crystallization, liquid immiscibility, and compaction play in the development of each magma intrusion.

Two Broad Magma Types

Tholeiitic

http://media.mnn.com/assets/images/2012/02/1_0.jpg

VS

Calc-Alkaline

http://cdn.theatlantic.com/assets/media/img/photo/2013/11/the-eruptions-of-mount-sinabung/s18_87965197/main_900.jpg?1420506374

Forms by melting Earth's mantle

... via Decompression

... at Spreading Centers and at Plumes

Forms: Oceanic Crust

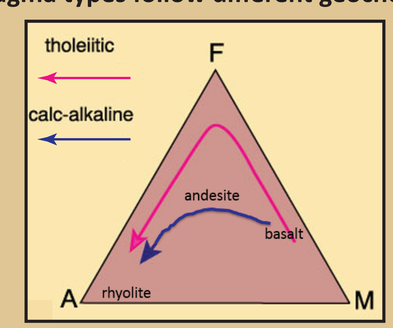
Forms by melting Earth's mantle

... via Hydration

... at Subduction Zones

Forms: Continental Crust

The two magma types follow different geochemical paths



AFM plots distinguish two magma types...
BUT why the different behavior? Now explained by 2 new models!

New Model for Evolution of Tholeiitic Magma Chambers

http://www.largeigneousprovinces.org/sites/default/files/2012Oct-fig-4.jpg

A Tale of Two Magma Chambers

Key observations shared by both Magma Chamber Types

- Large volumes of contemperaneous felsic magma found stratigraphically above mafic pile
- Small volumes contemperaneous felsic magma intrude mafic pile
- Mafic pile characterized by pronounced horizontal alignment of mafic crystalsvia compaction!

New Model for Evolution of Calc-Alkaline Magma Chambers

Photo: P. Ihinger

Photo: C. Tegner, Aarhus univ.

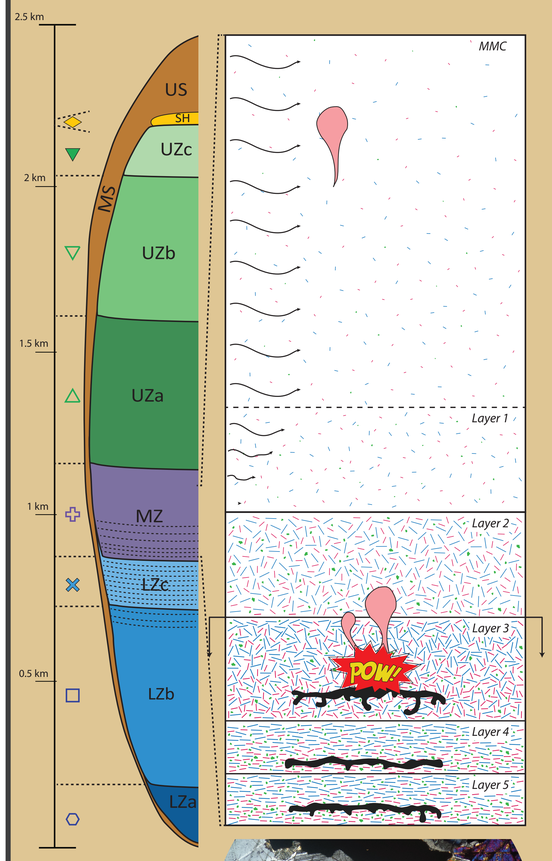
Key observations unique to
Tholeiitic Magma Chambers

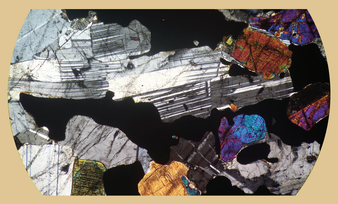
- Show strong enrichment in magnetite within mafic pile
- Exhibit multiple (hundreds) of succesive episodes of felsic extraction

Key observations unique to
Calc-Alkaline Magma Chambers

- Do not show strong enrichment in magnetite within mafic pile
- Exhibit one (maybe two) episodes of felsic extraction

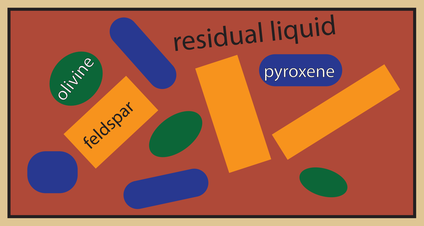
Photo: P. Ihinger





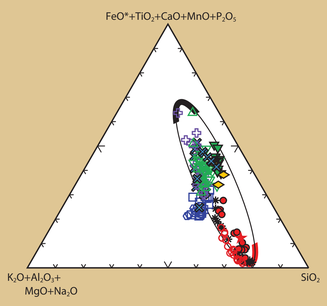
What's Common to Both?

With cooling, both magma types crystallize minerals (olivines, pyroxenes, and feldspars) leaving behind an interstitial liquid more felsic ('evolved') and **more buoyant**



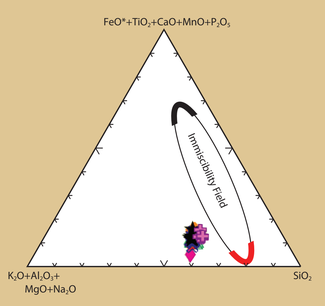
What's Different??

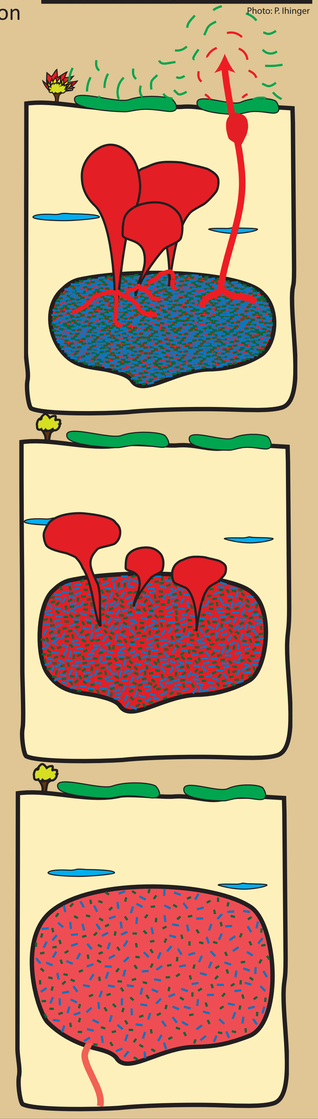
Liquid Immiscibility in the Crystal Pile



VS

NO Liquid Immiscibility in the Crystal Pile





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References

Ihinger, P. D., 2015, Liquid immiscibility in the Skaergaard crystal pile: Reconciling Bowen and Fenner perspectives on basalt evolution, submitted to: ***Nature Geoscience***, 10 pp.

Ihinger, P. D., Mahoney, J. B., Johnson, B. R., Kohel, C. A., Guy, A. K., Kimbrough, D. L., and Friedman, R. M, 2016, Origin and evolution of plutonism, volcanism, and deformation of the Boulder Magmatic Suite, Montana, manuscript draft to be submitted to: ***Geological Society of America-Bulletin***, 42 pp.

Observations & Conclusions

- Tholeiitic and Calc-Alkaline magma chambers evolve along contrasting geochemical paths.
- In a pair of recent studies, these paths have been attributed to the occurrence (and non-occurrence) of liquid immiscibility within the crystallizing pile.
- The difference in character between these two models can be successfully illustrated to visualise these differences.