The challenges associated with sequence stratigraphy in the glacial environment

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Glacial deposits

Sequence stratigraphy

Aim: Highlight the implications of uncertainties of a glacial environment on the sequence stratigraphy and suggest steps reduce these uncertainties

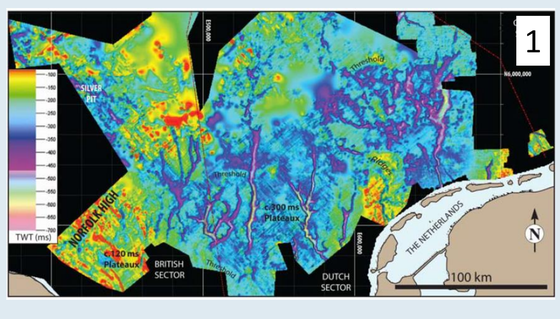
- Increasingly important due to growing significance as hydrocarbon reservoirs

- Successfully implemented in correlating depositional sequences in coastal settings
- Direct application in the glacial depositional environment remains challenging

Characteristics of sedimentation in glacial environments

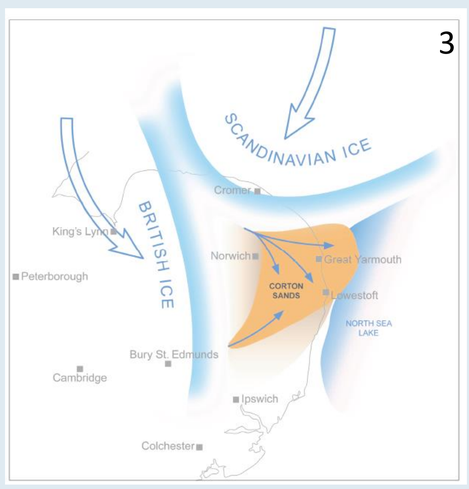
Isolated depressions (tunnel valleys)

- Incisions subglacially excavated below sea-level



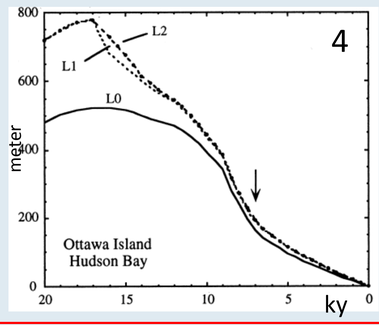
Multiple ice-lobes advance and retreat

- Affecting sediment input and Transforming the fluvial drainage patterns
- Ice-lobes influenced by local geography and climate result in diachronous events on basin scale
- Sediment source control by
  - ice-sheet location
  - Sea-level



Relative sea-level curve, isostatic rebound

- Glacio-isotatic depression
  - increases water-depth, accommodation space
  - Glacial rebound has a time lag compared to sea-level changes



References:

1- J. Moreau, M. Huuse, A. Janszen, P. Van Der Vegt, P.L. Gibbard, A. Moscariello, 2012 .The glaciogenic unconformity of the southern North Sea, *Geological Society, London, Special Publications* v.368

2- Google Earth, Oak Ridges Moraine near lake Ontario, Canada, source Google Earth 2014

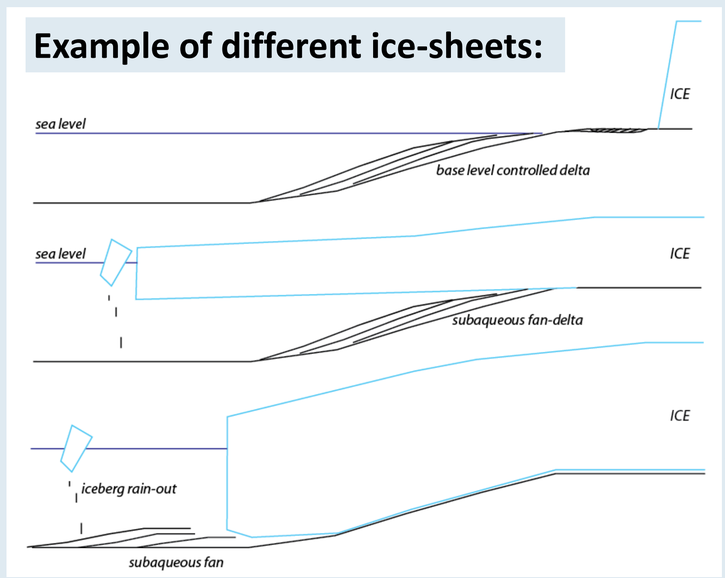
3- P.L. Gibbard, P. van der Vegt 2012. The genesis and significance of the Middle Pleistocene glacial meltwater and associated deposits in East Anglia. *In:* Dixon, R., Markham, C. & Markham, B. (eds.) *GeoSuffolk – a decade of achievement.*

