A large Paleozoic paleokarst system in Spitsbergen Svalbard

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Outline

- Geological setting
- The Spitsbergen breccias
- The brecciation process
- Seismic scale features
- Karst models and spatial distribution
- Diagenesis and timing of the karst system
- Barents Sea analog
- Conclusions

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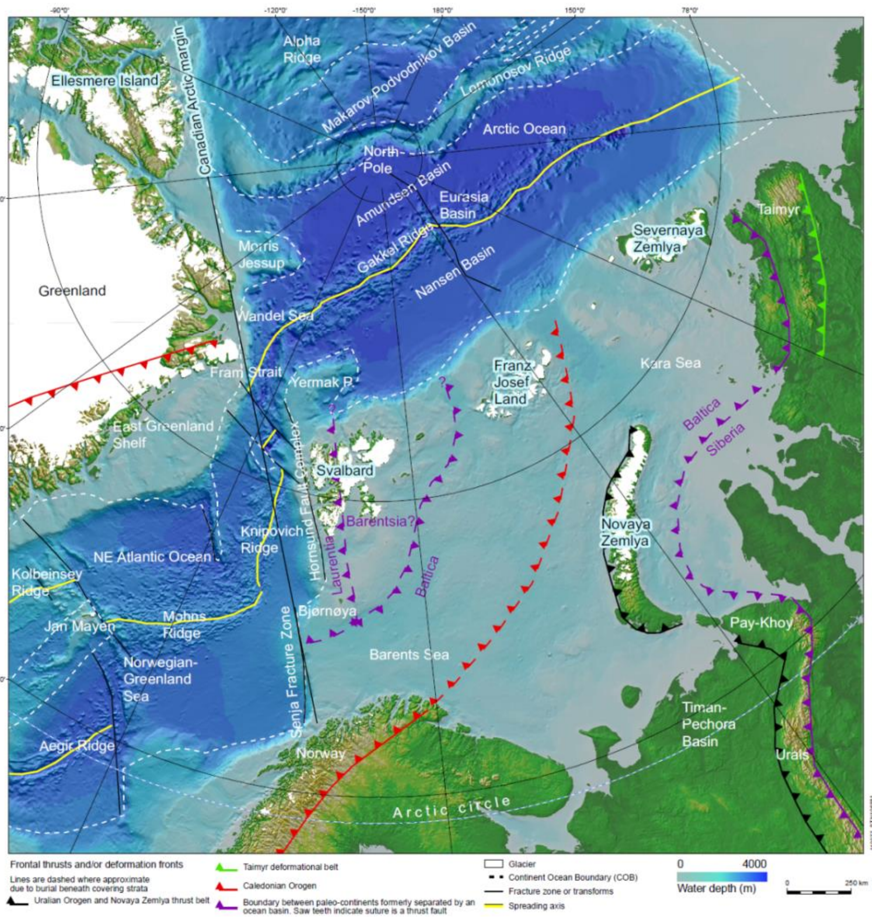
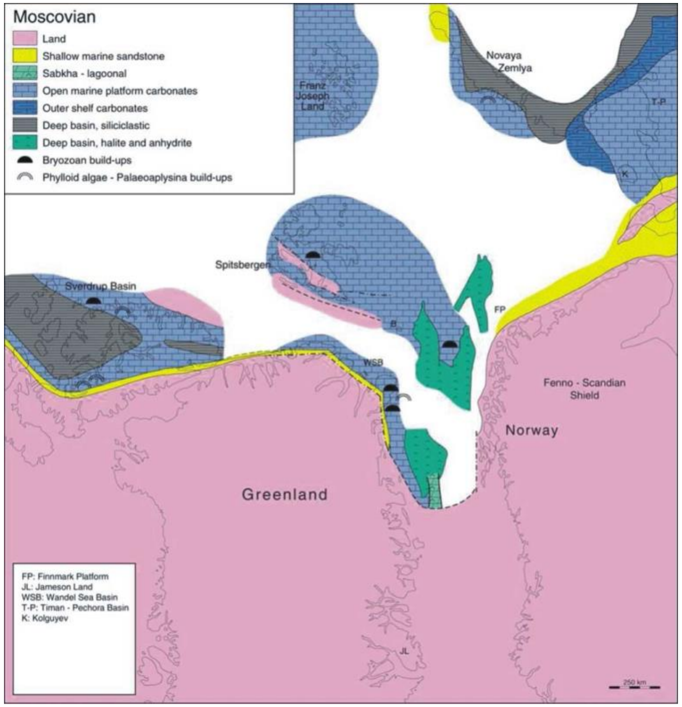
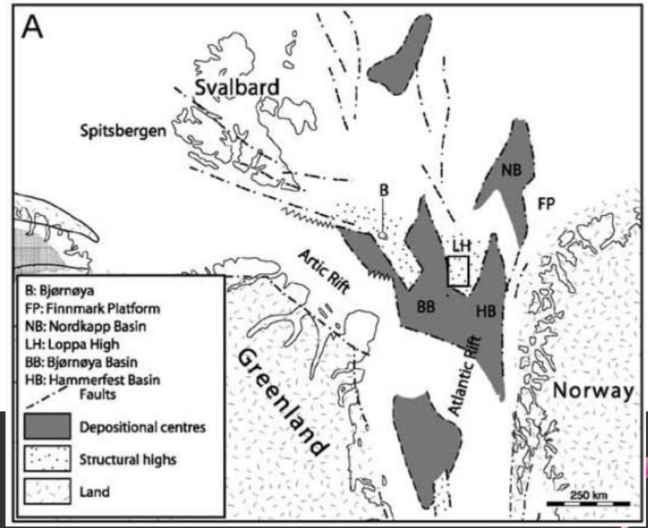
Geological setting





Moscovian Paleogeography (Stemmerik 2000)



