

# **The Seismic Architecture and Geometry of Glacial Grounding-Zone Wedges from Greenland and North Africa\***

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Search and Discovery Article #30310 (2013)\*\*

Posted December 23, 2013

\*Adapted from an oral presentation given at AAPG 3P Arctic Polar Petroleum Potential Conference & Exhibition, Stavanger, Norway, October 15-18, 2013

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## **Abstract**

Grounding-zone wedges (GZW) form where still-stands during ice-sheet retreat across polar shelves allow sediment build-up at the grounding-zone through delivery of deforming basal debris from fast-flowing ice streams. They are asymmetric in the ice-flow direction with steeper ice-distal (lee) sides. GZW dimensions are controlled by sediment flux, still-stand duration, cavity shape, and ice-stream width. Ice shelves beyond the grounding-zone appear to restrict accommodation space, preventing formation of high-amplitude ridges. GZW are mainly transparent or chaotic seismically, resulting from delivery of diamictic debris and reworking of sediments during minor ice oscillations. Off-lapping reflectors represent progradation into an ice-roofed cavity. Reflector truncations at the base indicate erosion during initiation. Channels are sometimes observed; meltwater flow is under high pressure. V-shaped incisions suggest high-energy flow. The observed architectural complexity suggests subglacially derived diamictic debris, sorted sediment in internal channels and turbidite deposits in a more ice-distal position. Recent study of NE and NW Greenland shelves reported and characterized several GZW and their dimensions; for example, sediment thickness, length in the direction of former ice flow, and ice-marginal width. GZW internal structure and geometry are examined and then compared with the geometry and sedimentology of examples from Late Ordovician glacial deposits onshore North Africa. GZW are indicators of periods of ice-sheet marginal stability, although retreat across a shelf between the locations of GZW may be rapid. The observed series of Algerian GZW thus records the episodic retreat of ice during deglaciation across a Late Ordovician continental shelf.

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# The seismic architecture and geometry of glacial grounding-zone wedges from Greenland and North Africa

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AAPG Stavanger, 15-18<sup>th</sup> October 2013

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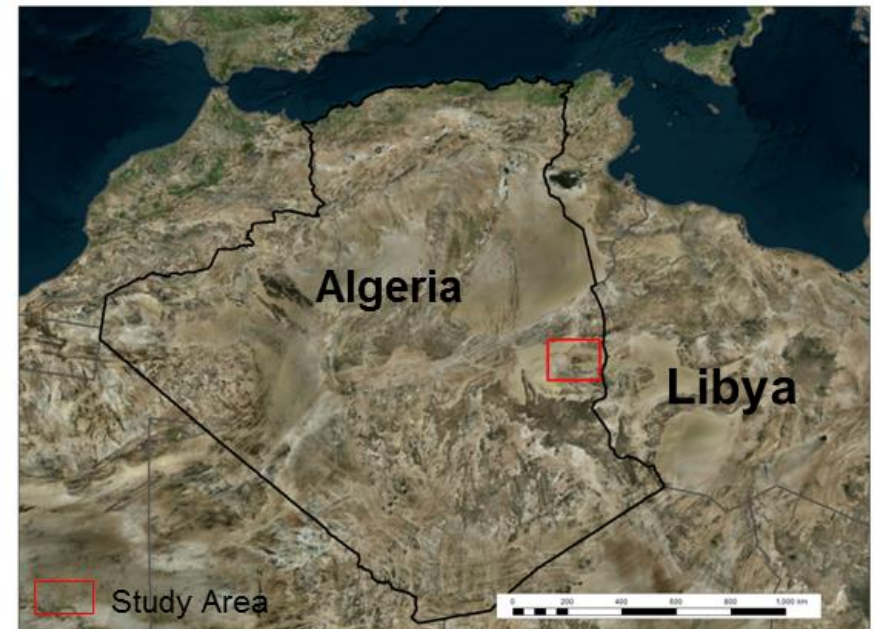


# Outline of Talk



- Context
- Glacial Retreat
- Grounding Zone Wedges (GZW):
  - Definition and Understanding
- A seismic stratigraphy approach to GZW:
  - Geometries and internal architecture
  - Late Quaternary Greenland and Late Ordovician Algeria
- Role of GZW in ice-sheet dynamics
- Conclusion
- Acknowledgements

