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Linking Sedimentary Textures to Neoproterozoic Climate Dynamics

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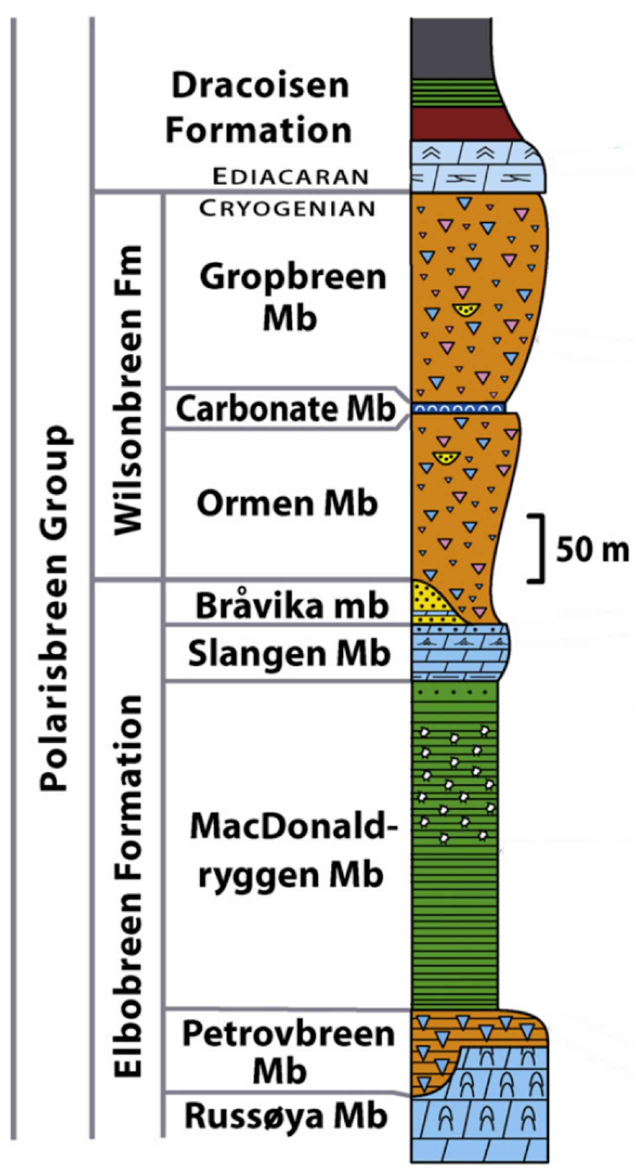
Introduction

The surface textures of siliciclastic grains, or **microtextures**, reflect the **transport history** and **depositional environment** of sedimentary grains. Recently, Smith (2016) demonstrated that the microtextures found in modern humid, arid, and glacial fluvial systems can serve as **paleoclimate indicators**. This result, when invoked alongside Walker et al.'s (1981) model of silicate weathering as a long-term control for Earth's global climate, suggests that **global climatic events like the Cryogenian "Snowball Earth" events may leave microtextural signatures in preserved sediments**.

The Bråvika Mbr. and J1701-156

(A)



(B)

