THE MASONTOWN KIMBERLITE, FAYETTE COUNTY, PENNSYLVANIA: INSIGHTS INTO EMPLACEMENT PROCESSES BY THE CHARACTERIZATION OF XENOCRYST SIZES AND SHAPES USING COMPUTED TOMOGRAPHY

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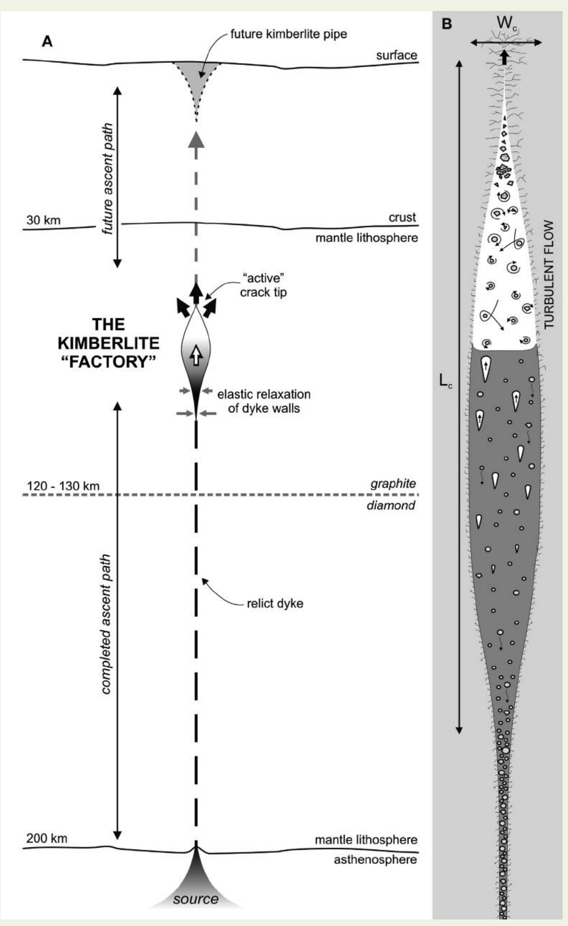
Introduction



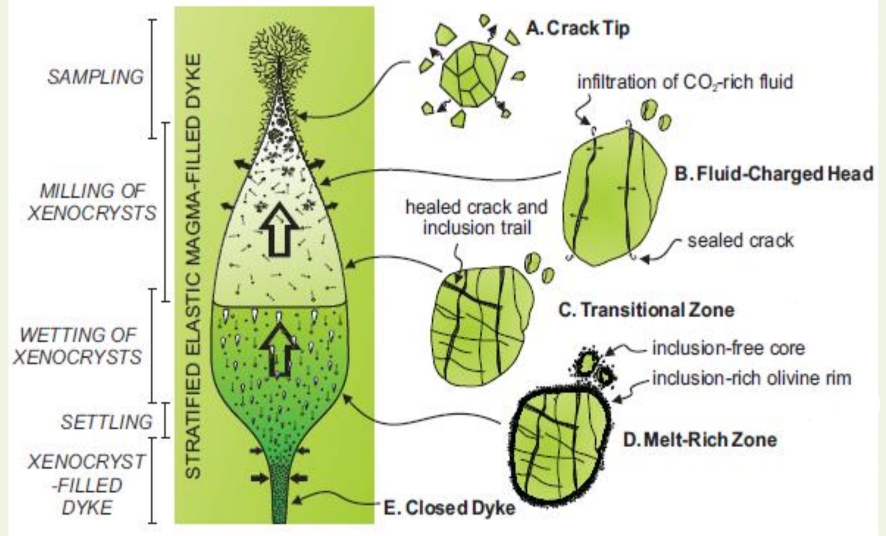
Kimberlite is a mantle-derived ultramafic rock found in dikes and diatremes.

Kimberlites must ascend very quickly because they preserve metastable minerals (e.g., diamonds) and they erupt explosively.

How does kimberlite magma ascend through the mantle and the lithosphere?

The **KIMBERLITE FACTORY** model (*Brett et al., 2015*) proposes a set of processes operate within the transient head of an ascending kimberlite dike.