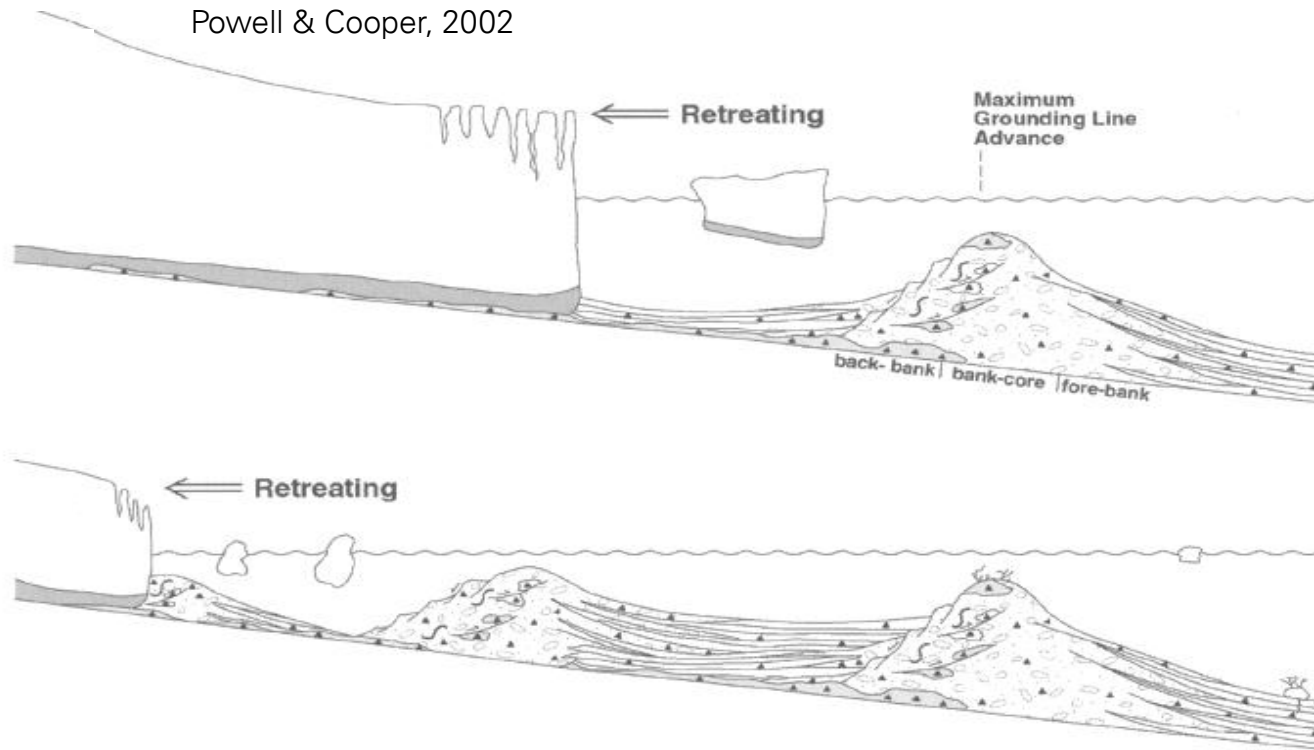
# Context



# Glacial Retreat



Powell & Cooper, 2002



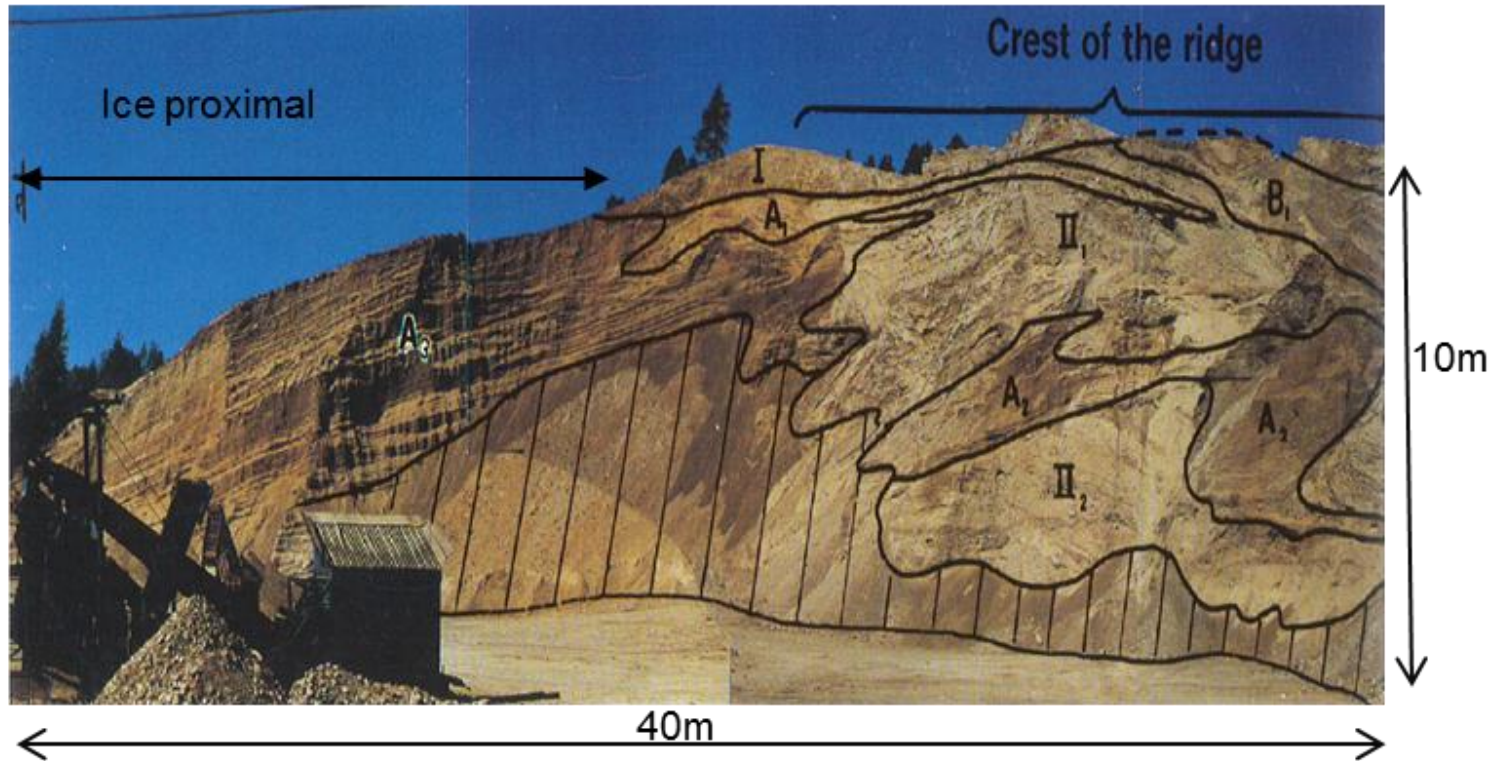
- As an ice sheet locally stabilises, its oscillations push and accumulate sediments in front of it
- The mounded feature is an initiation point of a grounding zone wedge (GZW)