From Elvebakk 2003

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Geological setting

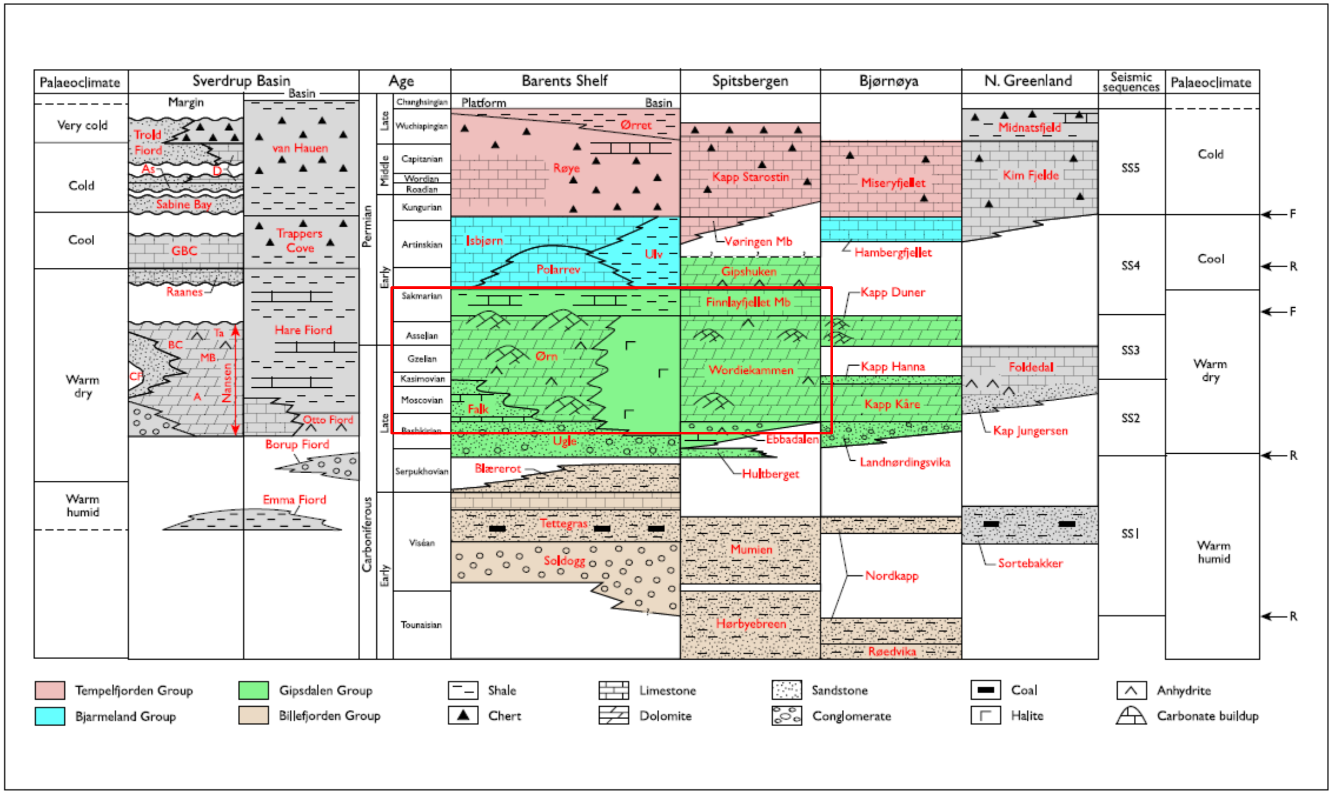
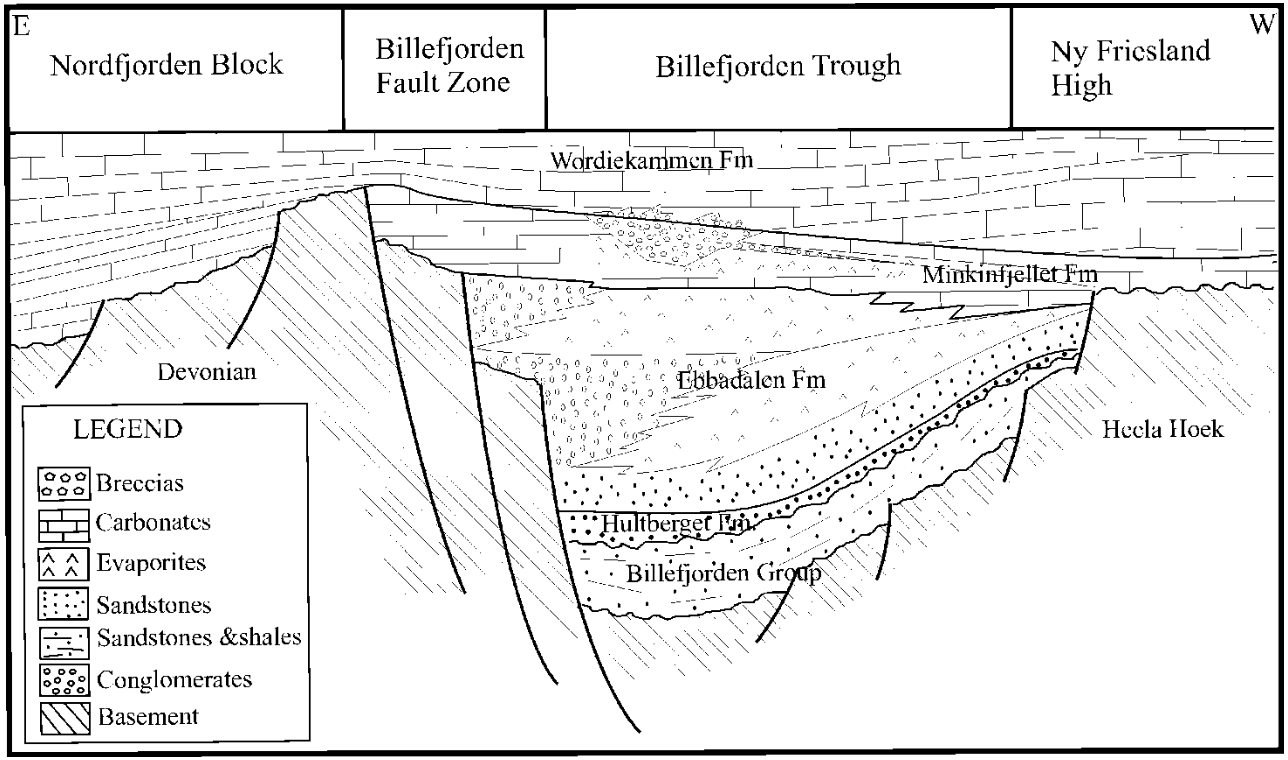


Fig. 2. Correlation of Upper Palaeozoic lithostratigraphic units between southern Norwegian Barents Sea, Svalbard, North Greenland and Arctic Canada with seismic sequences from the Finnmark Platform. Based on data in Dallmann et al. (1999), Beauchamp et al. (2001), Beauchamp & Baud (2003), Stemmerik (1997, 2000), Lindström (2003), Samuelsberg et al. (2003). A: Antoniette, D: Degerböls, BC: Belcher Canyon, CF: Canyon Fiord, MB: Mount Bayley, Ta: Tanquary, GBC: Great Bear Cape.

- The Late Carboniferous to Eary Permian Carbonates in Svalbard and the Barents sea is the adressed units

Geological setting



- The Billefjorden Trough: a narrow rift basin in Spitsbergen.
- The stratigrafic unit is the upper syn rift Minkinfjellet and the post rift Wordiekammen units