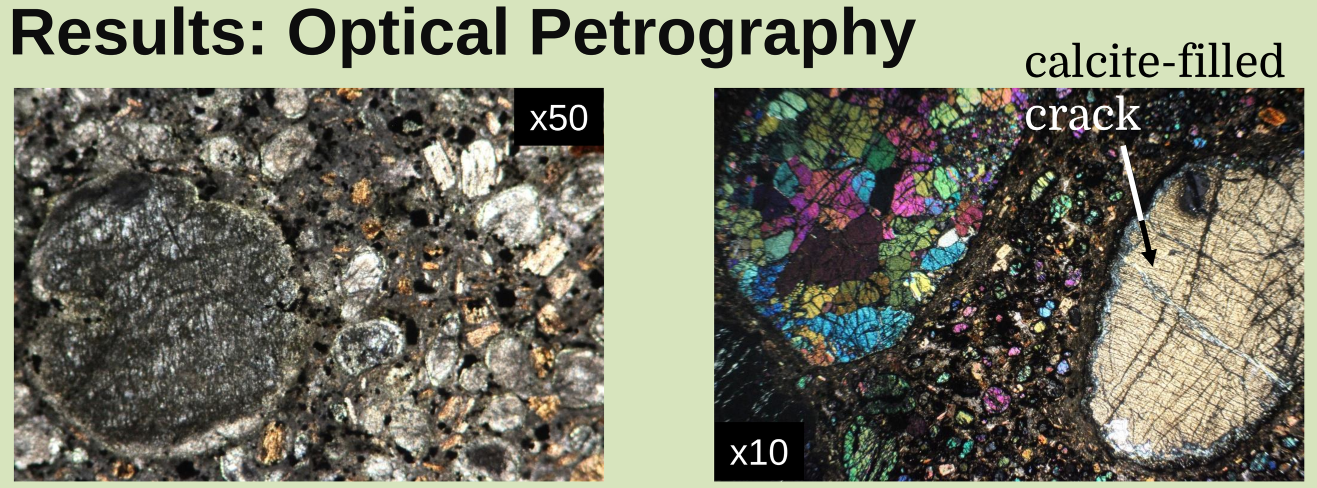
1. The dike tip fractures peridotite.
2. Xenocrysts are freed and decompress.
3. Xenocrysts are rounded.
4. Xenocrysts are wetted by melt.
5. Xenocrysts settle-out in the dike.



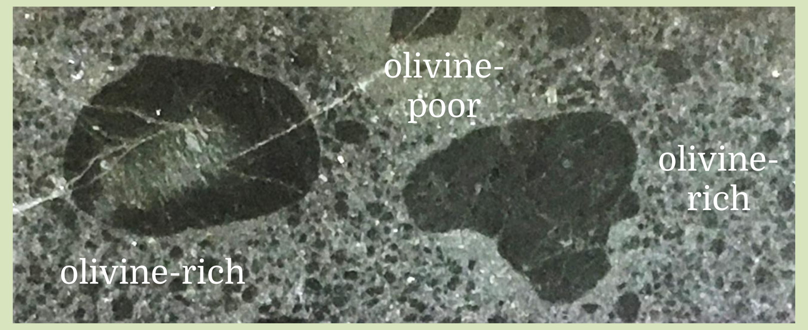
Methodology

- 3 samples (A-C) were provided by the Smithsonian Institute's NMNH; we used B.
- **Industrial computed X-ray tomography** (iCT) scanning performed at NETL Morgantown.
- iCT data provides non-destructive 3D images of a sample, allowing for **examination and measurement** of grains not visible from the outside.

