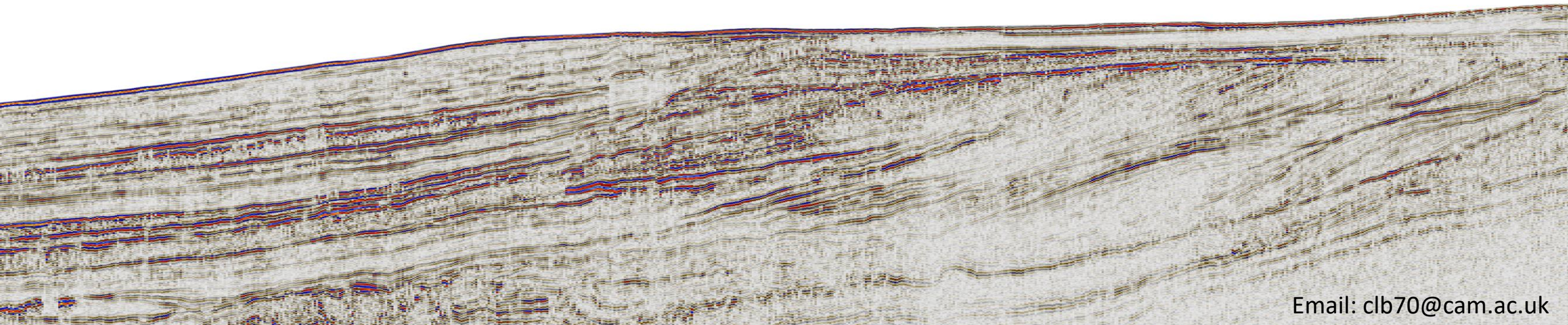


# Quaternary evolution of the northern North Sea

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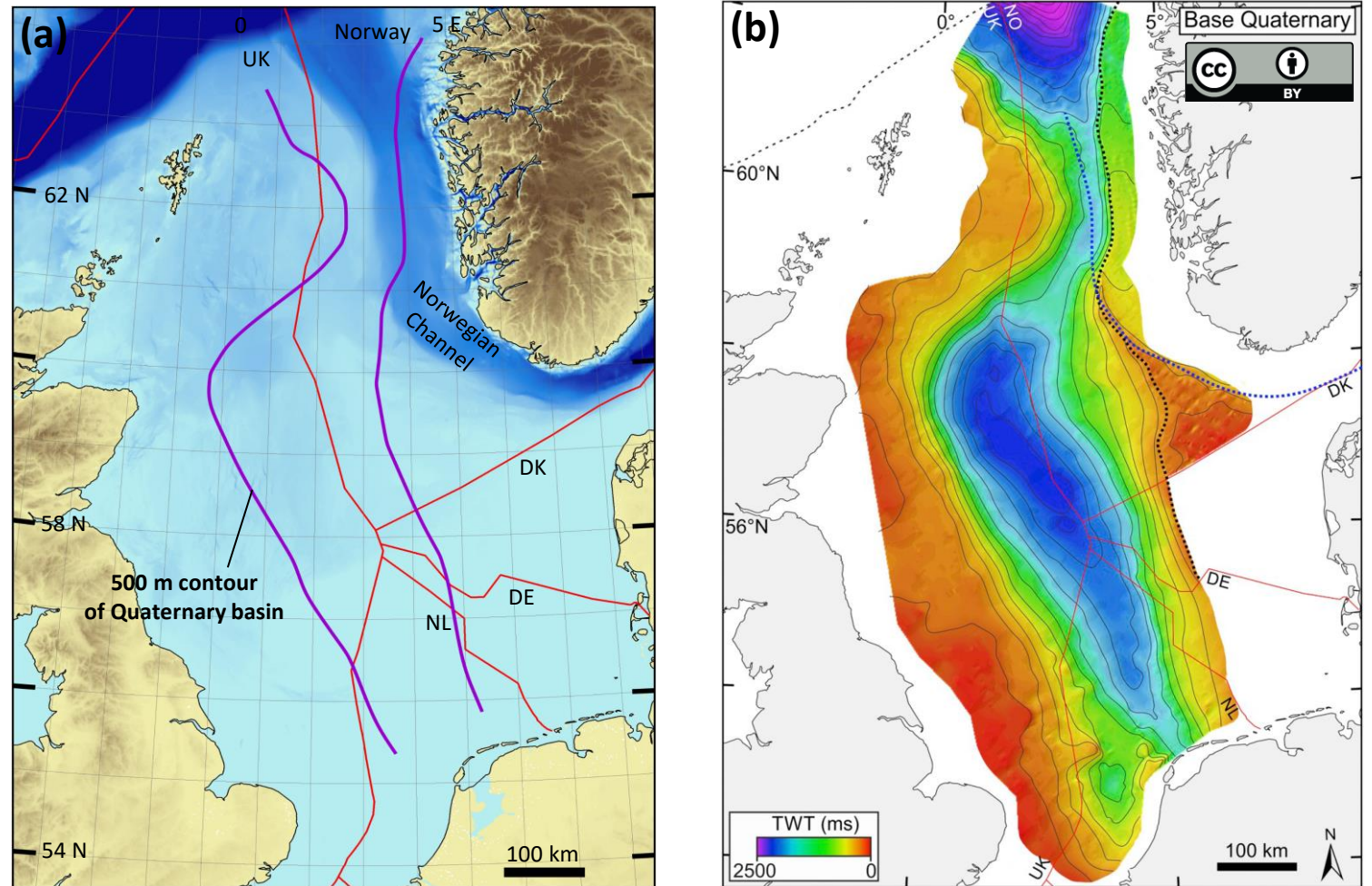