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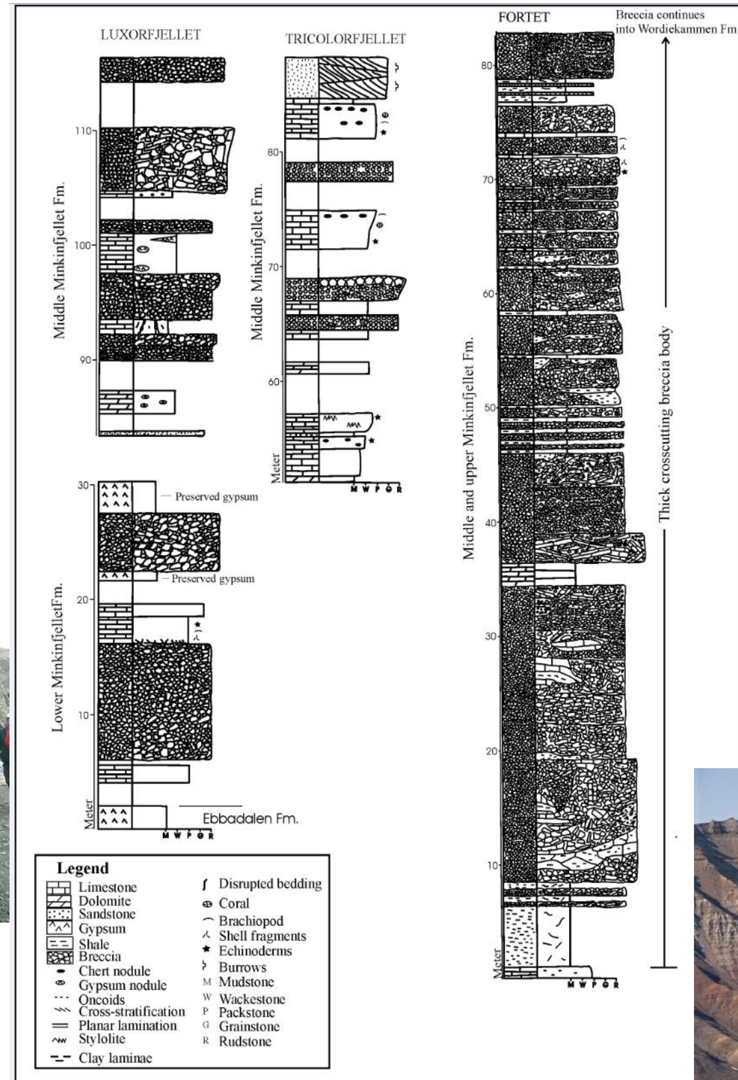
Breccias

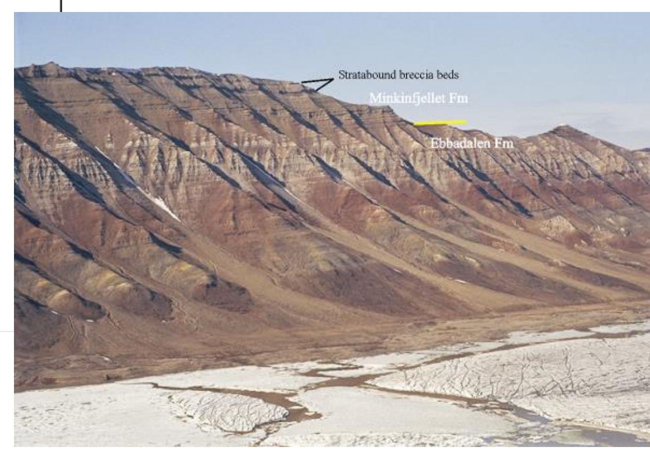
Thick breccia found at Fortet. Dark colour due to bitumen staining – Paleo reservoir



Massive breccia unit found in the central part of the basin – Fortet member

Stratabound breccia beds of 1-15 m thickness are commonly present in a large area

How were they formed?



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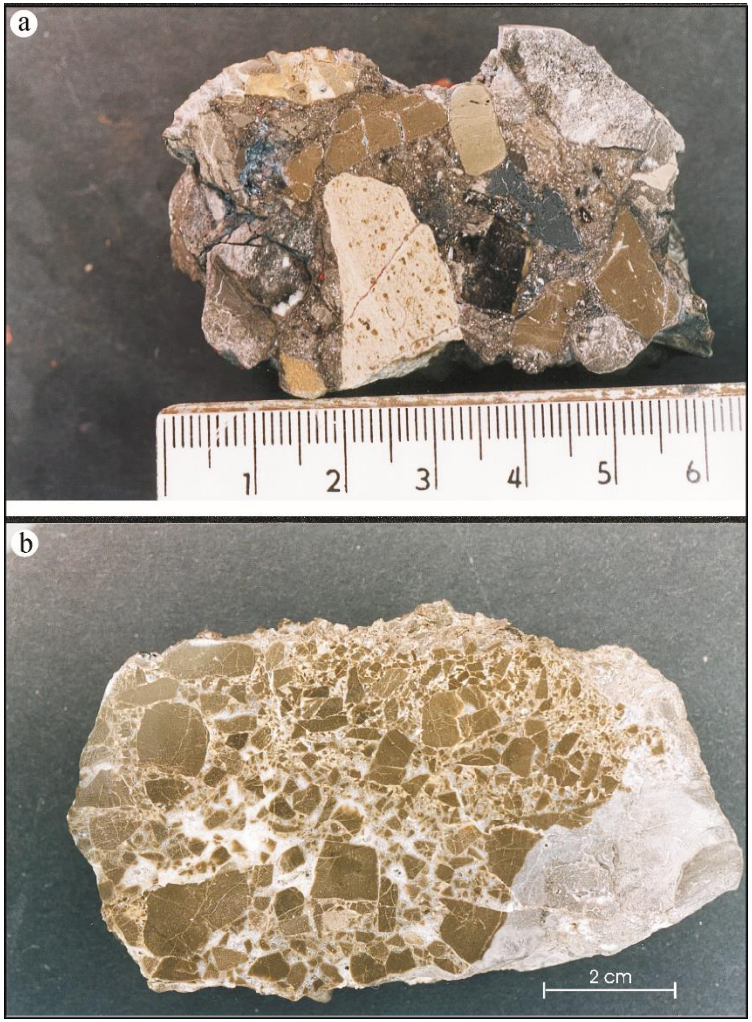
Breccias



Both polymict and monomictic breccias occur

Many of the breccias show Hydrocarbon staining.

Many types of breccias occur: from Monomict crackle breccias to highily chaotic re-brecciated polymict units.

The breccia type are connected to the degree of mixing during the collapse.

Several episodes of karst collapse lead to formation of complex breccias

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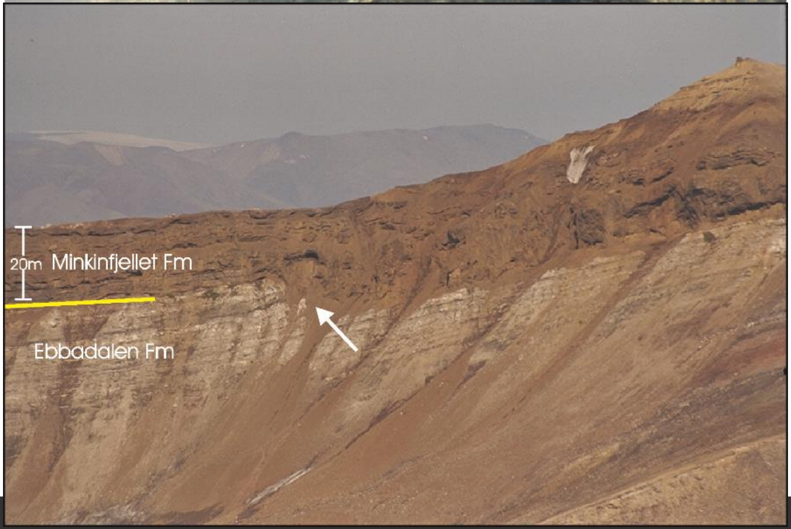
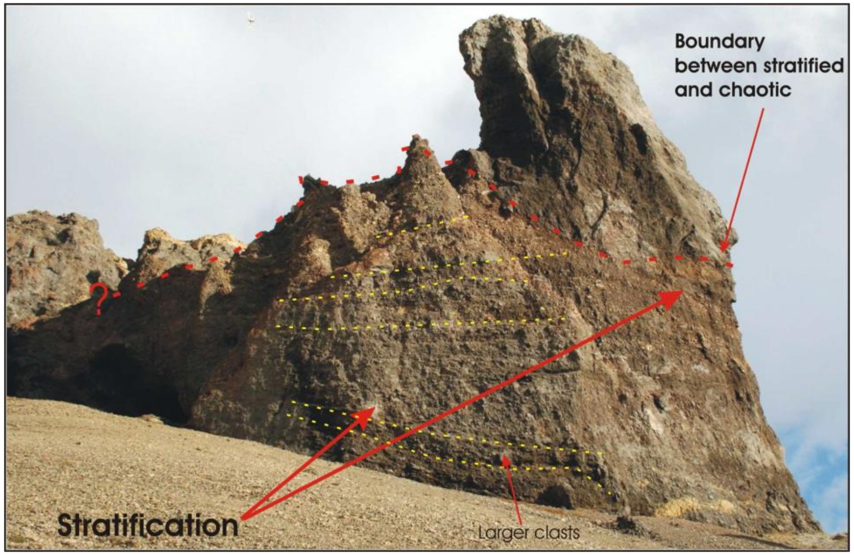
Brecciation process- evaporite karst



