# V51H-0151

# Dynamic development of mineral layering and crystal alignments by pulsed magmatic flow in crystal mush of an upper-crustal diabase sill

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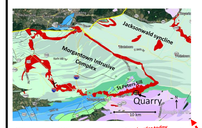
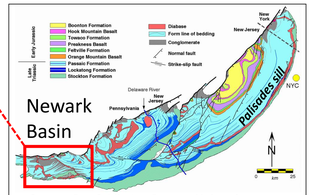
## 1.Tectonic Context: *Triassic Rifting of Pangaea, Basaltic Magmatism*




Schematic cross-section, looking NNW, minimal vertical exaggeration


Dimension stone Quarry in sill (5-6 km paleo-depth) Walls are cut along strike (ESE-WSW) and across strike (NNW-SSE)

Prominent plag-rich layers identify tops of intra-sill sills or magma "flow lobes," <1m thick on average

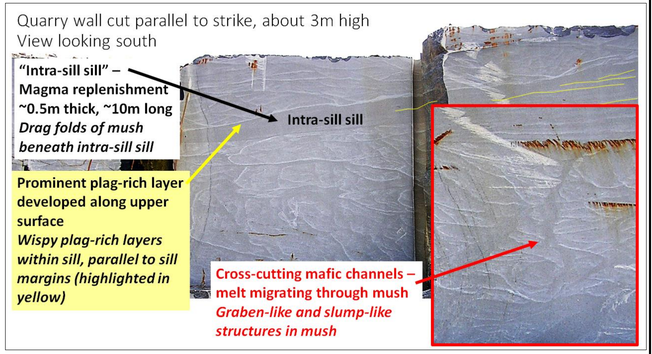



Source: Roy Schlische, Rutgers University; http://www-rci.rutgers.edu/~schlisch/

**Central Atlantic Magmatic Province (CAMP)**
**Newark Basin, Pennsylvania-New Jersey-New York, U.S.A.**
High-Ti Quartz-normative **basalts and diabase (dolerite) intrusions**
*Age:* 201.520 ± 0.034 Ma; *Duration: ~ 100,000 yrs.; Area: ~ 2-3 million km²*
Blackburn, et al., 2013, Science, v. 340, p. 941-945.
*Western Newark Basin:* Srogi, et al., 2017, Geol. Assn. NJ, Ann. Mtg. guidebook, p. 30-48.


Wall cut perpendicular to strike of sill, looking WSW, about 3m high. Modal layering dips about 20° NNW, tilted after solidification due to rift-basin border fault.

Quarry wall cut parallel to strike, about 3m high
View looking south




## 2. Mush in Basal Sill: *Opx-Plag Antecryst Layering Preserves Incremental Emplacement of Thin "Flow Lobes" Within Sill – Short Timescale Pulses?*

## 3. Fabrics in Modal Layers: *Separation of Pyroxene and Plagioclase Antecrysts and Alignment of Tabular Plagioclase are Consistent with Flow and Shear Thinning*

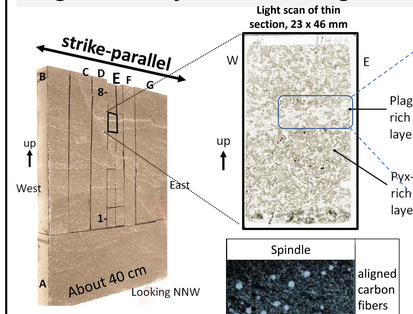
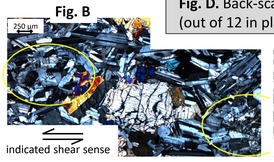
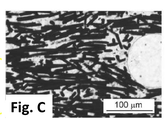
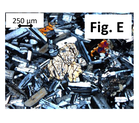



**Fig. A.** Shear thinning separates particles by shape, rotational viscometer experiments (Cimarelli et al., 2011, G³, Fig. 6e.)

**Evidence for Shear Flow:**
**Fig. B:** Areas of less aligned plag (**yellow circles**) resemble "pressure shadows," and
**Fig. C:** flow of carbon fibers around glass beads (Cimarelli et al., 2011, Fig. 7a).
**Fig. D:** Tiling and imbrication of tabular plagioclase (half-arrows show indicated shear sense).

