Tectonic vs impact zircon deformation:

From the Vredefort impact structure to Lunar tectonics: a possible key to distinguish geological processes

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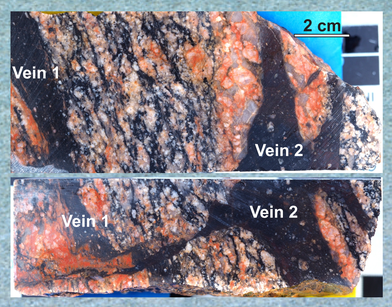
Main problem: How to distinguish tectonic from impact-related pseudotachylites?

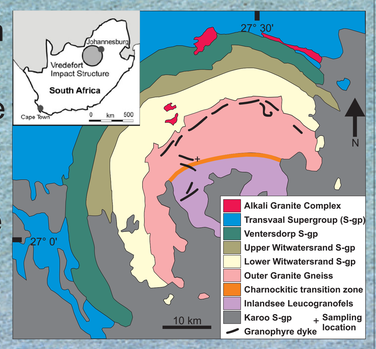
I

- **Pseudotachylites** are dark, cryptocrystalline, *in situ* veins that are found in both shock metamorphic and tectonic settings.
- There are no established criteria to distinguish between impact- and tectonic-related pseudotachylites.



Sample of the basement

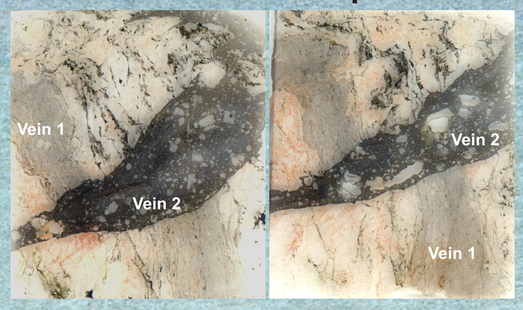
- All pseudotachylites found in the impactites of the Vredefort are considered to be impact-related.
- A sample of basement granite (left) from the Vredefort impact structure (right) has two veins. Vein 1 follows foliation and is cross-cut by Vein 2, suggesting an age relationship.



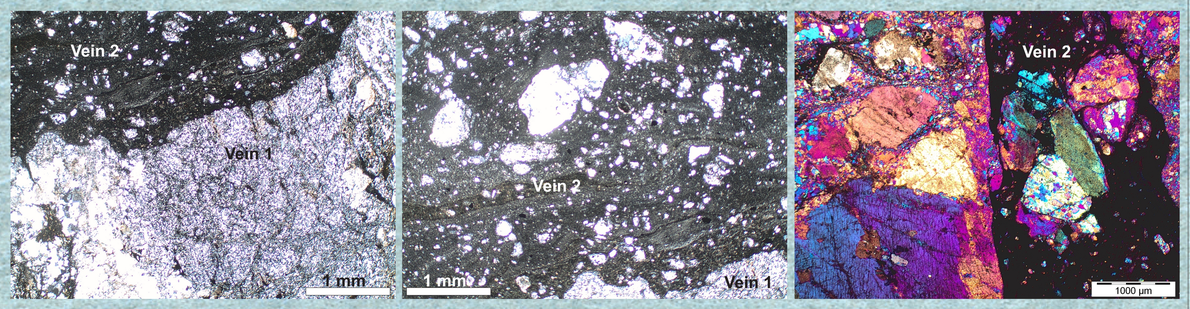
2.2 Ga Vredefort impact structure in South Africa

II

- **Thin sections and optical microscopy:**



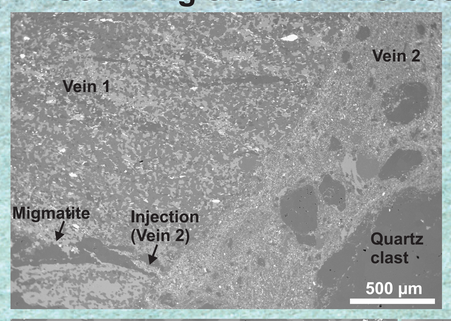
- Vein 1 is deformed, folded, recrystallized, foliated and offset, bears only a few clasts.
- Vein 2 is undeformed, irregularly-shaped, compositionally zoned, contains abundant clasts.
- Vein 1 is much older than Vein 2, hence the two veins formed as a result of different deformation events.



