Late Cenozoic paleoenvironment and erosion estimates for the NE Svalbard continental margin - preliminary result

Amando Lasabuda[1,2]*, Wolfram Geissler[3], Jan Sverre Laberg[2,1], and Stig-Morten Knutsen[4]

[1]Research Centre for Arctic Petroleum Exploration (ARCEx), University of Tromsø, Tromsø, Norway
*(amando.lasabuda@uit.no)
[2]Departement of Geoscience, University of Tromsø - The Arctic University of Norway, Tromsø, Norway
[3]Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung, Bremerhaven, Germany
[4]Norwegian Petroleum Directorate (NPD), Harstad, Norway

1. Introduction

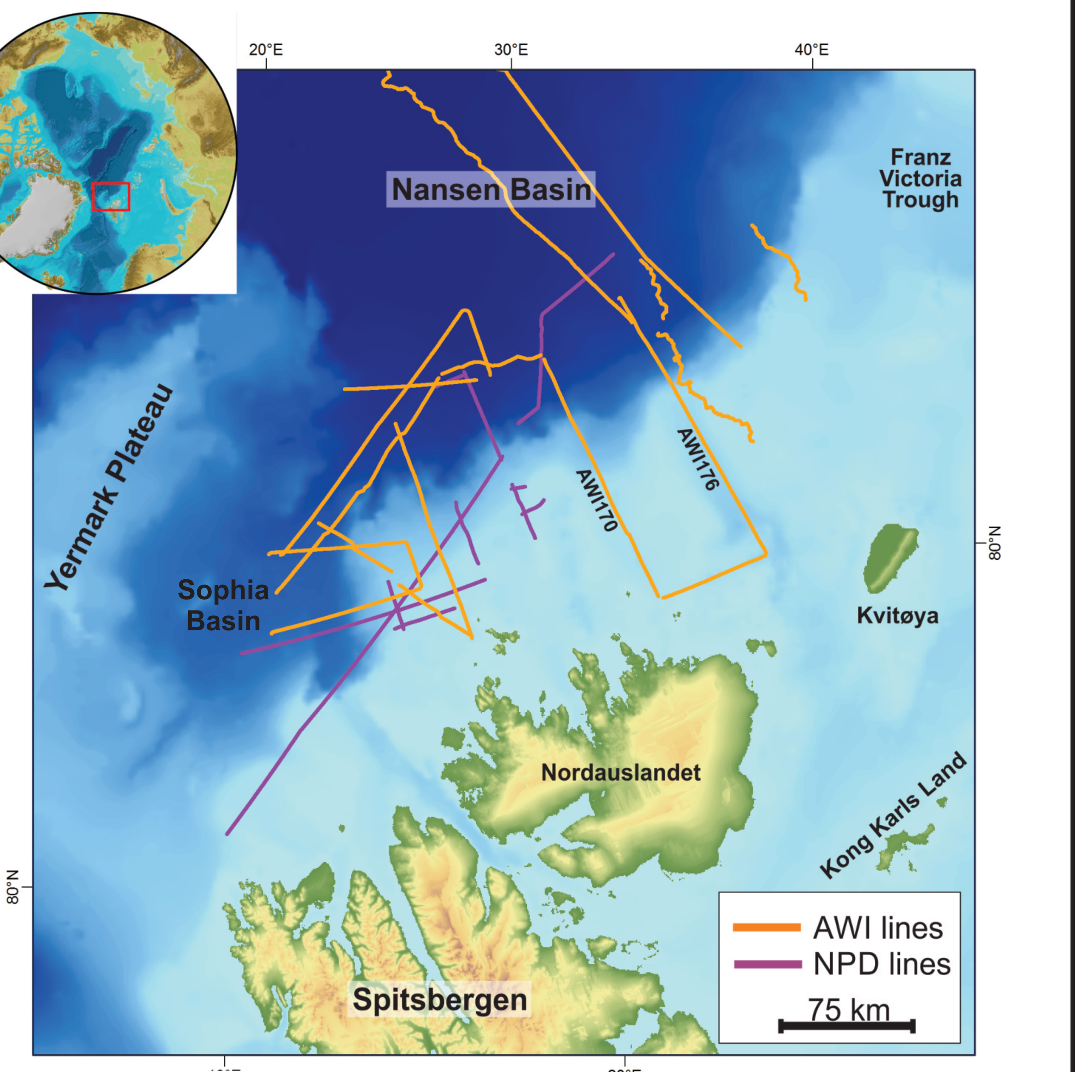
During the Late Cenozoic, the Barents Sea area was exposed to an extensive period of glaciations (Laberg and Vorren, 1996; Vorren and Laberg, 1997; Knies et al., 2009; Laberg et al., 2012). An ice sheet has repeatedly expanded from onshore, reaching the shelf edge and eroding the Barents Sea shelf deposits (Laberg et al., 2012). The eroded sediments were transported by the ice sheet to the adjacent continental slope and deposited forming Trough Mouth Fans (TMF). The Bjørnøya and Storfjorden TMFs are prominent Trough Mouth Fans along the western Barents Sea margin (Laberg et al. 1996; Hjelstuen et al., 1996). Laberg et al. (2012) estimated a high amount of average net glacial erosion in the Barents Sea area during these periods, i.e. when an ice sheet was overlying and eroding the Barents Sea shelf.