- The dominant process forming the breccias is dissolution of anhydrite beds followed by the collapse of overlying beds
- More recents studies have shown that the karst system is more complex and that classic carbonate karst is also a key process



Stratified sedimentary breccias (Nordeide 2008)

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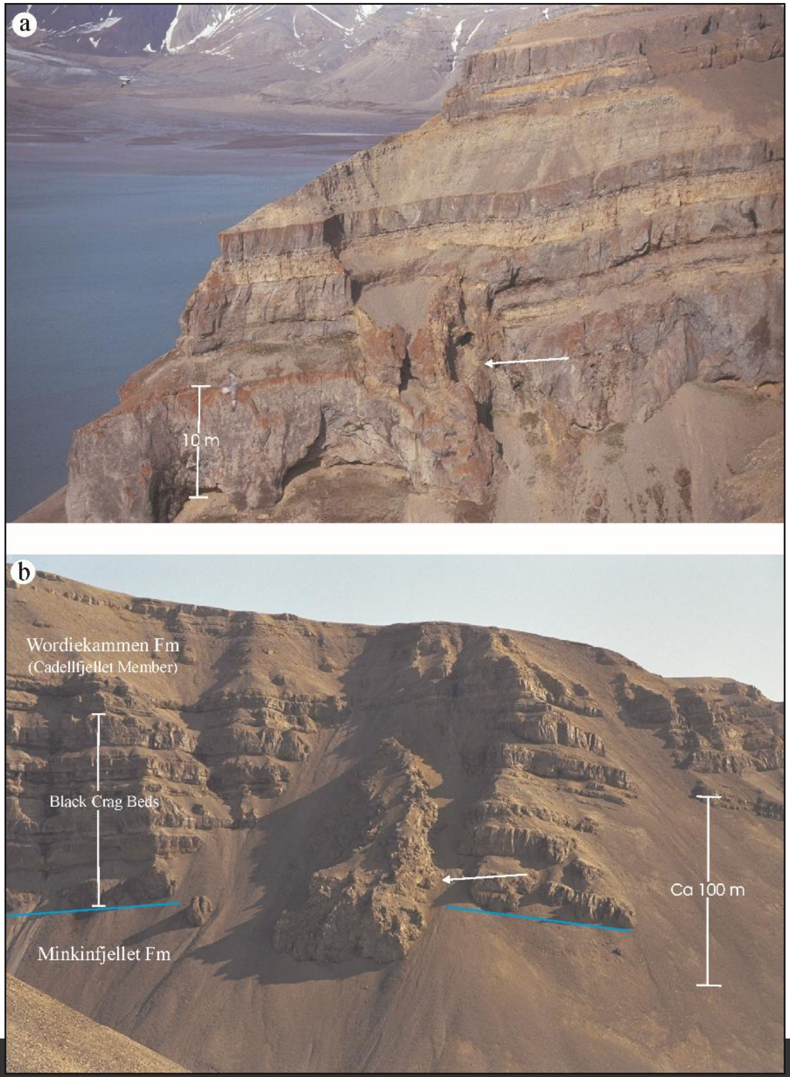
Brecciation Process - karst



Paleosinkholes is seen in the overburden of the main breccia bodies

Some of them have a huge size (minimum 300 meters) and have a circular shape.

Results of catastrophic collapse- propagation to the surface.

The stratigraphic position of these sinkholes give information about the timing of the collapse

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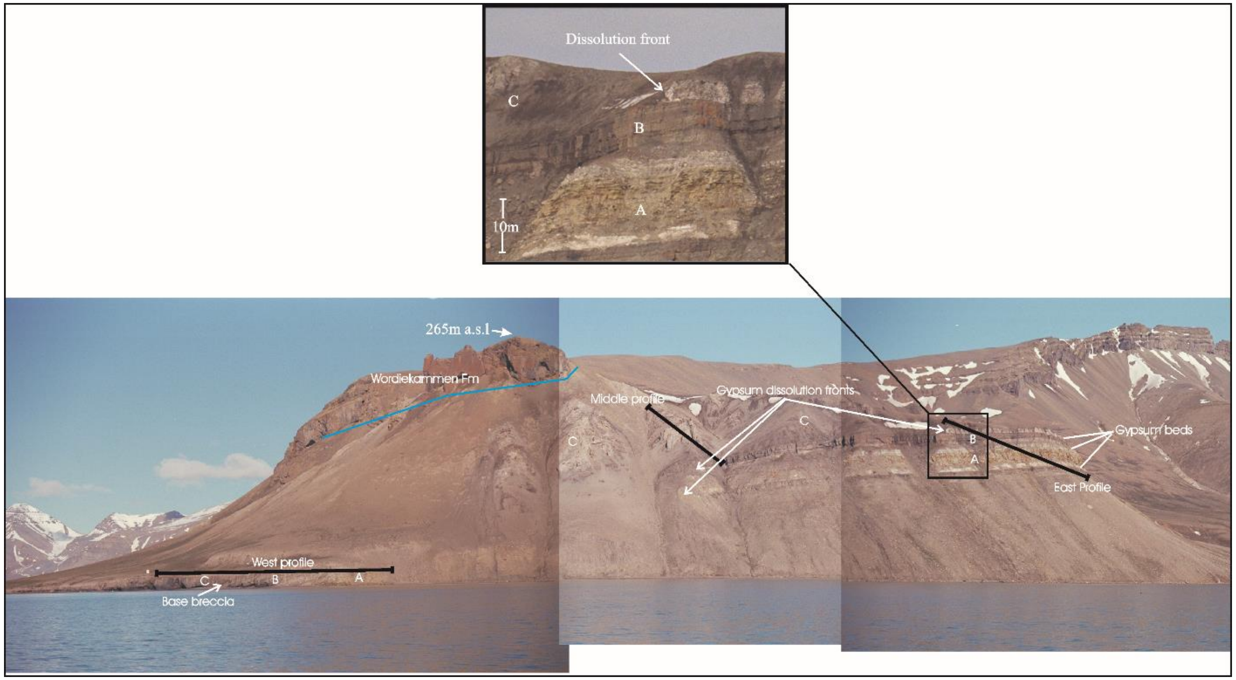
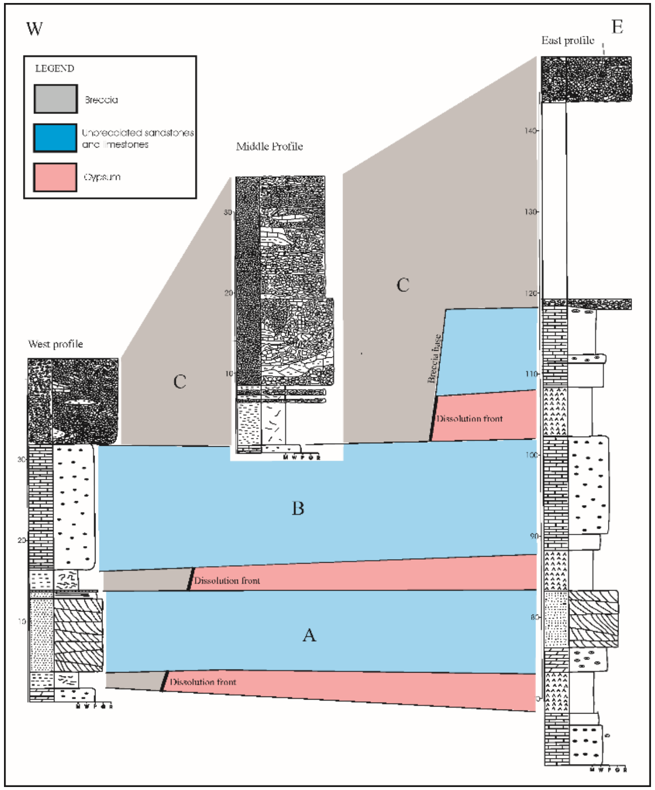
Brecciation Processes