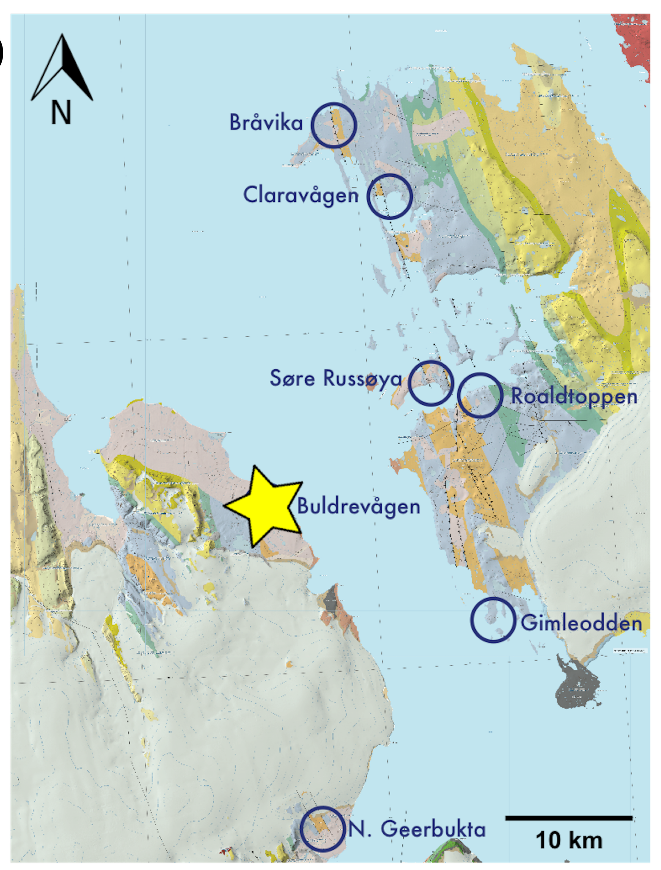


Figure 1. A) Composite stratigraphic column of the Polarisbreen Group of NE Svalbard (Hoffman et al., 2012). B) Map of NE Svalbard with the J1701-156 sampling location in Buldrevågen marked with a yellow star. Other Bergmann Lab sampling locations are marked with blue circles.

- **The Bråvika member** (Halverson et al., 2004) is a Cryogenian-aged, northward-thickening and coarsening-upward wedge of well-sorted and well-rounded quartz-chert arenite in the upper Elbobreen Formation of the Polarisbreen Group (Figure 1A; Hoffman et al., 2012) in Svalbard, Norway.
- Bråvika member has **varying facies interpretations**:
  1. **Terrestrial proglacial outwash** (sandur) facies associated with the Marinoan diamictites of the Wilsonbreen Fm. (Halverson et al., 2004).
  2. **Aeolian origin** with potential subaqueous reworking, **non-glacial** (Halverson, 2011; Hoffman et al., 2012).
- **J1701-156** is a well-sorted and well-rounded dolomitic sandstone from the Bråvika member.
- Julia Wilcots, a graduate student in the Bergmann Lab, collected J1701-156 from **Buldrevågen** (Figure 1B) in 2017. The sample was collected **156 m** above the contact with the Slangen member at 79°59.4895', 17°31.3329'.