On the southwestern Barents Sea margin, the process of erosion has included glacio-fluvial and glaciomarine erosion as well as subglacial erosion (Laberg et al., 2012). However, on the northern Barents Sea margin, very little is known related to the glacial history, processes of erosion and their timing due to very limited data available. The only data so far published was presented by Geissler and Jokat (2004) and Engen et al. (2009), documenting a considerable amount of Cenozoic sediments in this area.

Based on the available seismic data, we aim to identify and separate the glacial and pre-glacial sedimentary units deposited along the northern Svalbard margin and to investigate the lateral extent and temporal evolution of each unit in more detail as compared to previous studies. For the first time, the average sedimentation rate, erosion rate and net erosion of the margin will also be calculated and discussed. In addition, we will focus on the paleoenvironmental reconstruction for each period in order to reconstruct the development and evolution of the northern sector of the Barents Sea – Svalbard Ice Sheet (BSIS).

2. Study area and seismic data

- Sea-floor spreading in Arctic Ocean separating Lomonosov Ridge and the northern Barents Shelf was initiated at c. 60-55 Ma (Vogt et al. 1979, Jokat et al. 2013)
- The Nansen Basin was formed contemporaneous to the present-day ultra-slow spreading Gakkel Ridge 0.6-1.3 cm/yr (Jokat and Miksch, 2004). This basin shows up to 4 km sediment thickness (Engen et al., 2009).
- The Yermark Plateau and Moris Jesup Rise was an unseparated plateau prior to Oligocene (Jackson et al. 1984)
- The Sophia Basin may have been a failed rift in relation to connect Eurasian Basin and the Lofoten Basin (Engen et al, 2008)
- The northern Svalbard continental margin is suggested as non volcanic margin (Geissler and Jokat, 2004).