Results: Optical Petrography



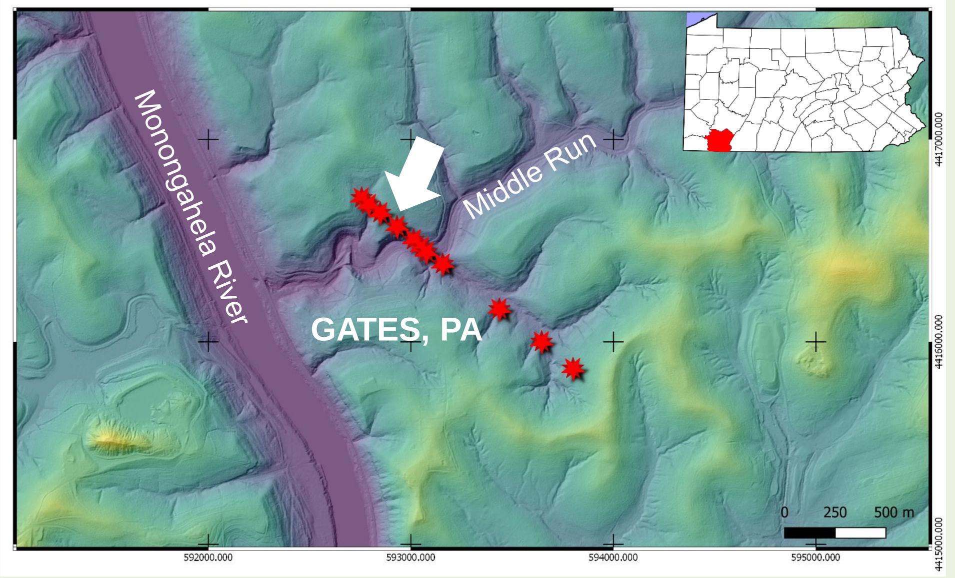
Rounded and melt-jacketed OPX (left) and olivine xenocrysts, and peridotite xenolith (right) in olivine-porphyry kimberlite.



1 cm-diameter, rounded xenoliths of serpentinized peridotite. Note: domains of olivine-rich and olivine-poor groundmass, including around the xenolith on the right.

Geologic Background

- The Jurassic Masontown kimberlite is a 5 - 50 cm wide dike in Fayette County, PA, emplaced during rifting between North America and Africa (*Prellwitz, 1994; Bikerman et al., 1997*).
- The kimberlite is olivine-porphyritic with a groundmass of serpentine, apatite, calcite, and sulfides.
- Xenocrysts of olivine, phlogopite, OPX, pyrope garnet, perovskite, and ilmenite (*Schultz & Hearn, 2015*).
- Xenoliths of peridotite, dunite, gabbro, granulite, and limestone



Results: iCT Analysis

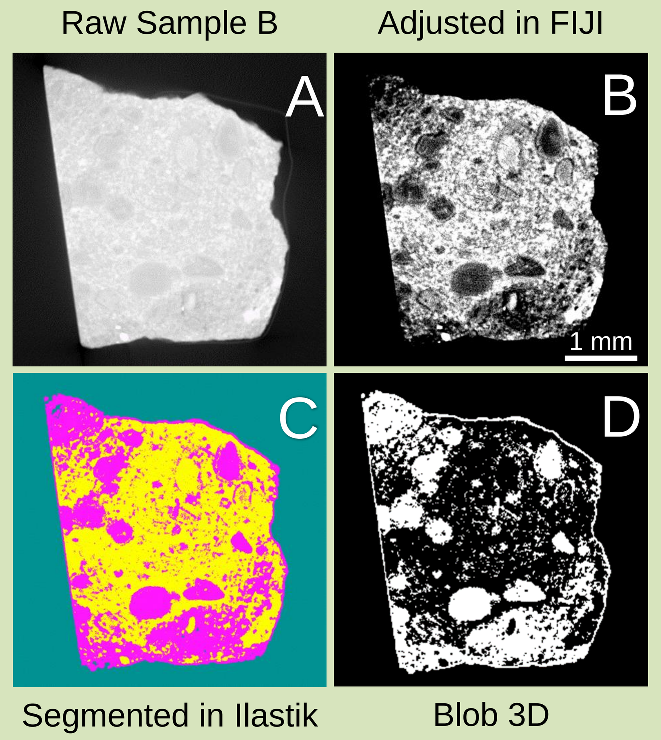
Raw iCT data in the form of a grayscale image stack (see A below).

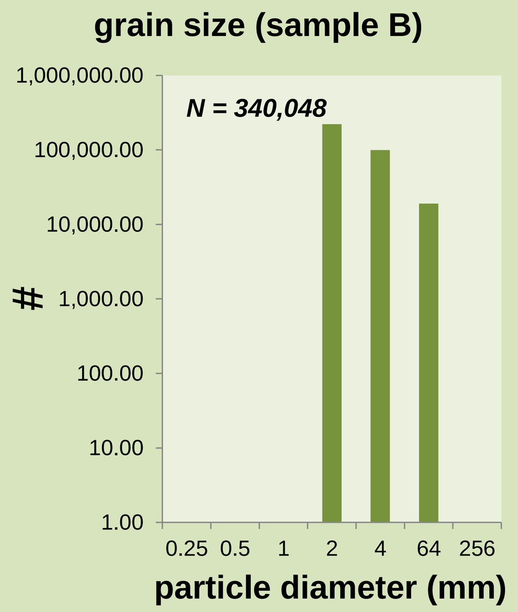
Brightness and contrast adjustments in FIJI **emphasize olivine xenocrysts** and regrowth rims (B) while improving grayscale value consistency throughout the data set.