- Sharp flat base of both stratabound breccia beds and large coalesced breccia bodies
- Typical for evaporite karst – the base of the breccia follow the original stratabound evaporite beds

Seismic scale breccia system

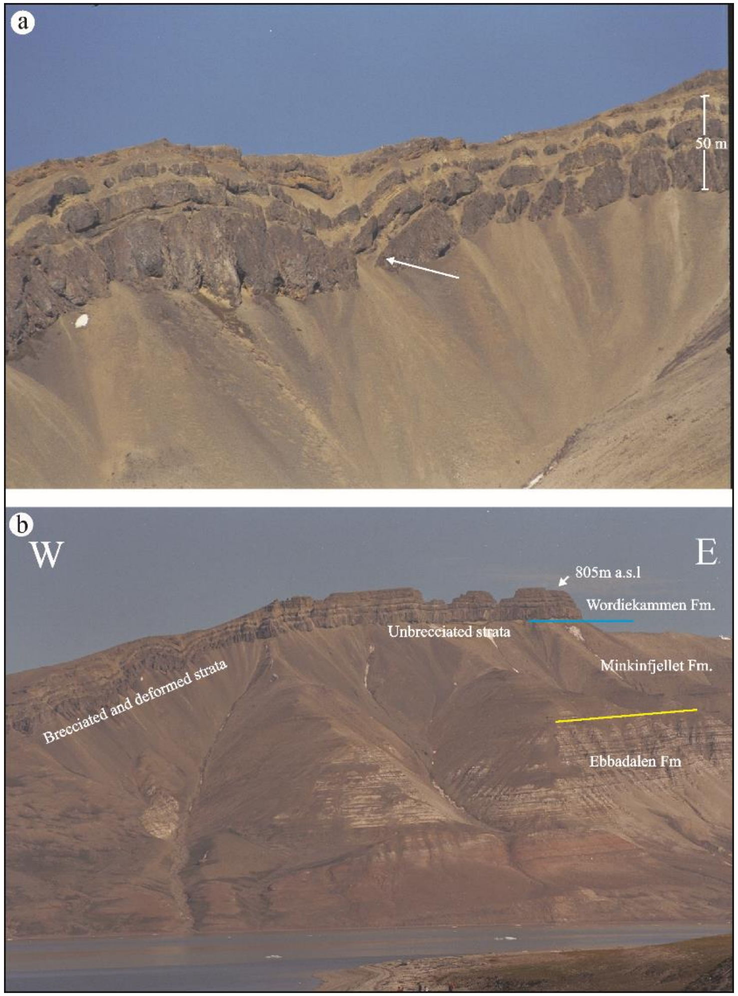




The karst system on Rudmosepynten is of seismic dimensions

The log correlation show that the karst system was deeper and more intense towards the central basin. System stepping up in the stratigraphy towards the east