Petrography and EDS Results

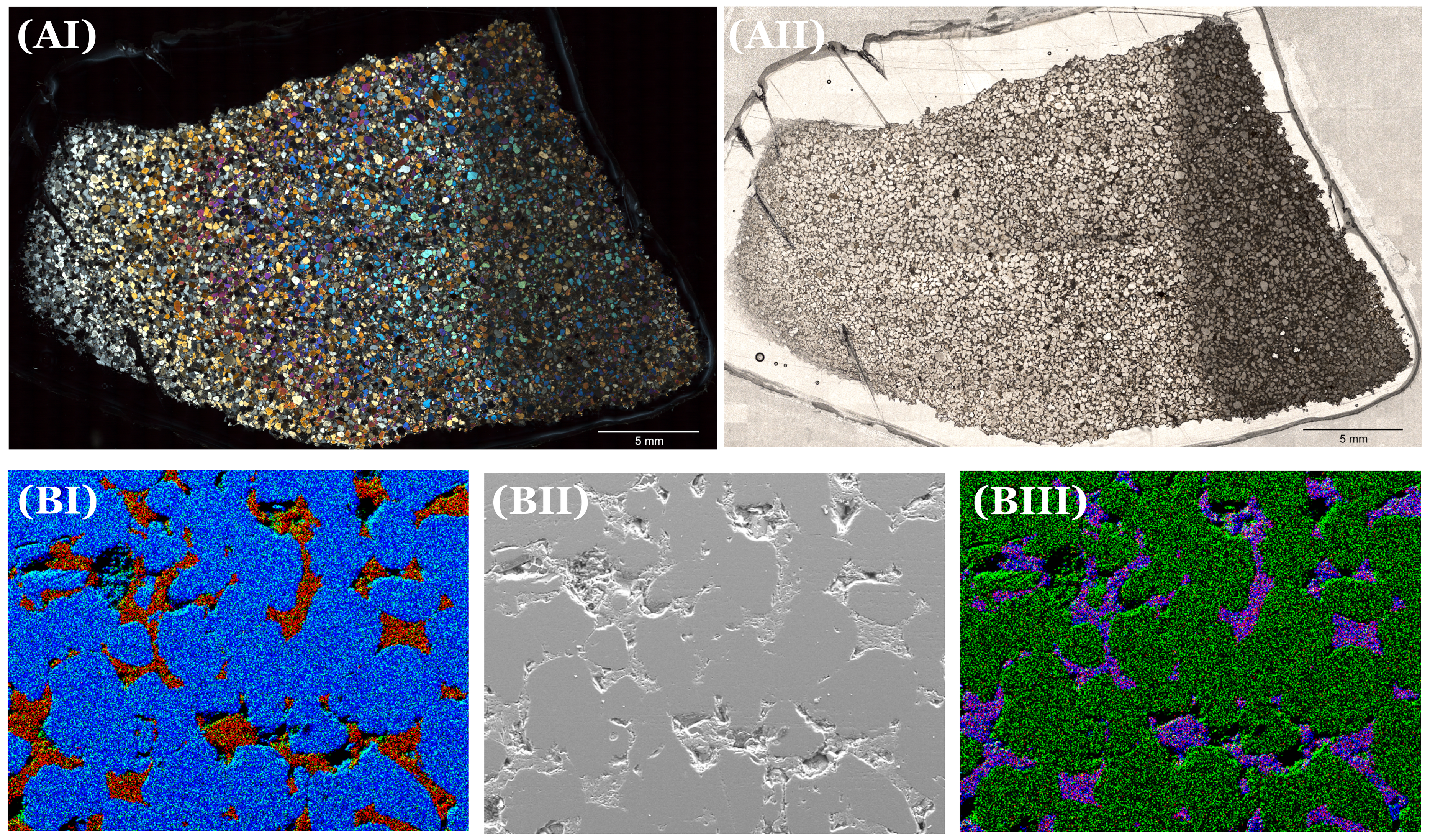


Figure 3. A) Stitched images of J1701-156 thin-section in AI) XPL and AII) PPL. Note the increasing birefringence in the quartz grains from left to right. B) EDS maps of polished J1701-156 section: BI) RGB map of R: Calcium, G: Oxygen, B: Silicon; BII) SE2 image of polished J1701-156 section; BIII) RGB map of R: Magnesium, G: Oxygen, B: Calcium