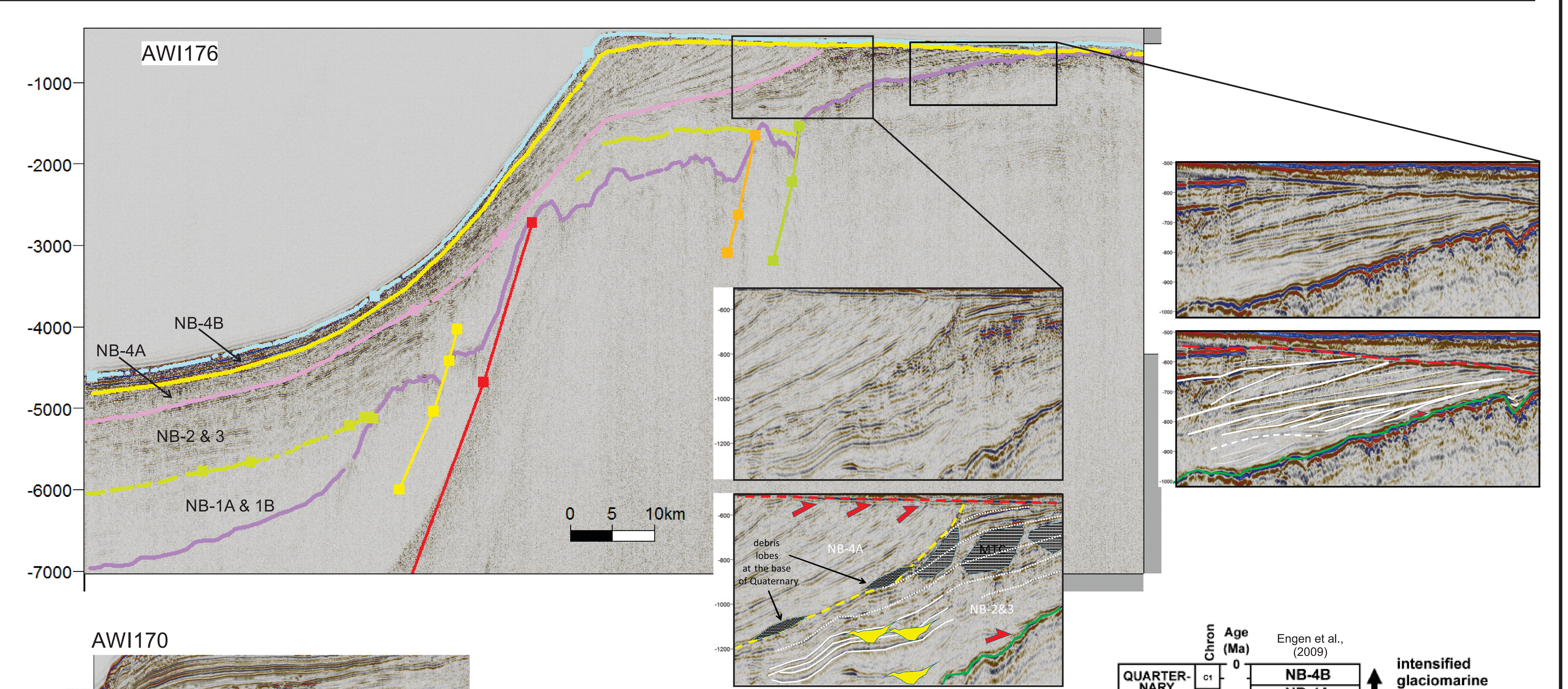
IBCAO v. 3, Jakobsson et al. (2012)