- Ice streams and sub-glacial tunnel valleys feed outwash fans at GZW
- Coarser sediments are usually deposited close to the tunnel mouth – thus the importance of finding GZW position



# Quaternary Grounding Zone Wedges



## GZW Outcrop data, Norway



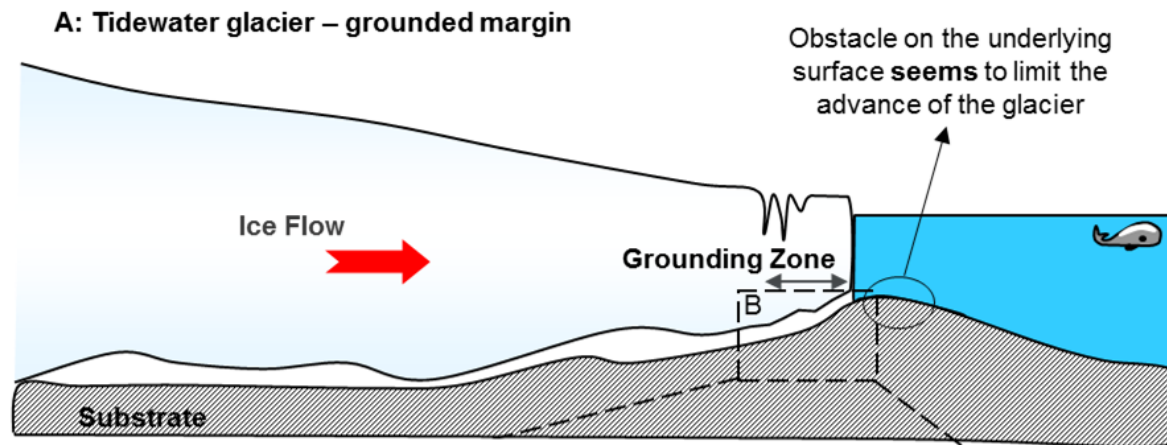
Marine ice grounding zone ridge, SE Norway (*Andersen & Borns, 1994*):