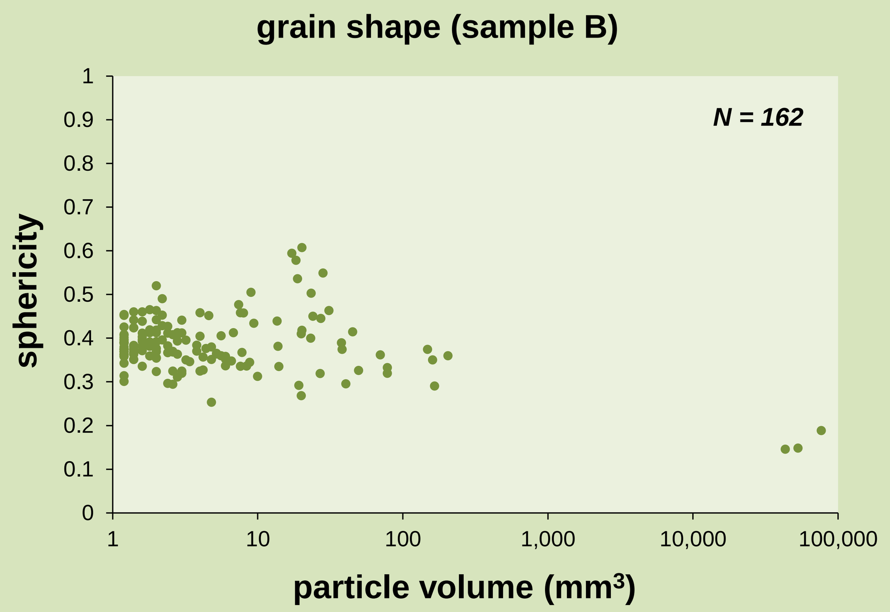
Segmentation using Ilastik differentiates olivine grains from the groundmass and background (C).

Segmented data can be uploaded to Blob 3D (D) to perform **measurements**.

Only one or two types of measurement (e.g. volume, surface area, etc.) were extracted at a time due to the **large data set** size.







- **Grain size data** from sample B obtained using Blob3D software shows the abundance of 1 to 4 mm-diameter grains (coarse sand to granules) in the groundmass, engulfing >4 mm (pebble-sized) xenoliths and xenocrystic megacrysts (e.g., phlogopite).
- **Grain shape data** show that megacrysts and xenoliths are very non-spherical (0.1-0.2) compared to moderately spherical grains (i.e. groundmass olivines).

Discussion

iCT analysis provides a wealth of data but is challenging to process and interpret.

CT analysis is used routinely for examining porosity and microstructure in rocks where there is a high density / attenuation contrast between minerals and voids. **This is not the case with kimberlite** where a rock sample is virtually 100% either olivine (S.G. 3.21-3.33) or serpentine (2.5-2.6): only where they occur together does the iCT successfully isolate grains (e.g., sample B).

Results show that grain size and grain shape data can be gathered and that different populations can be distinguished:

- rounded megacrysts and xenoliths in the Masontown kimberlite agree with the Kimberlite Factory model,
- relative and volumetric proportions of megacrysts / xenoliths can be estimated from the iCT data.

Conclusions

iCT analysis can be used to **estimate measurements** of physical features in kimberlites.

- iCT data allowed observation of sample properties that cannot be seen in hand samples or thin sections.
- The software programs involved **are not designed for kimberlite**—they work more effectively when there is more contrast between components of interest.
- Samples A and C (also from the SI NMNH) lacked sufficient contrast to analyze in the software programs.

Subspherical megacrystic xenocrysts and non-spherical xenoliths both exhibited very rounded textures.

- This **is consistent with abrasion associated with the Kimberlite Factory model** proposed by Brett et al. (2015).

Acknowledgements

Special thanks to NETL Morgantown for iCT scanning and the S.I.'s Museum of Natural History for loan of three samples. Thanks, too, to Dr. Ken Brown and Dr. Matt Brueseke for assistance in the field and useful kimberlite discussions. Funding and software provided by WVU.