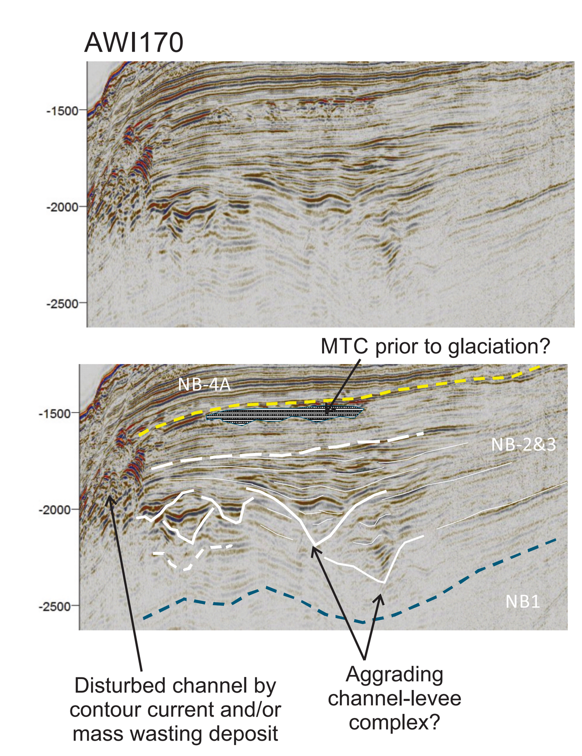
3. Seismic stratigraphic framework

- 6 seismic facies (SF1-SF6) can be distinguished and interpreted (Table 1).
- 4 key seismic units were defined (NB-1A&1B, NB-2&3, NB-4A, and NB-4B) following Geissler and Jokat (2004) and Engen et al. (2009). This study focuses on the two uppermost units; NB-4A and NB-4B.
- NB-4A and NB-4B are dominated by debrites intercalated with contourites and pelagic/hemipelagic deposits.
- NB4A and NB4B are considered as glacial-influenced units (e.g. AWI176) based on seismic pattern, geometry, and geomorphological comparison with other Trough Mouth Fan from other continental margins (e.g. Dahlgren et al., 2005, Rydningen et al., 2015)

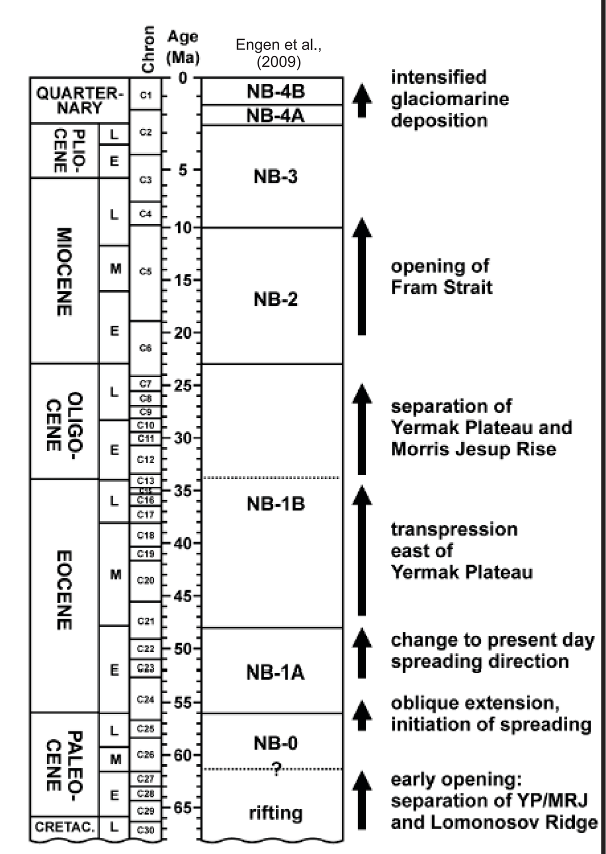
Seismic Facies (SF)	Description (amplitude, continuity, external and internal geometry)	Interpretation (lithology, origin, sediment process)	Figure example
SF1: Chaotic	Medium to high amplitude reflection, irregular top and base, internally chaotic but in some area shows imbricated pattern	Glacigenic/non-glacigenic debrites, slumps, slides, products of mass-wasting events. Together, SF1 and SF2 is termed Mass Transport Complex (MTC). SF1 is probably has coarser meterials, meanwhile SF2 is mud-dominated deposits.	
SF2: Semi-transparent	Low amplitude reflection, discontinuous, irregular top and base, internally structureless		
SF3: Tangential/oblique parallel	Low to medium amplitude reflection, continuous, stacked of angular packages, often truncated to the upper layer	Prograding glacigenic sedimentary wedges or widely known as Trough Mouth Fan (TMF). The TMF generally consists of variable lithology representing periodic glacigenic debris flow process. This is a product of the dynamics avdvance and retreat of glacier in the trough to the shelf edge.	
SF4: Paralel to sub-parallel	Low to high amplitude reflection, continuous to semi-continuous, commonly conformable top and base	Pelagic/hemipelagic sediment or glacimarine sediment. This is a result of slow-settling background sedimentation from iceberg or Ice Rafted Debris (IRD). For the pre-glacial seismic unit, SF4 could also represent turbidite sheets/fans consisting sand-shale interlayers.	
SF5: V-/U-shaped	Low to high amplitude and discontinuous reflection at the axial part, typicall V-/U-shaped morphology flanked by low-medium amplitude and semi- to continuous reflection package	Submarine channel-levee system. Channel may be sinuous or straight and often contains coarser sediment as the channel-fill deposit. Levee is interpreted as mud-rich overbank deposit as a result of overspill turbidite current from the channel thalweg.	
SF6: Contorted	Medium to high amplitude reflection, continuous, wavy morphology, commonly stacked with other SF6	Contourites. Sediment deposited by ocean bottom current as a result of ocean circulation. This package has typically mud-rich lithology. The high amplitude within this package is often related to the presence of gas hydrates.	