**A:** Foreset beds of gravel and sst dipping in a distal direction

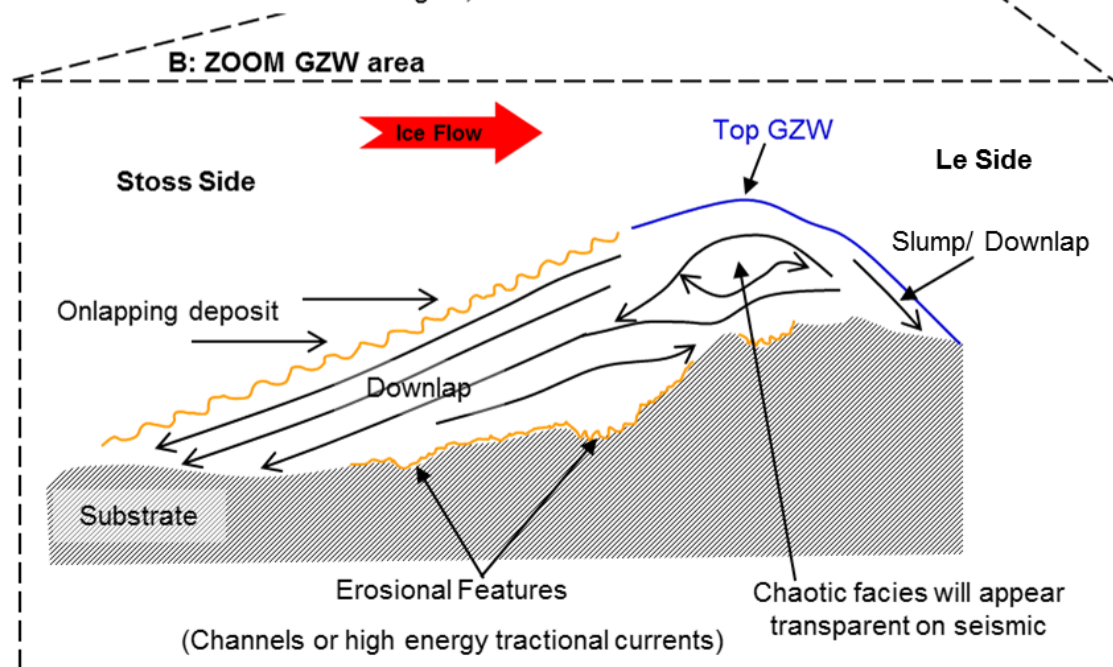
**I,II and II:** Tills / diamict

**B:** Stratified glaciifluvial cobbles, boulders and gravel

# Grounding Zone Wedge Morphology and Internal Architecture



*Modified from Dowdeswell & Fugelli, 2012*



