A Review of Impact Melt and Breccia Dykes in Terrestrial Impact Structures

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Link to abstract

INTRODUCTION

Hypervelocity impact events produce a wide variety of impactites, including shocked rocks, impact melt rocks, and breccias. Impactites are found in 4 main geological settings within and around impact structures: (1) as crater-fill deposits within the crater interior, (2) as dykes in the crater floor, wall/terraces or central uplift, and in (3) proximal or (4) distal ejecta deposits [1]. Here, we compare observations of impactite dykes from terrestrial impact structures.

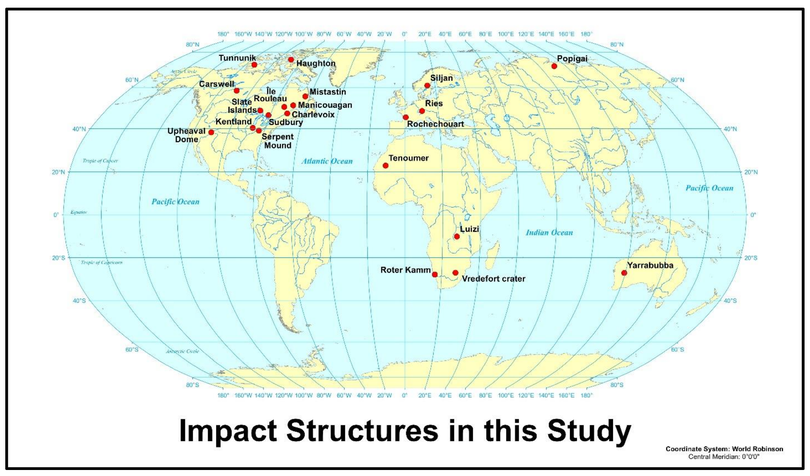


Fig. 1 (above). Distribution of craters in this study.

Table 1. Selected variables used in FAMD analysis.
Note that data was not always available for all variables.

Crater variables	**Level of exposure**	**Diameter (km)**		**Level of erosion** (scale from 1-7)	
Dyke variables	**Morphology**	**Orientation**	**Setting**	**Host rocks**	**Length / width (m)**
	Planar	Radial	Basement	Crystalline	Numeric variables
	Branching	Concentric	Uplift	Sedimentary	
	Anastomosing	Random	Wall/rim	Mixed	
		Along faults			
		Along contacts			
Lithology variables	**Matrix**	**Flow features**	**Breccia type**	**Origin**	
	Impact melt	Yes	Clast-supported	Allochthonous	
	Clastic	No	Matrix-supported	Parautochthonous	
	Pseudotachylite			Autochthonous	
Clast variables	**Content**	**Type**	**Shape**	**Variation**	**Origin**
	Clast-rich	Mineralic	Angular	Polymict	Locally derived
	Clast-poor	Lithic	Subangular / subrounded	Monomict	Local and exotic
	Clast-free	Lithic and glass	Rounded		Exotic