Table 1. Seismic facies classification for the NW Barents Sea continental margin



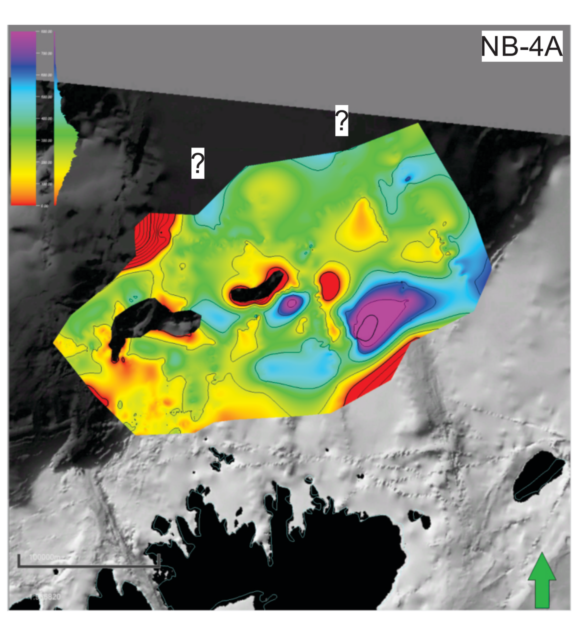


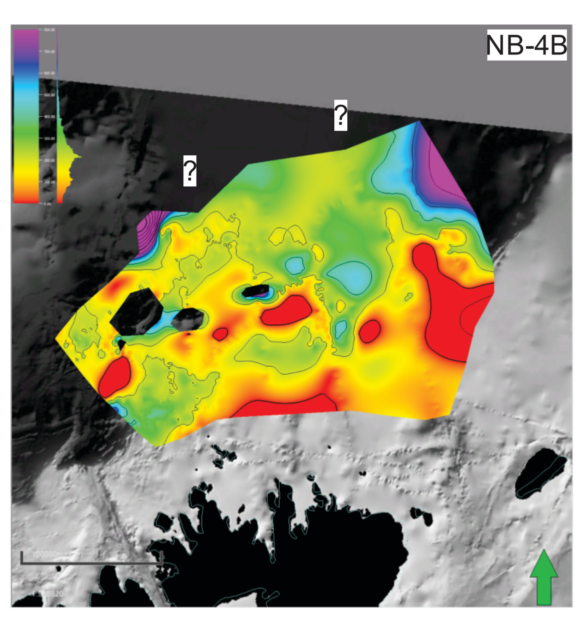
- Chronology of the base of the glacigenic sediment is inferred to be ca. 2.6 Ma. The closest IODP wells are at Yermark Plateau; site 910, 911, 912.
- Note a different style of progradation between unit NB-2/3 and NB-4A.
- At pre-glacial unit (NB-2/3), the progradation shows less steep angle. This is interpreted as an interplay between sedimentation and sea-level as well as ocean circulation.
- At glacial-influenced unit (NB-4A), the progradation displays steeper angle and interpreted as a series of glacigenic debrites.
- NB-4B at the upper slope corresponds to Upper Regional Unconformity (URU)