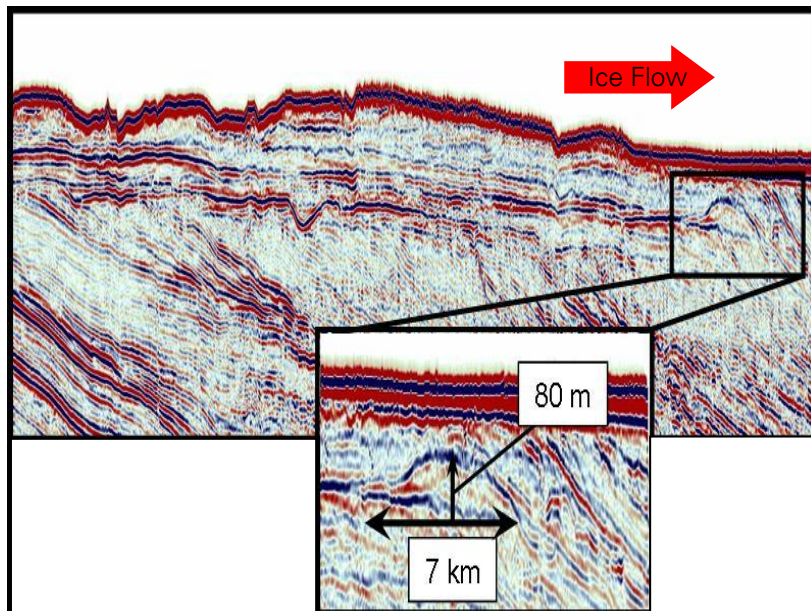
*Modified from Dowdeswell & Fugelli, 2012*



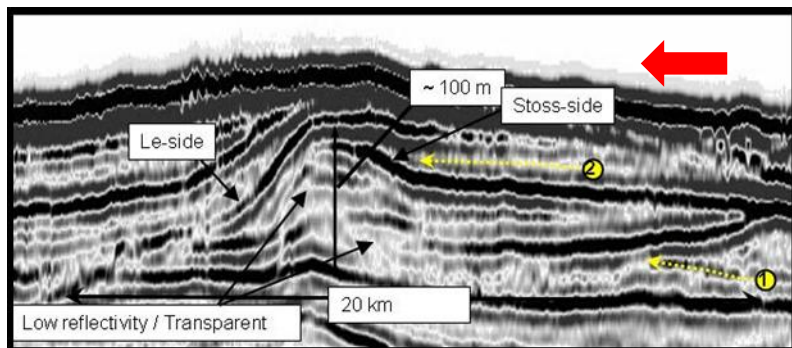
# Seismic Characterization of Glacial Deposits Offshore Greenland and Onshore Algeria



## Greenland Analogue

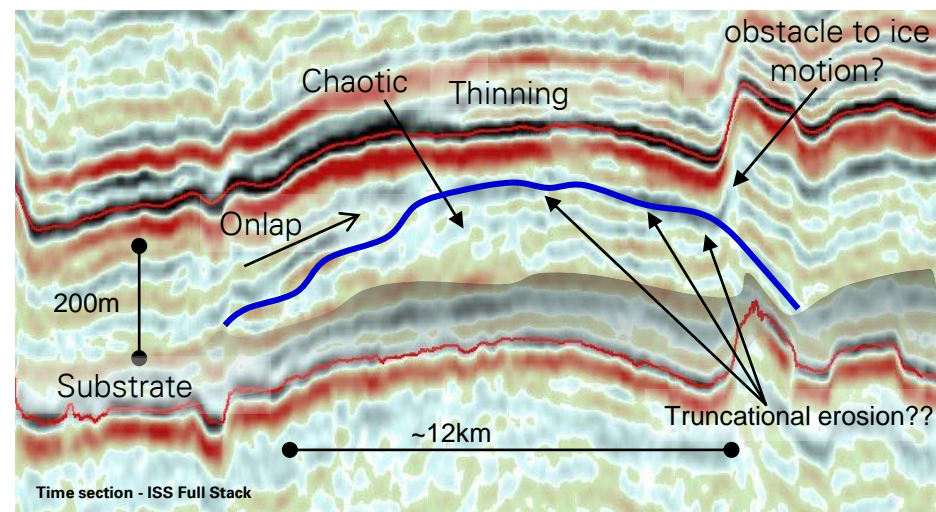
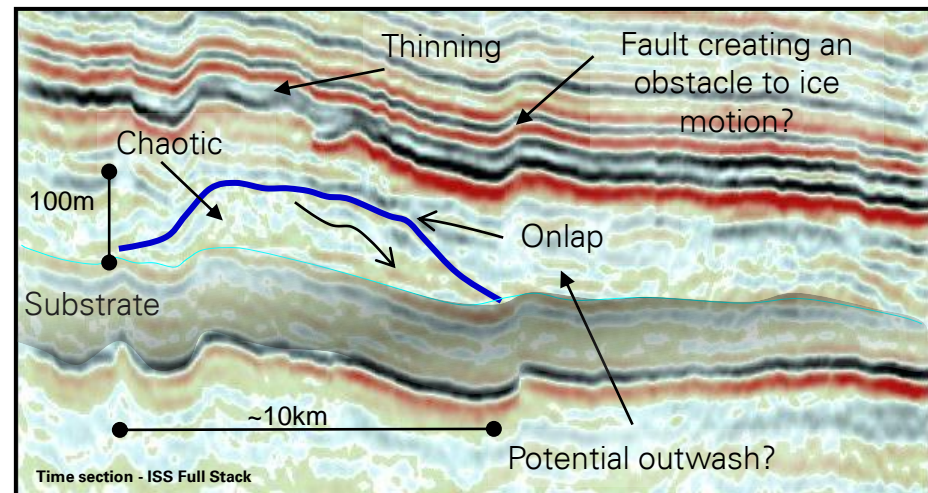