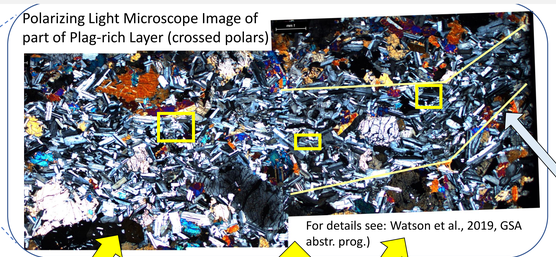



**Evidence for Flow:**
**Fig. E:** Tabular plagioclase wraps larger pyroxene phenocryst (similar to analog experiment, Fig. C).

Polarizing Light Microscope Image of part of Plag-rich Layer (crossed polars)



For details see: Watson et al., 2019, GSA abstr. prog.)

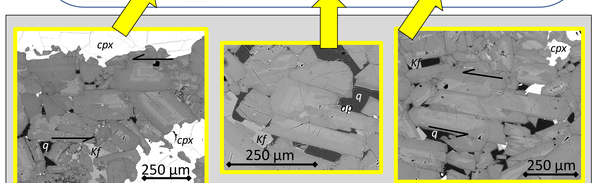
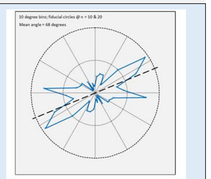
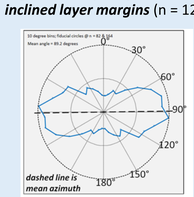



**Fig. D.** Back-scattered Electron (BSE) images: 3 examples of tiled plagioclase grains (out of 12 in plag-rich layer). Images made on FEI Quanta SEM.



Plag orientations in inclined segment of layer – ***parallel to inclined layer margins*** (n = 122)



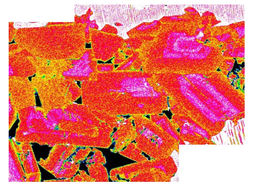

All plag orientations in layer (n = 1609)

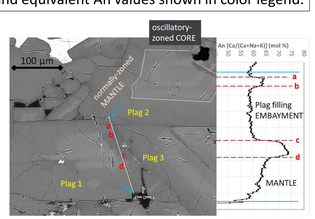
**Long-axis orientations of tabular plagioclase** – shape-preferred orientation (SPO) aligned parallel to layer margins – ***orientations not by compaction alone***

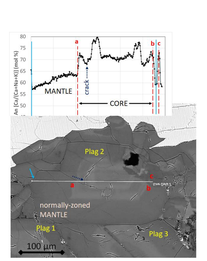
## 4. Compositions of Tiled Plagioclase Clusters: *Stages of Crystal Alignment and "Cementation" Revealed by Thresholding Ca X-ray Maps and Checked by EDS Linescan Data*

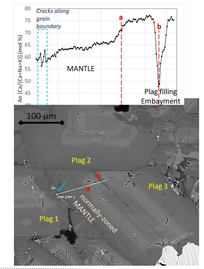
Ca X-ray maps, BSE images, and Linescan analyses obtained using FEI Quanta SEM and Oxford Aztec EDS with Silicon-Drift Detector. X-ray Quant maps are binned for weight % Ca and equivalent An values shown in color legend.