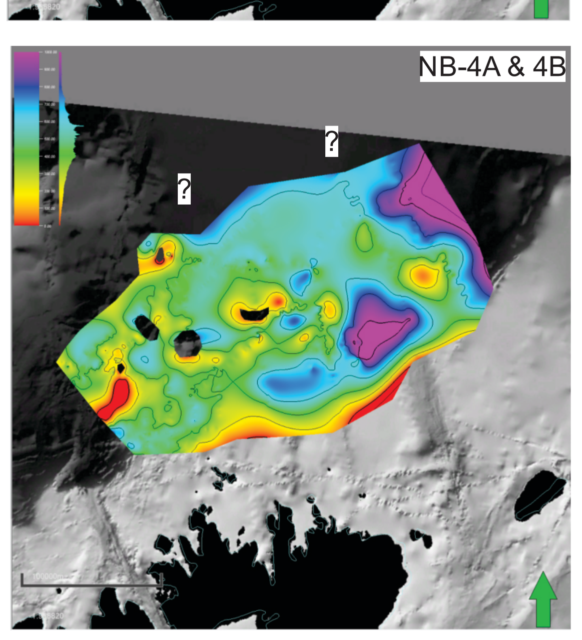


Engen et al., (2009), Berglar et al., (2016)

4. Isopach maps and avg. sedimentation rates







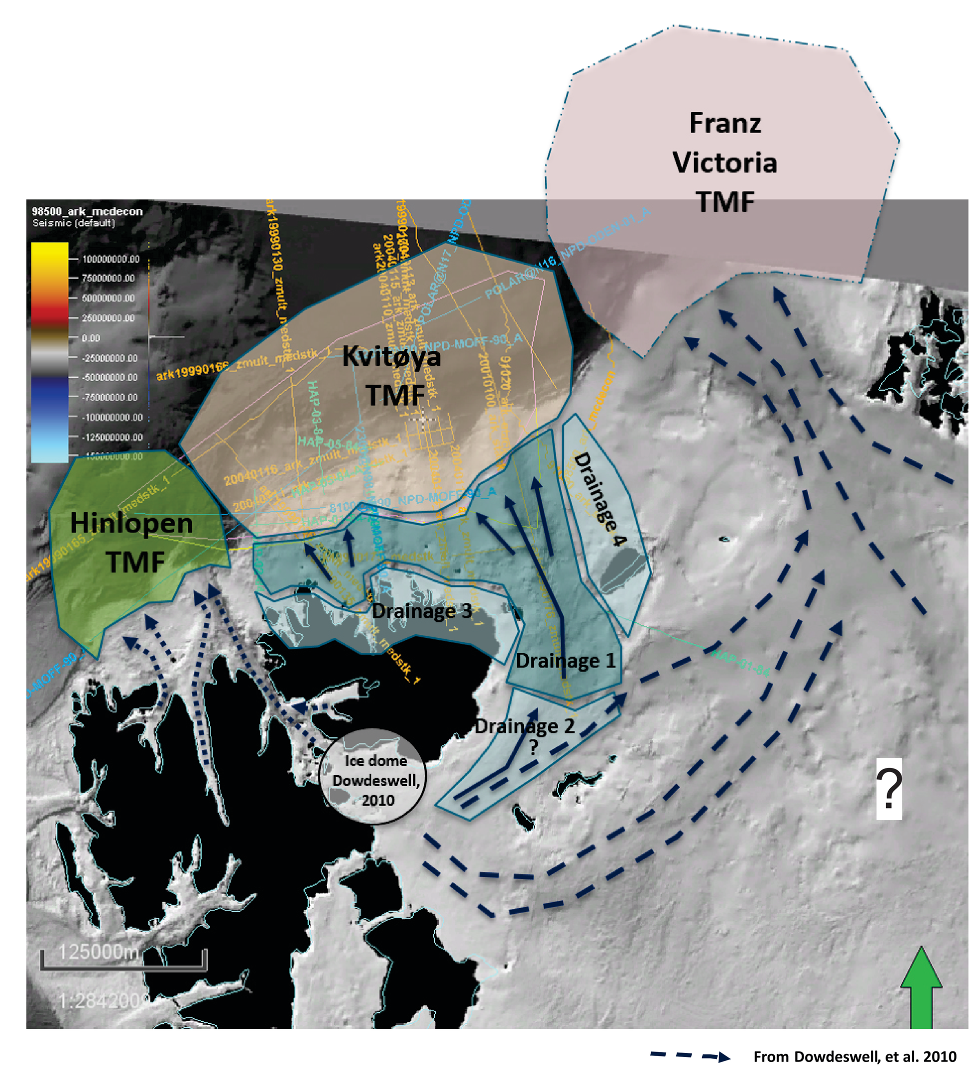
- Aparent well distributed sediment with local thickening and thinning.
- The **average sedimentation rate** for the Late Cenozoic is estimated to be **0.2 m/k.y.**