Reflection-seismic data showing example of a buried GZW, offshore NE Greenland . Note scale of the ridge (Dowdeswell & Fugelli, 2012)



Reflection-seismic data showing examples of buried GZW, NE Greenland (J.A. Dowdeswell and E.M.G. Fugelli, 2011)

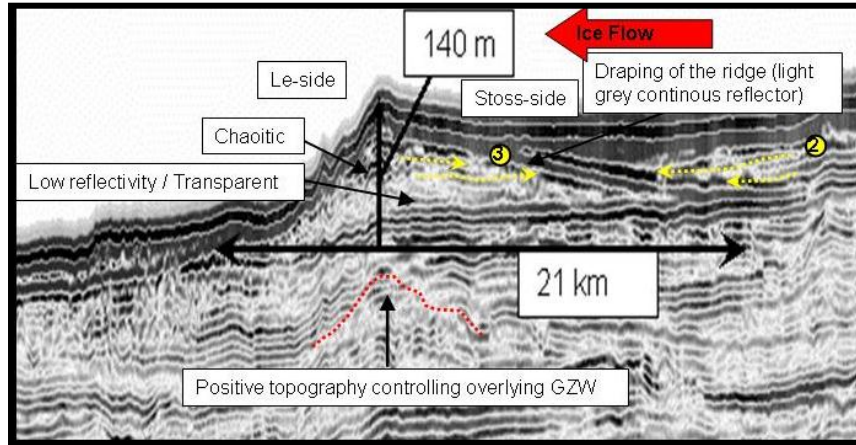
## Algeria Seismic



# Seismic Characterization of Glacial Deposits Offshore Greenland and Onshore Algeria

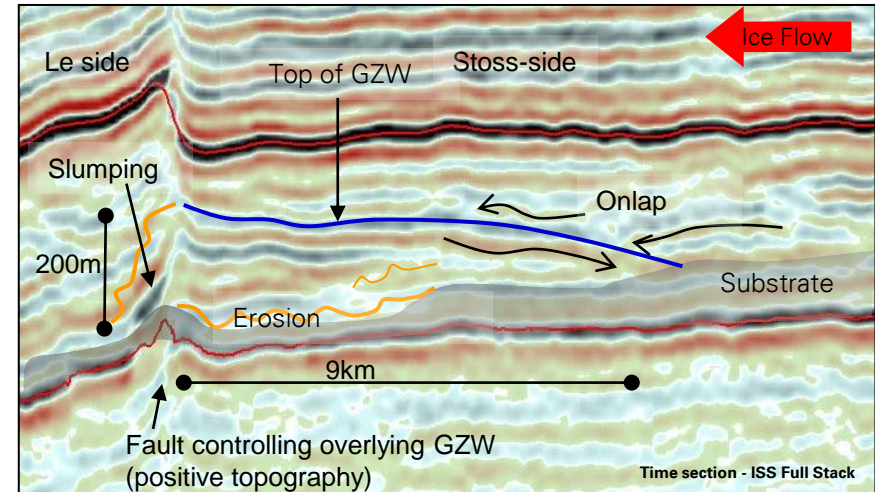


## Greenland analogue



The asymmetric shape of GZW in the direction of past ice flow, with a characteristically steeper ice-distal side, illustrated with reflection seismic records from NW Greenland (Dowdeswell & Fugelli, 2012)