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# 1. The North Sea was a deep basin at the start of the Quaternary ~2.6 Ma

- At present, the North Sea is relatively shallow (generally <200 m) apart from the deeper Norwegian Channel (**Fig. 1a**).
- Seismic data show that the bathymetry of the North Sea was dominated by the North Sea Basin at the start of the Quaternary (~2.6 Ma) (**Fig. 1b**) (Lamb *et al.*, 2017; Ottesen *et al.*, 2018; Rea *et al.*, 2018).
- A thick (up to 1 km) Quaternary succession is preserved within the North Sea Basin

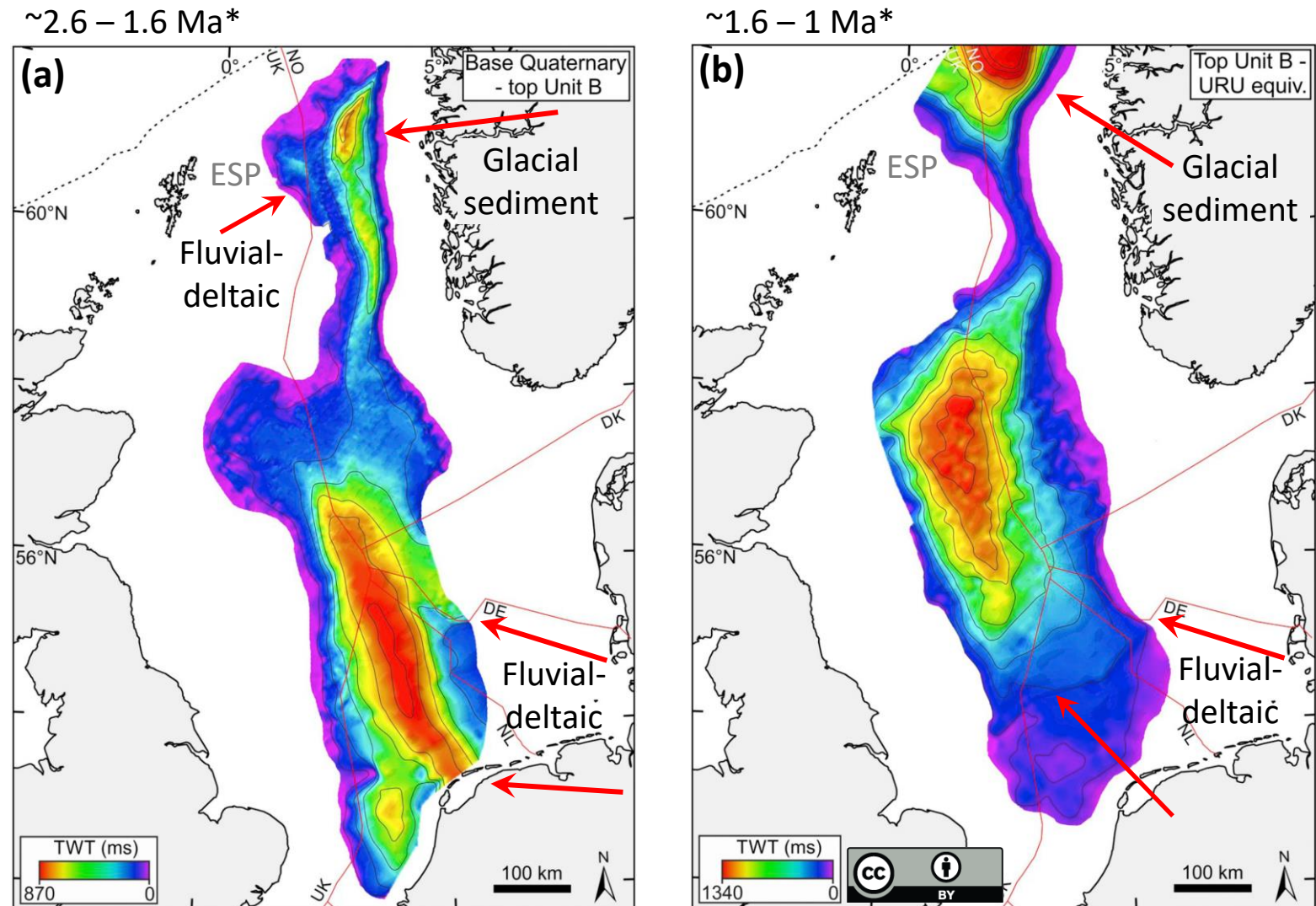


**Fig. 1. (a)** Present-day bathymetry of the North Sea, overlain by the 500 m contour of the Quaternary basin. **(b)** Structure map showing the geometry of the base-Quaternary surface in the North Sea. Adapted from Ottesen *et al.* (2018).

## 2. The North Sea was infilled mainly during the early Quaternary ( $\sim 2.6 - 0.8$ Ma) by:

- Fluvial-deltaic sediment derived from the Baltic (Eridanos) river system to the south (**Fig. 2**) (Gibbard, 1988; Overeem *et al.*, 2001; Kuhlmann and Wong, 2008).
- Glacial sediment delivered by the Scandinavian Ice Sheet to the former shelf break in the northern North Sea (**Fig. 2**).
- Fluvial-deltaic sediment derived from rivers on the East Shetland Platform (ESP)(**Fig. 2a**).

\*There is generally poor age control on the Quaternary sediments of the North Sea