Quantitative SEM Results

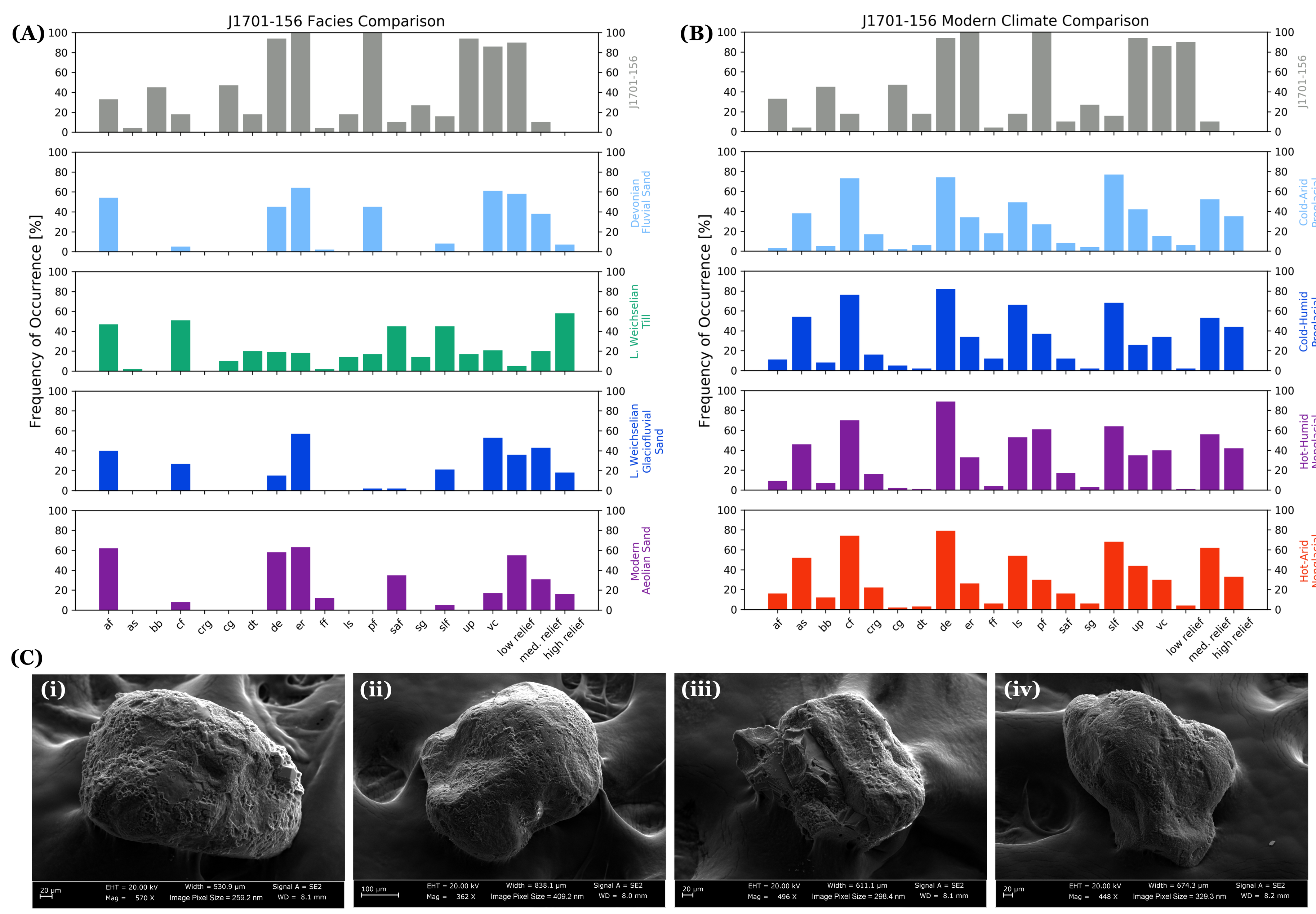


Figure 4. A) Facies comparison of J1701-156 SEM microtexture frequency with SEM microtexture frequencies of (from top to bottom): Devonian fluvial sand (Mahaney et al., 2001); Late Weichselian till (Mahaney et al., 2001); Late Weichselian glaciofluvial sand (Mahaney et al., 2001); and modern aeolian sand (Mahaney, 2002). B) Modern climate comparison of J1701-156 SEM microtexture frequency with SEM microtexture frequencies of (from top to bottom): cold-arid proglacial environment (Peru; Smith, 2016); cold-humid proglacial environment (Norway; Smith, 2016); hot-humid nonglacial environment (Puerto Rico; Smith, 2016); and hot-arid nonglacial environment (California; Smith, 2016). Refer to Table 1 for microtexture names. C) Sample images of treated quartz grains from J1701-156: i) well-rounded, low-relief grain with large quartz overgrowths; ii) well-rounded, low-relief grain with bulbous, rounded edges and dissolution etching; iii) well-rounded, medium-relief grain with precipitated features and straight grooves(?); iv) well-rounded, low-relief grain with v-shaped percussion cracks and upturned plates.