## Algeria Seismic



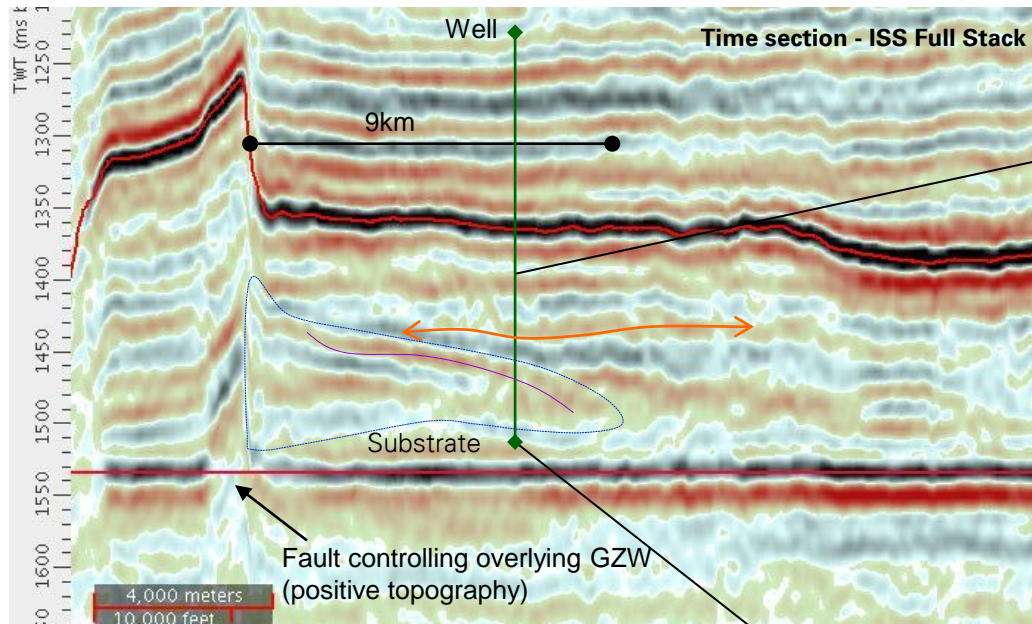
## Seismic characteristics of GZW observed onshore Algeria Late Ordovician deposits

- Similar in shape and scale to the Greenland GZW - 10s of Kms
- Mounded features with onlapping reflectors frequently observed – Positive relief
- The internal architecture shows basal downlap and chaotic seismic facies
- Erosion by ice and meltwater channels make base of the GZW difficult to identify on 3D seismic data
- By comparison with offshore NE Greenland; this positive topography and internal downlaps are used as indicators of possible ice-flow direction on Algeria data
- Obstacles on the substrate (e.g. faults) influence the position of the GZW