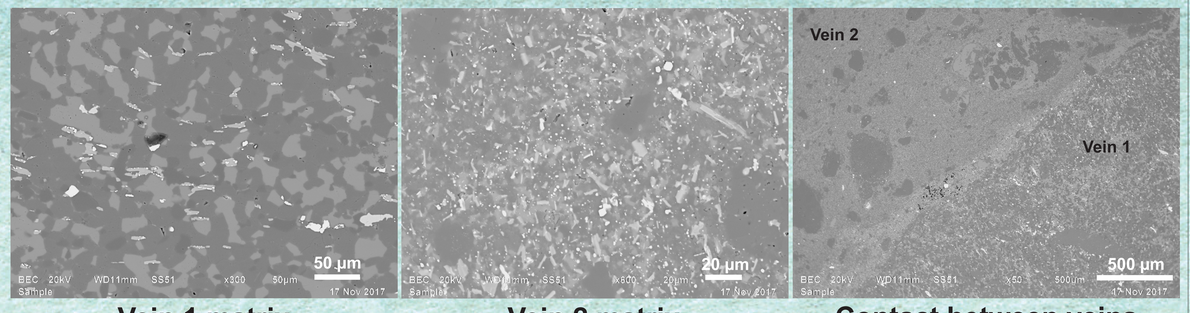
Contact between veins, XPL | Zoning in Vein 2, XPL | Clasts in Vein 2, XPL+gypsum plate

III

- **Scanning electron microscopy: backscatter electron images**



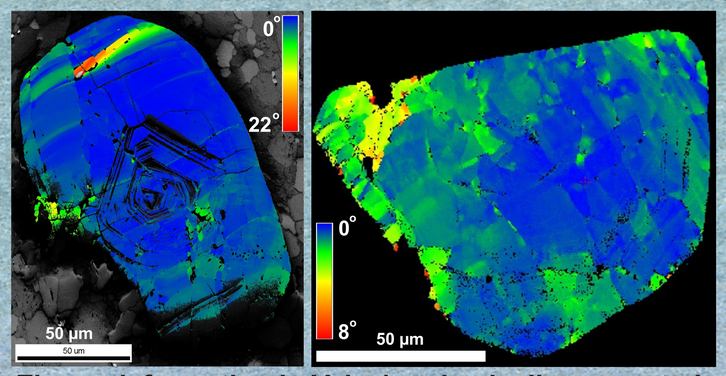
- Vein 1 is more coarse crystalline than Vein 2.
- The average grain size in Vein 1 is ~25 µm, biotite grains are oriented roughly parallel to the lineation.
- The average grain size of the groundmass in Vein 2 is ~5-10 µm. Microlites are not preferentially oriented.