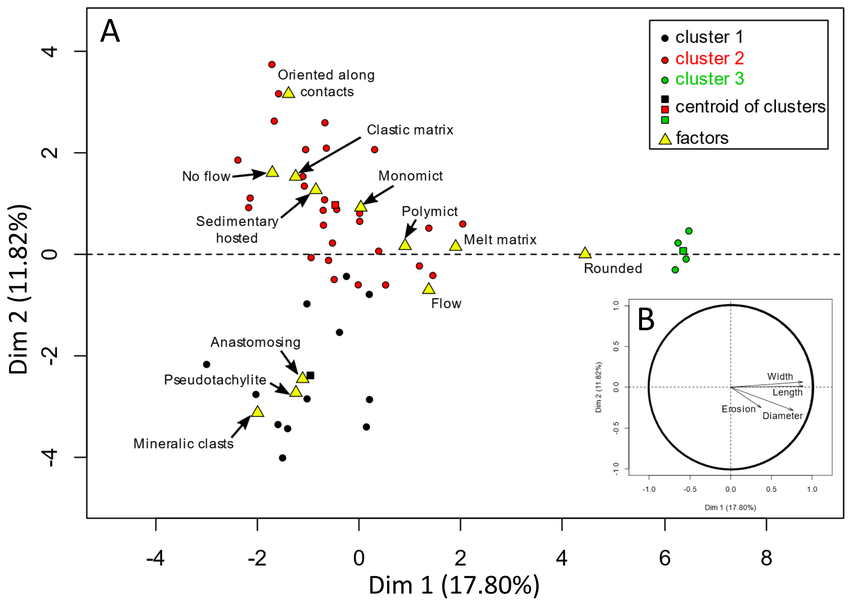
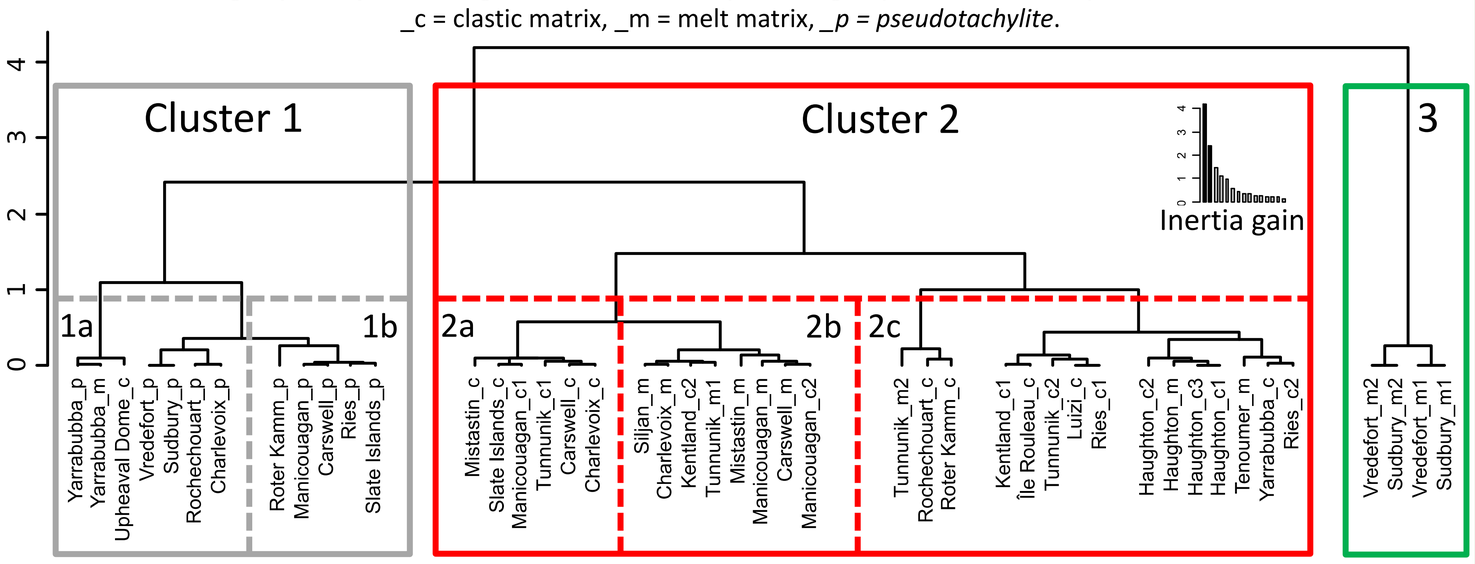


Fig. 2 (above). A) Factor map of the first 2 dimensions calculated using FAMD, accounting for 29.62% of the total variation. Select factors that contributed significantly to the variation are represented by yellow triangles. **B)** The contribution of the quantitative variables calculated using PCA.

METHODS

1. We identified 29 impact structures in which impactite dykes were mentioned in published, peer-reviewed journals
2. Of these, 9 were excluded for analysis due to:
   - Lack of description of dykes or;
   - No surface exposure
3. We identified types of dykes present in each
   - Pseudotachylite (n=10)
   - Clastic matrix (i.e., lithic breccia) (n=21)
   - Impact melt matrix (n=14)
4. We documented variables related to the dyke (Table 1)
5. These factors were analysed using **factor analysis of mixed data (FAMD)** in the software R. FAMD combines 2 techniques to describe a group of individuals (i.e., dykes):
   - Compare quantitative variables using **principal component analysis (PCA)** [2]
   - Compare qualitative variables using **multiple correspondence analysis (MCA)** [3]
6. We used this data to perform **hierarchical clustering on principal components (HCPC)** [4] to group the dykes based on the differences and similarities of their variables

Fig. 3 (below). Clustering results of HCPC analysis. Sub-groups are identified by dashed lines.
_c = clastic matrix, _m = melt matrix, _p = *pseudotachylite*.