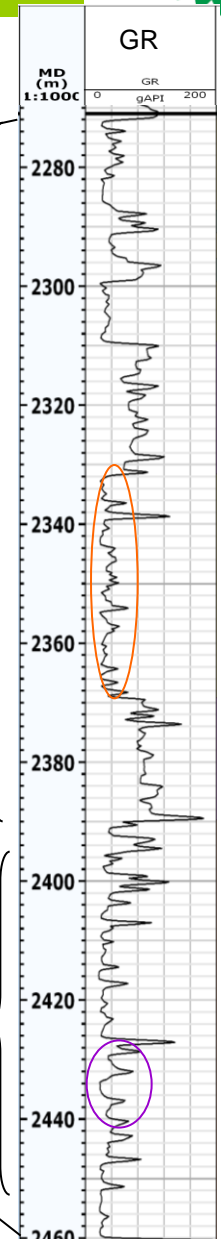
# Grounding Zone Wedge Stratigraphy



Pro-glacial marine setting

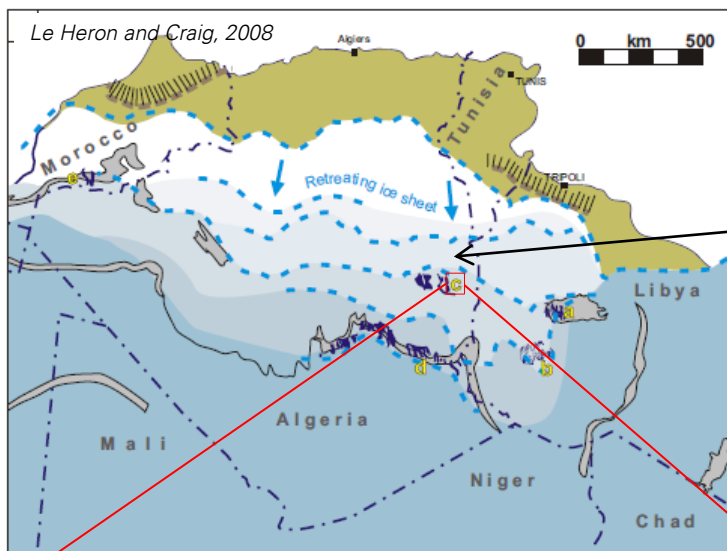
- Inside of the GZW: Cross-bedding suggesting a thick stack of tractional sandstones
- Above the GZW: Onlapping sand (40 m) interpreted as a stack of slightly argillaceous high density turbidite sandstones
- Strong similarity to stratigraphy in mapped marine ice-contact systems onshore Norway (i.e. Mona Ridge, Lønne et al., 2001)

Grounding Zone Wedge



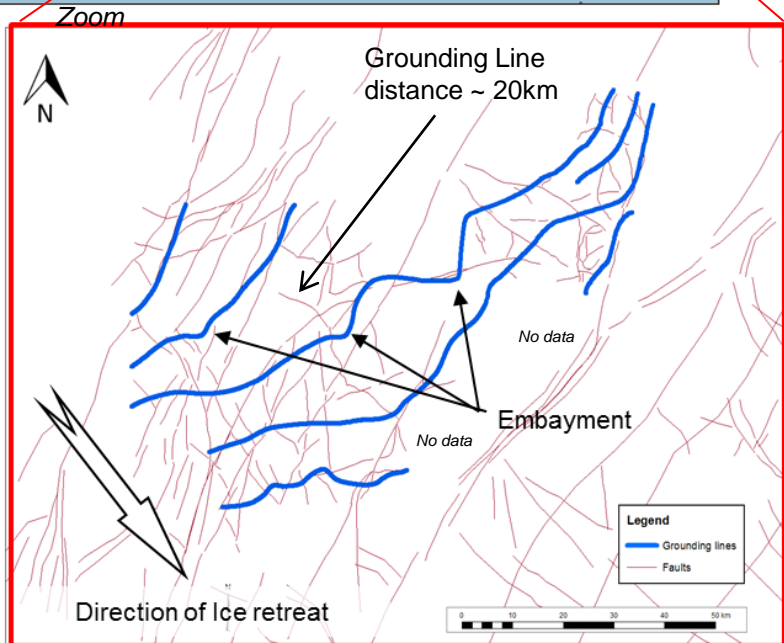
# Illizi Basin, Algeria

## Late Ordovician GZW - A Guide to Past Ice Margins



Grounding Line distance >250km

- Observations:
  - About 10 GZW have been mapped in the study area.
  - They were positive topographic features on the seafloor that younger turbidite lobes onlap
  - GZW are often located close to a basement fault and in topographic lows
  - The orientation of an asymmetric GZW is NW-SE, indicating the direction of the ice retreat
- Extrapolated grounding lines mark the different retreat phases of the Late Ordovician ice sheet.
- Within a large retreat, 5 grounding lines have been mapped – separated by 20 - 40kms
- Quality of the seismic was key to interpret the GZW. Multiple contamination was really obscuring the GZW image



# Conclusions



- Outcrops and seismic from Quaternary-Recent GZW (from Greenland and Norway mainly) have been key to recognize and interpret Cambro-Ordovician GZW in Algeria
- They are similar in shape and size to the Greenland and Norway analogues, reaching 10s of km length and 100s m height. This scale won't be seen on outcrop - HUGE scale
- Glacial processes are similar in Algeria and Greenland but the architecture can be slightly different due to the geological setting (Algeria being in an intra-cratonic basin)
- At a longer-lived GZW location, the amount of meltwater sediments expelled from the ice sheet must be quite important and form great target locations
- Glacial shelf embayment related to ice still-stands containing possibly significant sand deposition have been derived from GZW positions



# Acknowledgements



- My co-authors and Martin Wells
- BP North Africa and Resource Management Team
- Seismic Data
  - TGS-NOPEC
  - GEUS
  - Nunaoil
- Sonatrach, our partners in Algeria