4- K. Lambeck, Y. Yokoyama, P. Johnston; A. Purcell; 2000 Global ice volumes at the Last Glacial Maximum. Earth and Planetary Science Letters 181, p513-527

5- M.E. Brookfield , I.P. Martini. 1999. Facies architecture and sequence stratigraphy in glacially influenced basins: basic problems and water-level=glacier input-point controls (with an example from the Quaternary of Ontario, Canada). Sedimentary Geology 123, p. 183–197

These effects are further amplified by the associated large scale/rapid eustatic sea-level changes which are

Example of different ice-sheets:



Land ice
sediment source at ice-margin, glaciofluvial transport to coast

	Glacial deposition	Sea-level fall	Sea-level minimum	Sea-level rise	Sea-level max
Ice advance	progradation - disruption of fluvial system - glacial incision	Enhanced or Reduced FSST	Enhanced or Reduced, LST	Enhanced or Reduced, TST	Enhanced or Reduced, HST
Ice max	Glacial deposition relative close to coastline	Close Sed. source FSST	Close Sed. source, LST	Close Sed. source, TST	Close Sed. source, HST
Ice retreat	Retrogradation sediment source, meltwater incisions	High sed. supply FSST	High sed. supply , LST	High sed. supply , TST	High sed. supply , HST
Ice min	Glacial deposition further landinwards	Remote sed. source FSST	Remote sed. source, LST	Remote sed. source, TST	Remote sed. source, HST

Floating ice
sediment source at grounding line and rainout

	Glacial deposition	Sea-level fall	Sea-level minimum	Sea-level rise	Sea-level max
Ice advance	prograding, main source at grounding line, distally increase iceberg rainout	grounding line progradation, end of floating ice	Glacial deposition relatively sea-wards	reduced ice effect, grounding line retrogradation	Glacial deposition relatively land inwards
Ice max	Sediment transported far into marine, lacustrine domain	grounding line progradation, end of floating ice - prograding FSST	Glacial deposition relatively sea-wards	grounding line retrogradation, TST	Glacial deposition relatively land inwards
Ice retreat	backstepping fans - turbidites from grounding line, decrease rainout	grounding line progradation, reduced TST effect	Glacial deposition relatively sea-wards	enhanced TST effect	Glacial deposition relatively land inwards
Ice min	Sediment transported close to coast, less far into marine/lacustrine	grounding line progradation, end of floating ice reduced HST effect	Glacial deposition relatively sea-wards	enhanced HST	Glacial deposition relatively land inwards

Grounded ice in standing water
sediment source at grounding line and rainout

	Glacial deposition	Sea-level fall	Sea-level minimum	Sea-level rise	Sea-level max
Ice advance	glacial erosion, incision, likely eroding subaqueous fans	no SL effect	no SL effect	no SL effect until floating ice	no SL effect
Ice max	Sediment transported distal to coast - at grounding line	no SL effect	no SL effect	no SL effect until floating ice	no SL effect
Ice retreat	backstepping subaqueous fans, stranded sequences	no SL effect	no SL effect	no SL effect until floating ice	no SL effect
Ice min	Sediment transported proximal to coast - at grounding line	no SL effect	no SL effect	no SL effect until floating ice	no SL effect

Balance between the effect of ice-movement and sea level changes

- *In glacial environments where land-ice is present, eustatic sea level changes represent the most important control*
- *In glacial environments where floating ice is present, there is a complex balance between the dominance of sea level or ice movement controls*
- *In glacial environment where grounded ice is present, ice movement will be the dominant control*

Challenges for the future:

- *Characterise deposits related to sea-level controlled and glacial controlled sediment source*
- *Identify the effects and time-scale of glacio-eustatic rebound in the glacial record*