Vein 1 matrix | Vein 2 matrix | Contact between veins

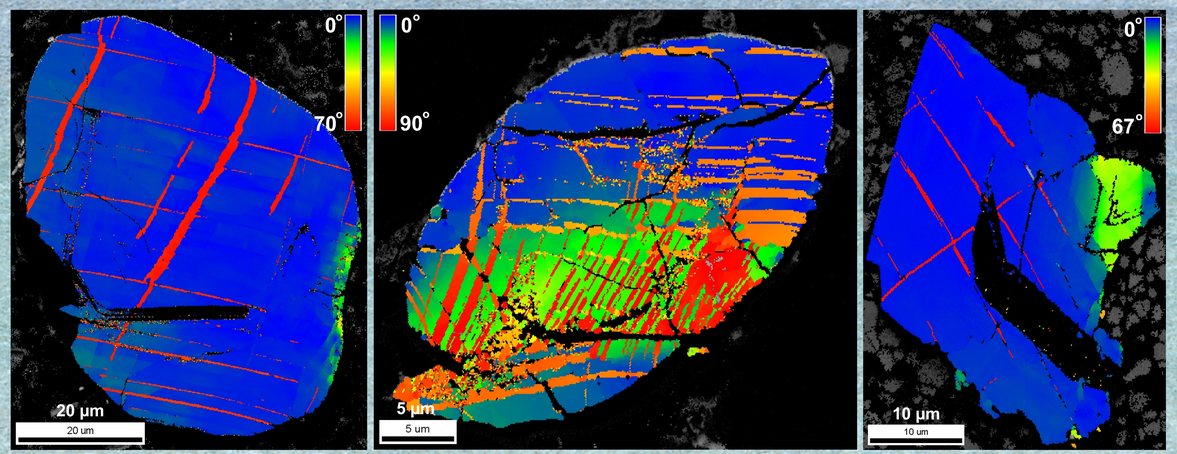
IV

- **Zircon deformation:** a solution to the problem of origin! Electron backscatter diffraction



- Deformation patterns in zircon from Vein 1 (left) are similar to seismic deformation: planar deformation bands (PDBs) and chessboard patterns (Kovaleva et al. 2015).
- Deformation patterns in zircon from Vein 2 (below) are shock microtwins: robust evidence of impact-related deformation (Moser et al. 2011).

Zircon deformation in Vein 1: seismically-generated planar deformation bands

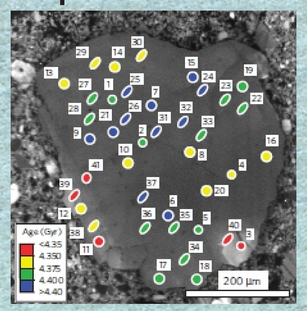


Zircon deformation in Vein 2: impact-generated shock microtwins

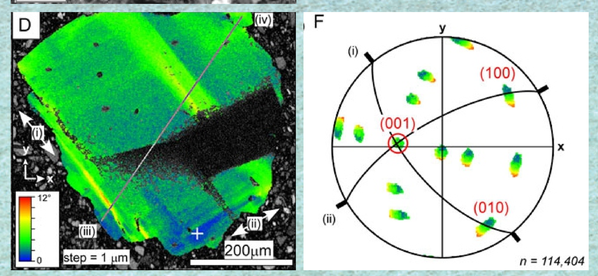
Conclusion: Vein 1 is of seismic origin, Vein 2 is of impact origin

V

- **Implications:** Can we apply this knowledge to zircon removed from its original context?



- "The Oldest" zircon from the Lunar breccia 72215 (Apollo 17) indicates the age of crystallization of the Lunar magma ocean at > 4.40 Ga (left).
- Younger domains, represented by red and yellow points (left), were interpreted as impact-related plastic deformation (Nemchin et al. 2009).



- EBSD map (Timms et al. 2012) shows that deformation pattern in "The Oldest" zircon is PDBs (left).
- PDBs are consistent with tectonic (seismic) deformation, which may have occurred as the Lunar magma ocean was crystallizing. *There is no evidence of shock deformation.*

References:

Kovaleva, E., Klötzli, U., Habler, G., and Wheeler, J. (2015) Planar microstructures in zircon from paleo-seismic zones. American Mineralogist, 100, 1834–1847.

Moser, D.E., Cupelli, C.L., Barker, I.R., Flowers, R.M., Bowman, J.R., Wooden, J., and Hart, J.R. (2011) New zircon shock phenomena and their use for dating and reconstruction of large impact structures revealed by electron nanobeam (EBSD, CL, EDS) and isotopic U–Pb and (U–Th)/He analysis of the Vredefort dome. Canadian Journal of Earth Sciences, 48, 117–139.

Nemchin, A., Timms, N.E., Pidgeon, R., Geisler, T., Reddy, S.M., and Meyer, C. (2009) Timing of crystallization of the lunar magma ocean constrained by the oldest zircon. Nature Geoscience, 2, 133–136.

Timms, N.E., Reddy, S.M., Healy, D., Nemchin, A.A., Grange, M.L., Pidgeon, R.T., and Hart, R. (2012) Resolution of impact-related microstructures in lunar zircon: A shock-deformation mechanism map. Meteoritics and Planetary Science, 47, 120–141.