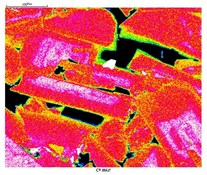

Color legend for Ca X-ray Maps

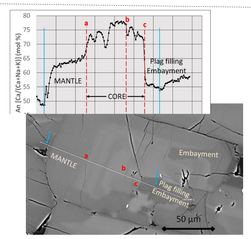


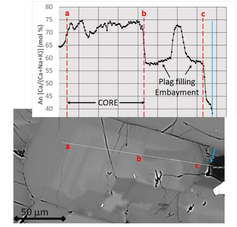


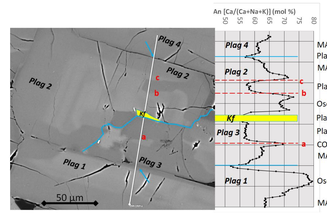



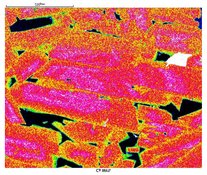



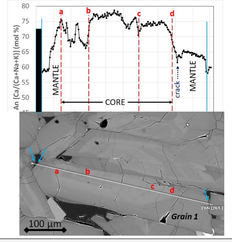



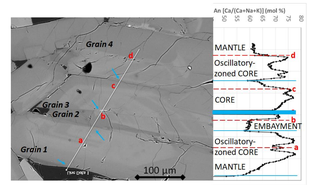


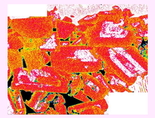



| Location | An (mol %) | Ca (wt. %) | X-ray map bins | *Comments* |
|---|---|---|---|---|
| Core, high-An zones | > 70 | 10-12 | 10-11, 11-12 | *up to An83* |
| Core, low-An zones | 66-73 | 9.5-10.5 | 9-10, 10-11 | |
| Mantles (normal zoning) | 53-67 | 7.8-9.5 | 8-9, 9-10 | *highest An next to oscillatory-zoned core* |
| Plag filling embayment | 48-61.5 | 7.1-9 | 7-8, 8-9 | *highest An is 58-61, 8.5-9 wt.% Ca* |
| Plag-plag grain boundary | 51-59 | 7.5-8.6 | 7-8, 8-9 | *mostly An56-59, 8-8.5 wt.% Ca* |
| Plag-qtz or Plag-Kf grain boundary | < 42-54 | < 6-7.8 | <6, 6-8 | |

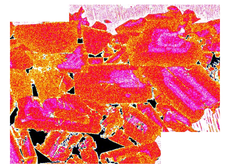
Tiled plagioclase have similar compositions in comparable zones, as summarized in the Table above. Note compositions overlap between most zones. Linescan data help refine bins for X-ray maps and thresholding to explore stages of crystallization (below).

**Color Threshold Ca X-ray Maps in ImageJ (Fiji) to highlight compositional zones.** Turn high-An zones (magenta and pink pixels) to white to see sharp, euhedral Ca-rich zones in cores:

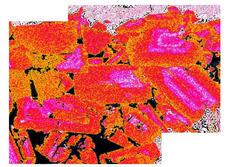


RIMS to CORES: Use Color Threshold in ImageJ (Fiji) to sequentially color pixels in compositional zones.

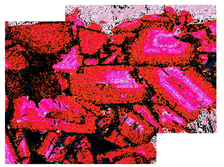
***1. An <42-54, outer rims are white; quartz is black***



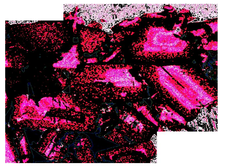
***2. An <42-54, outer rims are black; note orange pixels (An55-62)***



***3. up to An62 is black (liquid); grains are separated by liquid***



***4. up to An66 is black (liquid) note patchy zoning in mantles***



Interpret Stages of Crystallization:

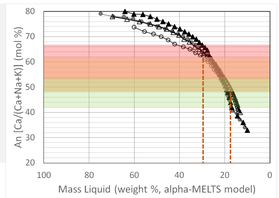
***4. outer rims are thin and occur next to quartz (and K-feldspar)***

***3. CEMENTATION STAGE; orange pixels are cementing composition (An55-62)***

***2. ALIGNMENT AND IMBRICATION STAGE (note thin melt films)***

***1. ANTECRYST STAGE - patchy zoning – ascent? resorption?***

## 5. MELTS models of Crystallization Stages: *Alignment and Impingement at 50-30% Liquid; Cementation at 30-20% Liquid (orange, right) Flow in Crystal-Rich Slurries*




**WHITE:** Oscillatory-zoned Cores
*Na-rich zones overlap with Mantles*
**RED:** Mantles around Cores
**ORANGE:** Outer Mantles, Plag filling Embayments, and Plag-Plag Boundaries
**GREEN:** Thin rims along Plag-Qtz and Plag-Kf Grain Boundaries
*Black symbols: bulk rock composition*
*Gray symbols: average lava/chill comp.*
*Closed: 0.5 and Open: 1.0 wt.% H2O*

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