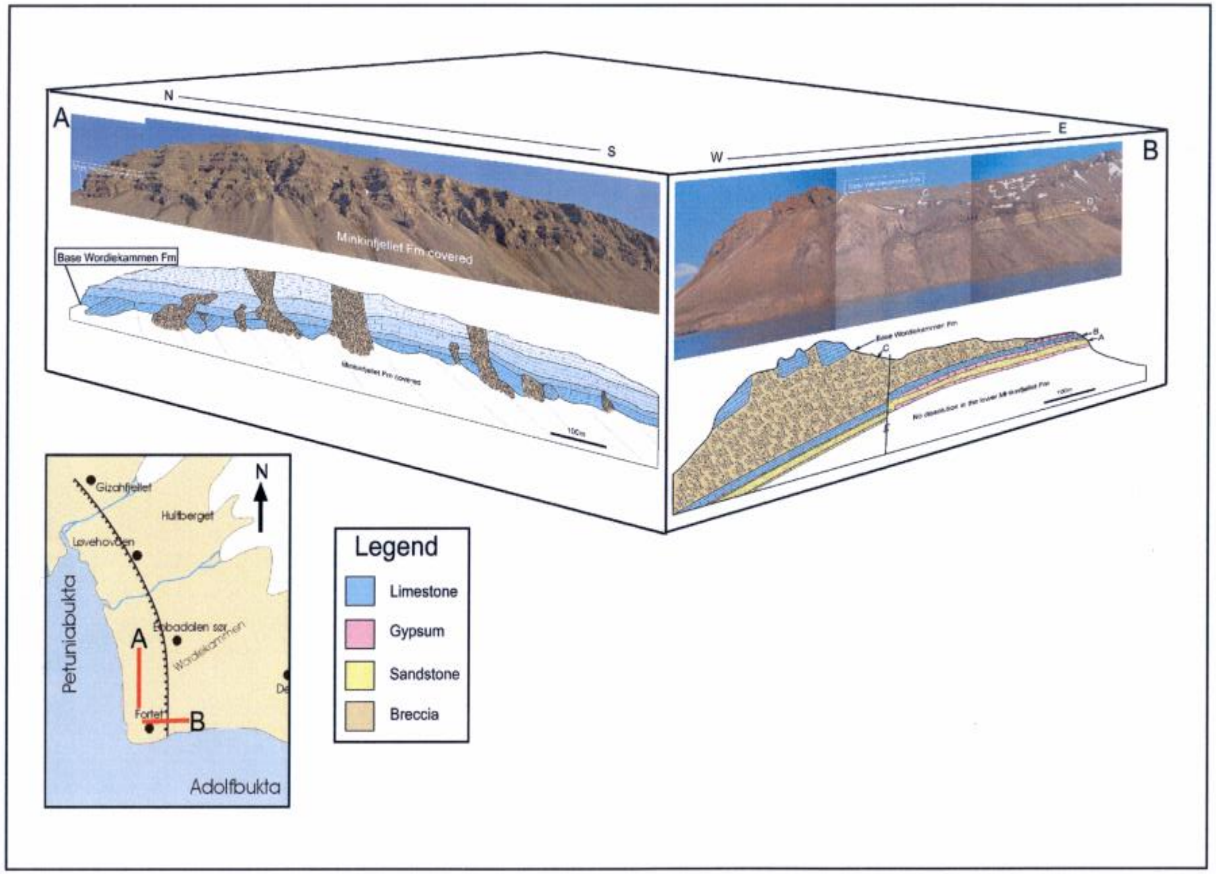
Seismic scale karst features



The evaporite dissolution has affected the non-evaporitic overburden

Large scale V-structures is seen above the most intensely karstified areas

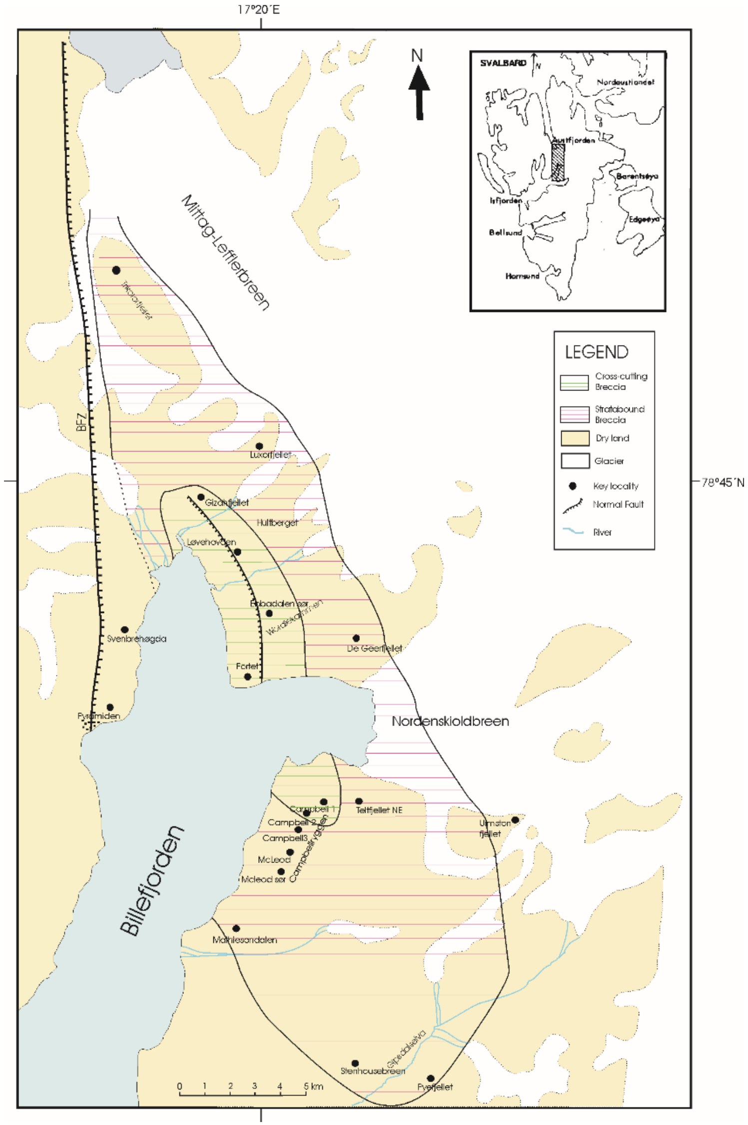
Karst Distribution



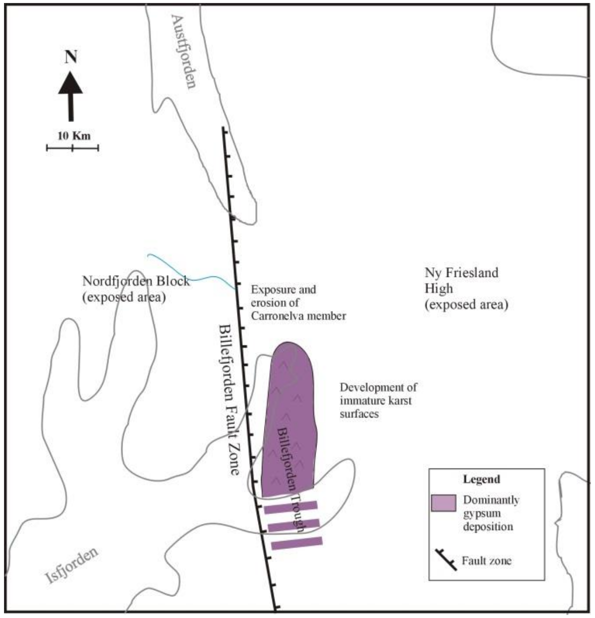
A summary model for the outcrop at Fortet.

The relationship between massive coalescent breccia units and the sinkholes/breccia pipes can be observed

Karst distribution and size



- In total the breccia and karst system is present within an area of approximately 10 x 40 km
- This is a minimum estimation of the size of the system – due to limitation of outcrops
- The central basin show more intense karstification than the basin margins. This is controlled by the primary deposition of evaporites



A lowstand in the mid Minkinfjellet fm contolled the deposition of thick evaporites at this stage