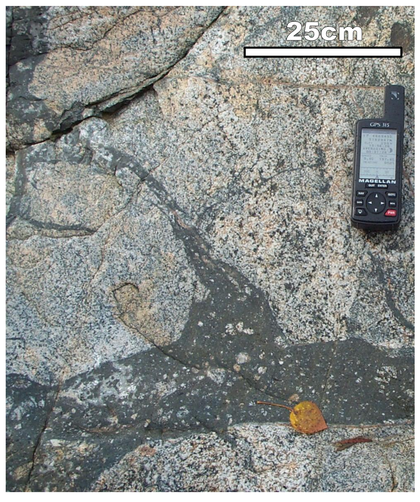


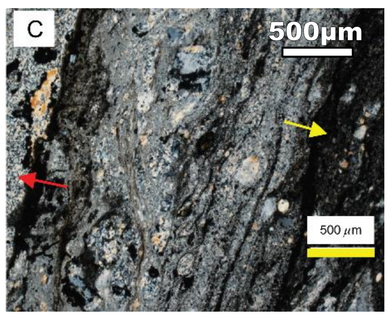
Cluster 1 – "Pseudotachylites"

Found in any size crater (2.5 – 300km)
Small size (often <1cm wide)
Anastomosing morphology

1a
Very short (often <1m long)
Uplift, rim, basement-hosted
No flow features
Primarily mineralic clasts

1b
Up to ~100m long
Basement-hosted
Flow features
Lithic and glass clasts





Pseudotachylite from Sudbury without (left) and with (top; image credit: [5]) flow banding

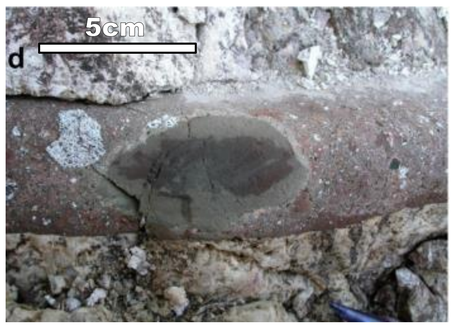
Cluster 2 – Clastic/melt, <10m

Mixture of clastic/melt matrix dykes
Typically 10s of m long, up to 10m wide
Basement or uplift hosted (2-100 km diameter)

2a
Clastic matrix
Mixed host
Some flow features
Polymict

2b
Melt matrix
Mixed host
Some flow features
Polymict

2c
Clastic matrix
Sedimentary host
No flow features
Monomict



Melt-bearing dyke from Manicuouagan (top; image credit: [6] and lithic breccia dyke from Haughton (right; Image credit: Jennifer Newman)

Cluster 3 – Impact melt, >100m

Only found in large craters >200km diameter
Can be 10s of km long, >100m wide
Contains well-rounded clasts
Typically polymict, local + exotic clasts
Commonly clast-rich interiors, clast-poor margins

The Foy Offset Dyke at Sudbury (top) and a boulder of Vredefort granophyre (left; image credit: [7])

CONCLUSIONS

- Three primary clusters are identified by FAMD and HCPC analysis: Pseudotachylite-type anastomosing dykes, **clastic / impact melt dykes <10m wide**, and **impact melt dykes ≥100m wide**
- Some variables are more critical to differentiating between clusters: **Length and width, morphology (i.e., anastomosing vs planar), clast roundness, types of clasts (mineralic vs lithic), flow features**
- The division between clastic-matrix and impact melt-matrix dykes in **cluster 2** is not clear when considering the selected variables.

References: [1] Osinski, G. R. et al. 2018. *J. Volcanol. Geoth. Res.* 353, 25–54. [2] Wold, s. et al. 1987. *Chemometr. intel. lab.* 2, 37–52. [3] Abdi, H. and Valentin, D. 2007. *Encyclopedia of measurement and statistics*, pp. 651–657. [4] Husson, F. et al. 2010. *Applied Mathematics Department.* [5] O'Callaghan, J.W. et al. 2016. *Econ. Geol.* 111, 1705–1729. [6] Thompson, L.M. and Spray, J.G. 2017. *Meteorit. & Planet. Sci. 52, 1300-1329.* [7] Reimold, W.U. and Koeberl, C. 2014. *J. Afr. Earth Sci.* 93, 57-175.

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