Seismic units	Age range (Ma)	Velocity average (km/s)	Area (10^3 x km^2)	Volume (10^3x km^3)	Sedimentation rates (m/k.y)
Late Cenozoic	0-2.6	1,9	45,26	23,19	0,20
NB3B	0-1,5	1,9	48,19	15,33	0,21
NB3A	1,5-2,6	1,9	36,66	12,94	0,32
NB2	2,6-23	2,3	41,04	61,45	0,07
NB1	23-55	3,4	41,05	163,82	0,18

5. Late Cenozoic paleoenvironmental reconstruction and erosion estimates

Seismic units	Area of the drainage A (10^3xkm^2)	Volume of the source area (103x km 3)	Sediment discharge (106tonne per year) with density 2,5	Sediment yield (tonne per km 2 per year)	Erosion (m)	Erosion Rates (m/k.y)
Late Cenozoic	42,258	23,19	22,30	527,67	548,77	0,21
NB3B	42,258	15,33	25,55	604,62	362,77	0,24
NB3A	42,258	12,94	29,41	695,94	306,21	0,28
NB2	42,258	61,45	7,53	178,21	1454,16	0,07
NB1	42,258	163,82	18,62	440,53	3876,66	0,18

- **Paleoenvironment** and the **drainage area are deliniated.**
- The inferred **sediment source** is from **the Barents shelf, Nordaustlandet, and partly Kvitøya**
- For the first time, the Late Cenozoic **average net erosion** and **erosion rate** for the northern Barents Sea margin are estimated and correspond to **c. 520 m** and **0.21 m/k.y.,** respectively.
- Comparison with other formerly glaciated continental margin shows an agreement for the Late Cenozoic average erosion rates estimates.



Areas	Area of the drainage A (10^3xkm^2)	Volume of the source area (10^3x km^3)	Erosion (m)	Erosion Rates (m/k.y)
N Svalbard (Kvitøya Fan) - **This study**	42,2	23,1	548	0,21
NW Barents Sea (Storfjorden Fan)	116	69	1681	0,63
SW Barents Sea (Bjørnøya Fan)	576	464-395	1090-1030	0,41-0,38
Troms Margin	43-14	2,2-2	50-140	0,02-0,05
Mid Norway (NAUST Fm)	160	83,7	524	0,19