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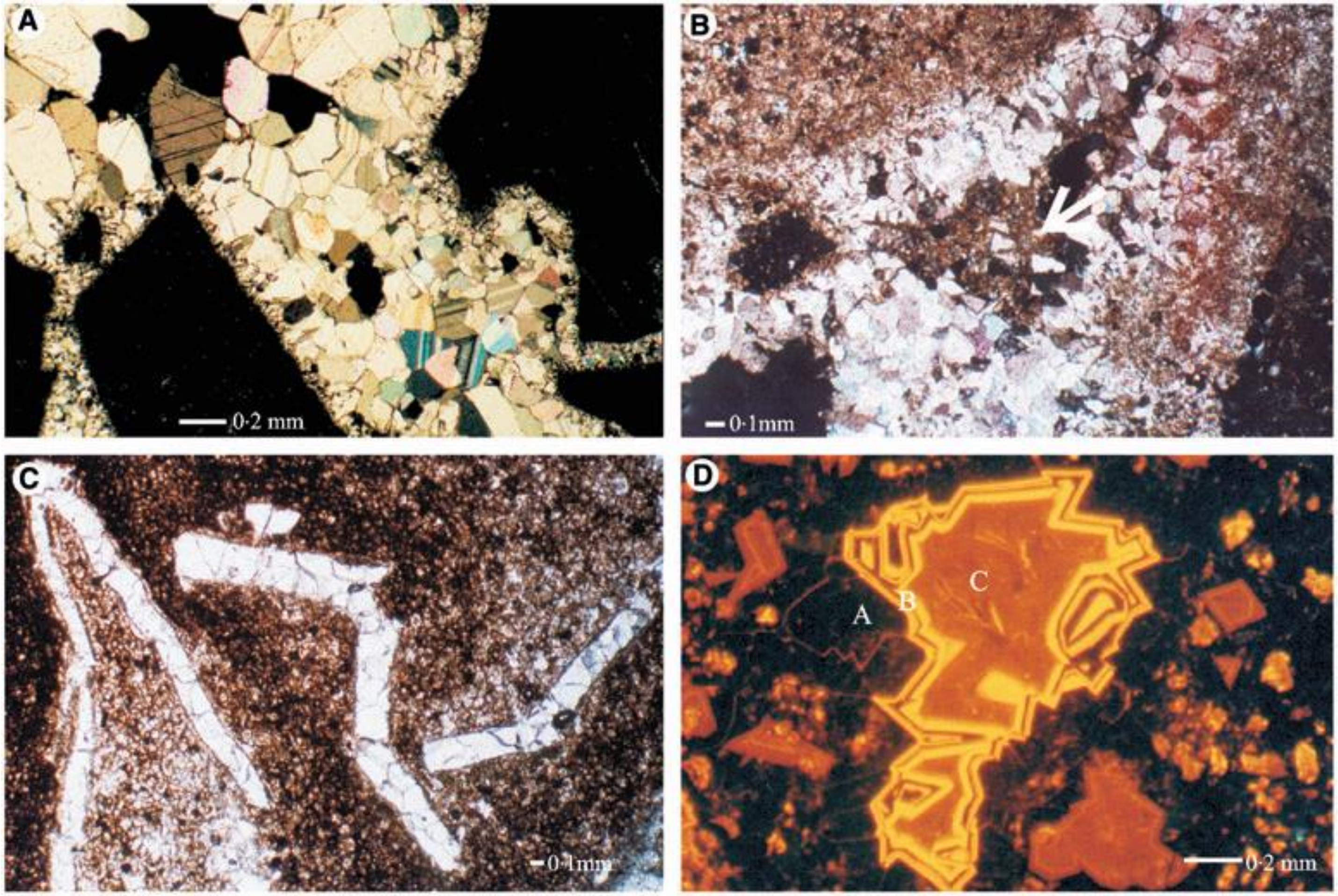
Breccia diagenesis



- Pre-compaction shalow burial drusy cements (A)
- Vadoze silts (B)
- Re-brecciation (C)
- Generations of cements seen in CL (D)

- Fluid inclusions in the cements gave final melting temperatures of 0,0 to +0,1 C

Cementation in fresh pore waters

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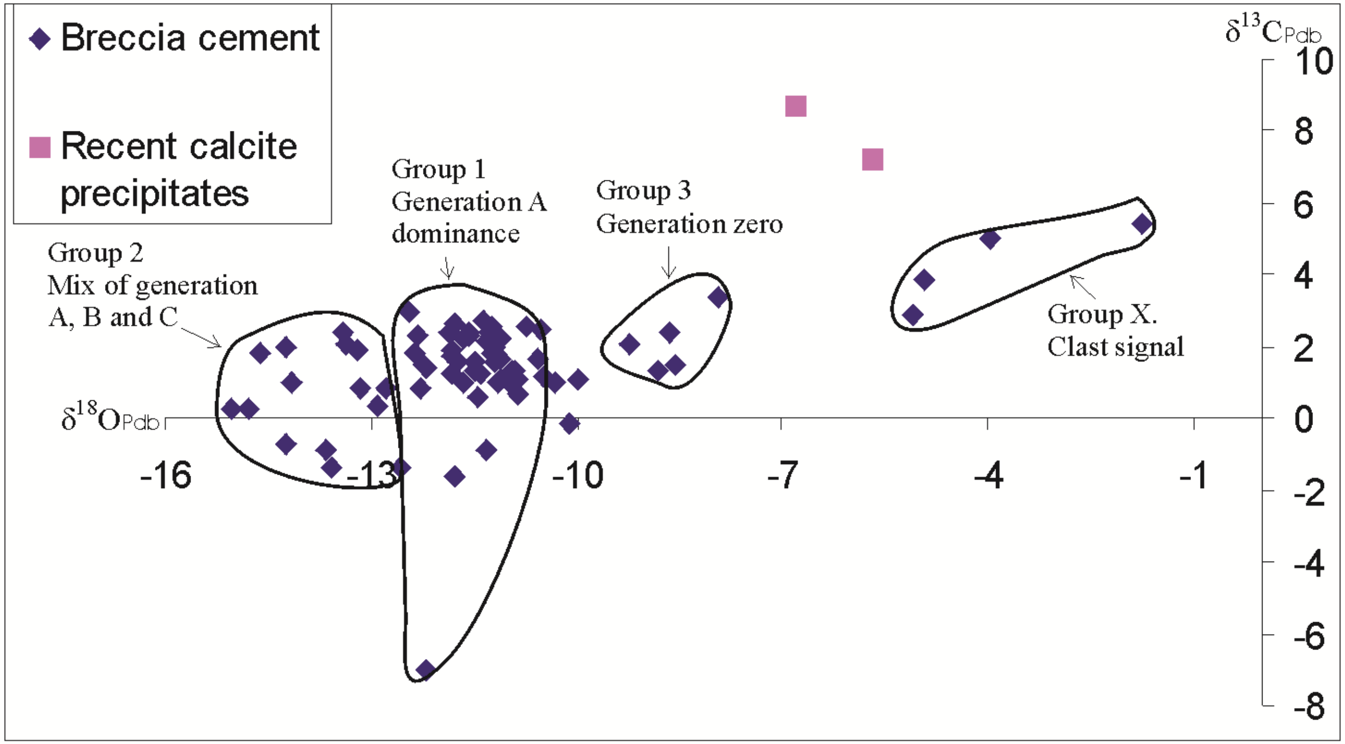
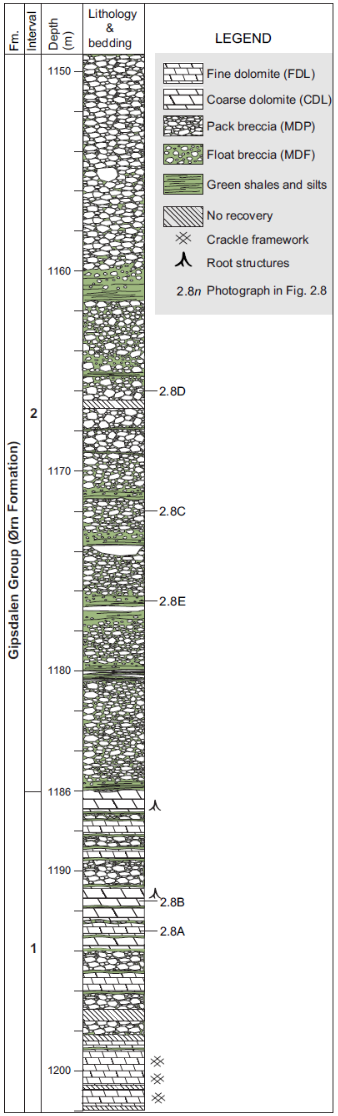
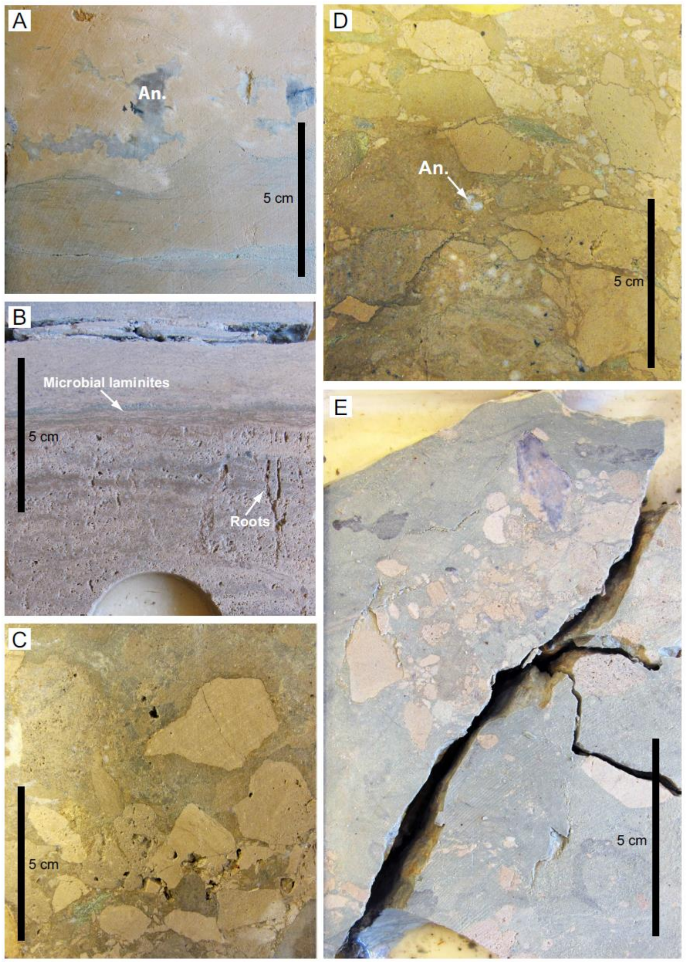
Timing