Methods: Petrography, EDS, and SEM

- Sample was analyzed under the **blind conditions** of Smith (2016).
- **Petrography:**
  - **Created a thin section of J1701-156** of ~30 μm thickness using a Struers Accutom-100 Saw and Struers LaboPol Polisher.
  - **Created detailed, stitched ima**ges of sample in **cross-polarized light (XPL)** and **plane-polarized light (PPL)** using a Zeiss Axio Imager Polarizing Microscope (Figure 2, AI, AII).
- **Semi-Quantitative Energy Dispersive Spectrometry (EDS):**
  - **Created a thick section of J1701-156**, polished it to 1 μm grit using the Struers LaboPol Polisher, and **coated it with 5 nm 80/20 Pt-Pd** to prevent charging under the SEM.
  - Used Zeiss FESEM Ultra55, its accessory AMTEK EDAX EDS System, and EDAX Genesis (v. 6.51[a]) at the Harvard Center for Nanoscale Systems (CNS) to **create EDS maps of J1701-156**.
  - **Converted resultant .BMP image files to .FITS** using ImageJ (v. 1.47ib) and used .FITS files to **create RGB images** of selected elements (Figure 2, BI, BIII) using SAOImage DS9 (v. 7.5[c]).
- **Quantitative Scanning Electron Microscopy (SEM):**
  - **Disaggregated quartz grains** in J1701-156 from carbonate matrix in 20% hydrochloric acid solution at 50°C; **wet sieved grains** to 150 – 1000 μm grain size fraction; treated grains with 20% hydrochloric acid solution at 50°C for 24 hours to **remove remnant carbonate coatings**; and treated grains using **citrate-bicarbonate-dithionite (CBD) method** (Janitsky, 1986) to **remove iron-oxide and manganese-oxide coatings**.
  - Arranged **50** randomly-selected, treated grains into 10 rows and 5 columns on an aluminum SEM stub with double-sided carbon tape in the manner as Smith (2016). **Coated the grains with 5 nm 80/20 Pt-Pd** to prevent charging under the SEM.
  - Used Zeiss FESEM Ultra55 at the Harvard CNS to **capture high-resolution images** of each quartz grain. Used EDS system to **confirm quartz mineralogy**.
  - **Recorded the presence/absence of 17 microtextures** (Table 1) in each image in the style of Mahaney (2002).

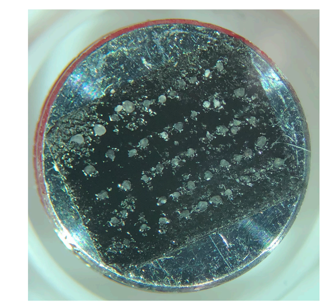


Figure 2. SEM stub with arranged grains

Microtexture Name	Abbreviation	Microtexture Name	Abbreviation	Microtexture Name	Abbreviation	Microtexture Name	Abbreviation	Microtexture Name	Abbreviation
Abrasion features	af	Arc-shaped steps	as	Breakage blocks	bb	Conchoidal fractures	cf	Crescentic gouges	crg
Curved grooves	cg	Deep troughs	dt	Dissolution etching	de	Edge rounding	er	Fracture faces	ff
Linear steps	ls	Precipitation features	pf	Sharp angular features	saf	Straight grooves	sg	Subparallel linear fractures	slf
Upturned plates	up	V-shaped percussion cracks	vc						

Table 1. Microtexture names and abbreviations

Interpretations and Future Work

- J1701-156's high proportion of low-relief grains and v-shaped percussion marks (Figure 4A) indicate that the Bråvika member may represent a fluvial facies, but the high frequency of post-depositional silica overgrowths and dissolution etching on the grains due to age may have overprinted other microtextures.
- There appears to be no relationship between J1701-156's microtextures and any of the climate regimes of Smith (2016) (Figure 4B). The high frequency of post-depositional silica overgrowths and dissolution etching due to age may have overprinted other microtextures.
- There is significant variance in microtextural identification between this study, Mahaney et al. (2001), Mahaney (2002), and Smith (2016).
- To better interpret the results in Figure 4A and Figure 4B, PCA analysis will be applied to these results.
- Future work will compare J1701-156 with a modern depositional environment that represents one of the proposed endmember facies for the Bråvika member.

Acknowledgements

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b. https://imagej.nih.gov/ij/download.html
c. http://ds9.si.edu/site/Download.html