References

- Berglar, K. et al. 2016. Initial opening of the Eurasian Basin, Arctic Ocean. Frontiers in Eart Science. 4:91.
- Dahlgren, K.I.T., Vorren, T.O., Stoker, M., Nielsen, T., Nygård, A., and Sjerup, H. 2005. Late Cenozoic prograding wedges on the NW Europe continental margin: their formation and relationship to tectonic and climate. Marine and Petroleum Geology 22.
- Dowdeswell, J., Hogan, K., Evans, J. Noormets, R., Cofaigh, C. O., and Ottesen, D. 2010. Past ice-sheet flow east of Svalbard inferred from streamlined subglacial landforms. GSA Bulletin v. 38, no. 2, p. 163-166.
- Dowdeswell, J., Ottesen, D., and Rise, L., 2010. Rates of sediment delivery from the Fennoscandian Ice Sheet through an ice age. GSA Bulletin v. 38, no. 1, p. 3-6.
- Engen, Ø., Faleide, J.I. and Dyreng, T. 2008. Opening of the Fram Strait gateaway: A review from plate tectonic constraints. Tectonophysics (450), p. 51-58.
- Engen, Ø., Gjengedal, J., Faleide, J. I., Kristoffersen, Y., and Eldholm, O., 2009. Seismic stratigraphy and sediment thickness of the Nansen Basin, Arctic Ocean. Geophys. J. Int. 176. 805-821.
- Geissler, W. and Jokat, W. 2004. A geophysical study of the northern Svalbard continental margin. Geophys. J. Int. 158, 50-66.
- Hjelstuen, B.O. Elverhøi, A., Faleide, J.I. 1996. Cenozoic erosion and sediment yield in the drainage area of the Storfjorden Fan. Global and Planetary Change,
- Jackson, H.R., Johnson, L., Sundvor, E. and Myhre, A. 1984. The Yermark Plateau: formed at a triple junction. Journal of Geophysical Research. Vol. 89.
- Jakobsson M. 2012. The international bathymetric chart of the Arctic Ocean (IBCAO) version 3.0. Geophysical Research Letters, v. 39.
- Jokat, W. and Miksch, U. 2004. Sedimentary structure of the Nansen and Amundsen Basins, Arctic Ocean. Geophysical Research Letters, v. 31.
- Jokat, W., Ickrath, M, and O'Connor, J. 2013. Seismic transect across the Lomonosov and Mendeleev Ridges: constraints on the geological evolution of the Amerasia Basin, Arctic Ocean. Geophysical Research Letters, v. 40.
- Knies et al. 2009. The Plio-Pleistocene glaciation of the Barents Sea-Svalbard region: a new model based on revised chronostratigraphy. p. 812-829
- Laberg, J. S., Andreassen, K, and Vorren, T. O. 2012. Late Cenozoic erosion of the high-latitude southwestern Barents Sea shelf revisited. GSA Bulletin, v. 124, p. 77-88.
- Laberg J.S. and Vorren T.O. 1996 The Middle and Late Pleistocene evolution of the Bear Island Trough Mouth Fan. Global and Planetary Change. p. 309-330.
- Rydningen T.A., Laberg, J.S., Kolstad, V. 2015. Late Cenozoic evolution of high-gradient trough mouth fans and canyons on glaciated continental margin offshore Troms, northern Norway. GSA
- Vogt, P., Taylor, Kovacs, and Johnson. 1979. Detailed aeromagnetic investigation of the Arctic Basin. Journal of Geophysical Research. vol. 84.
- Vorren, T.O. and Laberg J.S. 1997. Trough Mouth Fans - Paleoclimate and ice-sheet monitors. Quaternary Science Review. p 865-881.

Acknowledgements

This study is part of the work package 1, ARCEx project which is funded by the Research Council of Norway together with industry partners (grant number 228107). Alfred Wegener Institute (AWI) and Norwegian Petroleum Directorate (NPD) are acknowledged for the seismic data. Seismic interpretation was caried out in Petrel (Schlumberger).