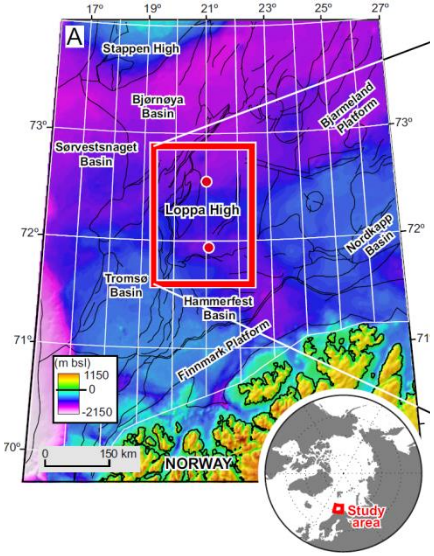


- Stable isotopes of the Breccia cements suggest that the cements are precipitated during increasing temperatures
- Group 1 is still more negative than the Moscovian meteoric calcite line (-7,4). Meaning that the meteoric cement must be warm (35 C) which correspond close to 500 m burial depth.
- The high breccia pipes into the overburden supports such a deep karst system
- **The karst system is probably related to known Gzelian and Asselian/Sakmarian long lived exposures**

The Barents Sea analog

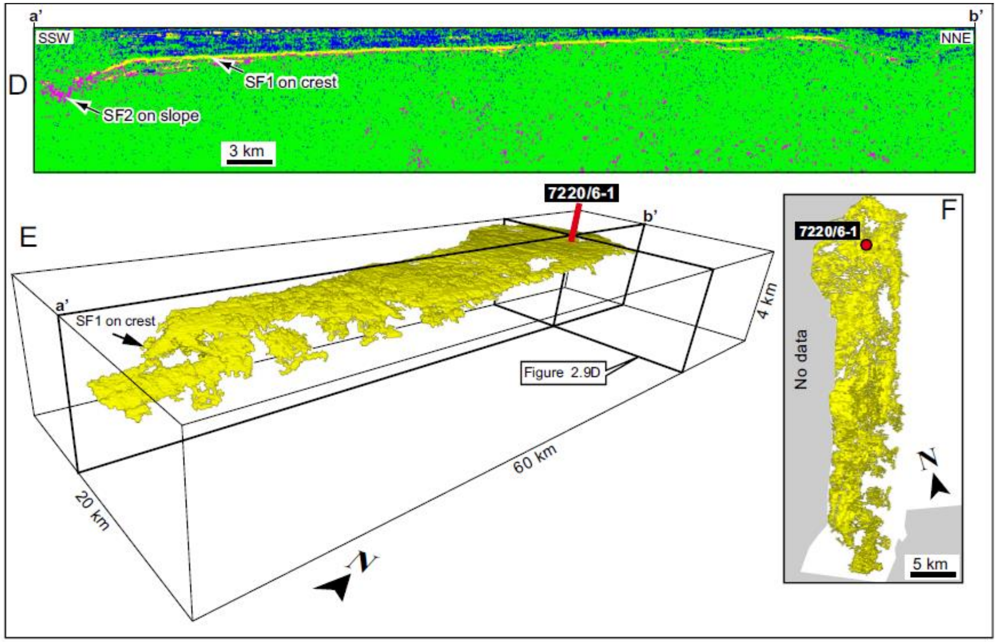




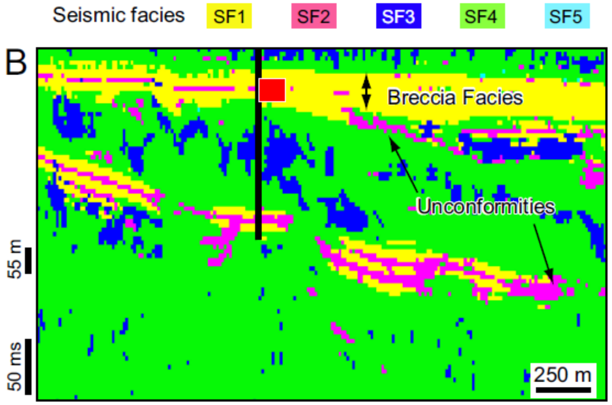


- 7220/6-1 (Obelix) cored interval
- Breccia formation is interpreted to be Solution Collapse due to dissolution of Evaporites (Sayago et al 2012)
- The stratabound and coalesced thick breccias seen in the core is very similar to the Spitsbergen breccias

The Barents Sea analog



Figures from Sayago et al 2012



- Seismic multi-attribute analysis by Sayago et.al 2012
- They were able to map the solution collapse breccias on the Loppa high.
- The results showed that the breccia deposits occupied an area 40 km long and 10-12 km wide and were locally 10-150 m thick

- **The Loppa High breccia system is very similar to the Spitsbergen karst both in terms of processes, size and facies distribution**

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Conclusions

- A seismic scale paleokarst system was mapped in the Carboniferous in central Spitsbergen
- The major karst process is evaporite dissolution that happen in the shallow burial realm – not at the surface
- Fluid inclusions and stable isotopes support that meteoric waters caused the karst and that is was related to major exposure surfaces in the Lower Permian
- A similar karst system- both in terms of size, age and processes developed in the Loppa High in the Barents Sea.
- The Spitsbergen outcropping karst system turned out to be a highly relevant analog for the karst and brecciation processes going on the Loppa high in the Barents Sea.

There's never been a better time for good ideas

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