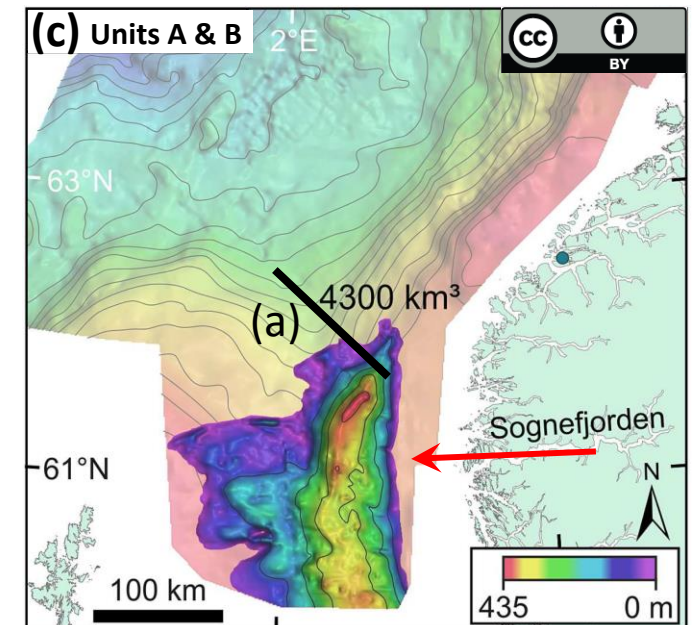
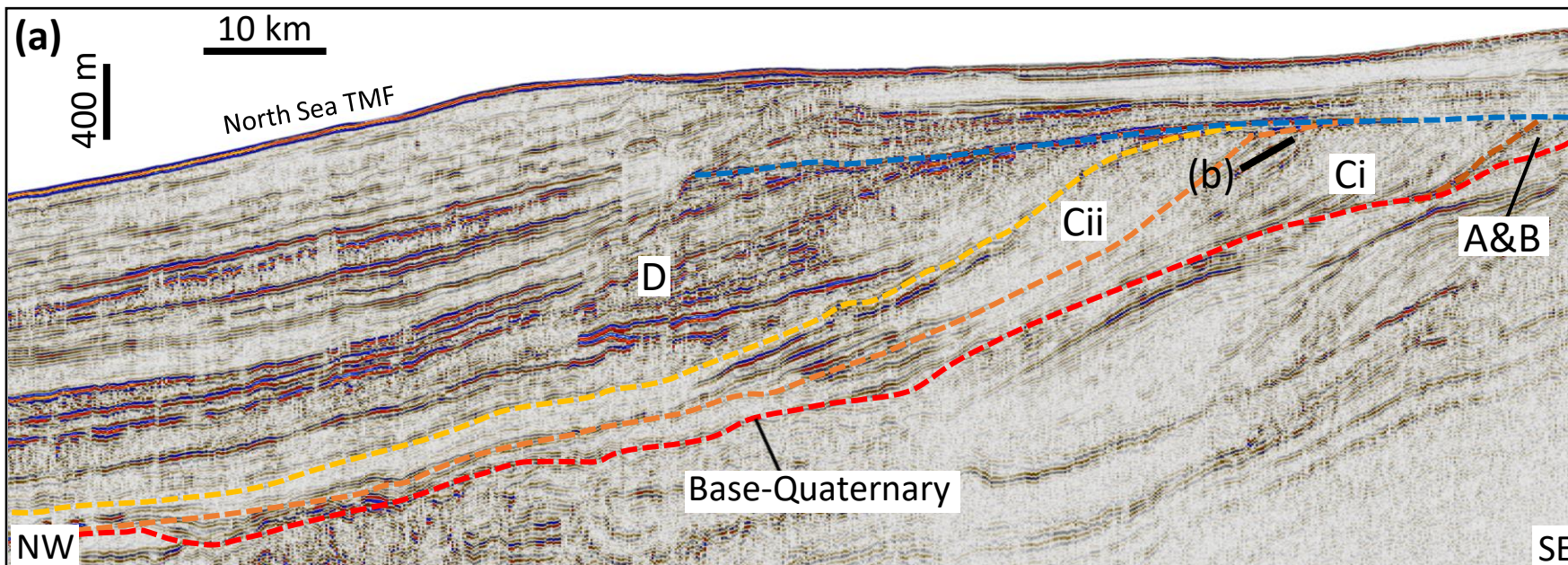
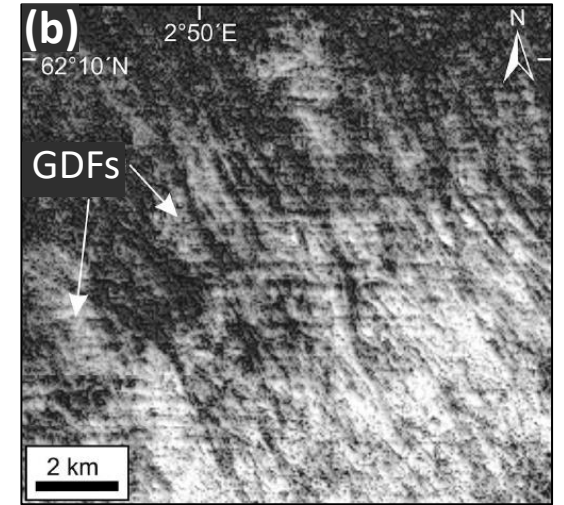


**Fig. 2.** Sediment thicknesses between Early Quaternary surfaces that are (a)  $\sim 2.6$  and  $\sim 1.6$  Ma in age, (b)  $\sim 1.6$  and  $\sim 1$  Ma in age. Adapted from Ottesen *et al.* (2018).



### 3. Grounded ice first reached the former shelf break beyond Sognefjord, Norway

- A glacial depocentre, containing numerous stacked glacial debris-flows (GDFs), built out into the northern North Sea from southern Norway since the earliest Quaternary (**Fig. 3**) (Ottesen *et al.*, 2014, 2018).
- The geometry of the oldest preserved part of this depocentre (Units A and B) (**Fig. 3c**) shows that grounded ice initially reached a limited area of the former shelf break beyond Sognefjord, Norway (Batchelor *et al.*, 2017; Løseth *et al.*, In Revision).



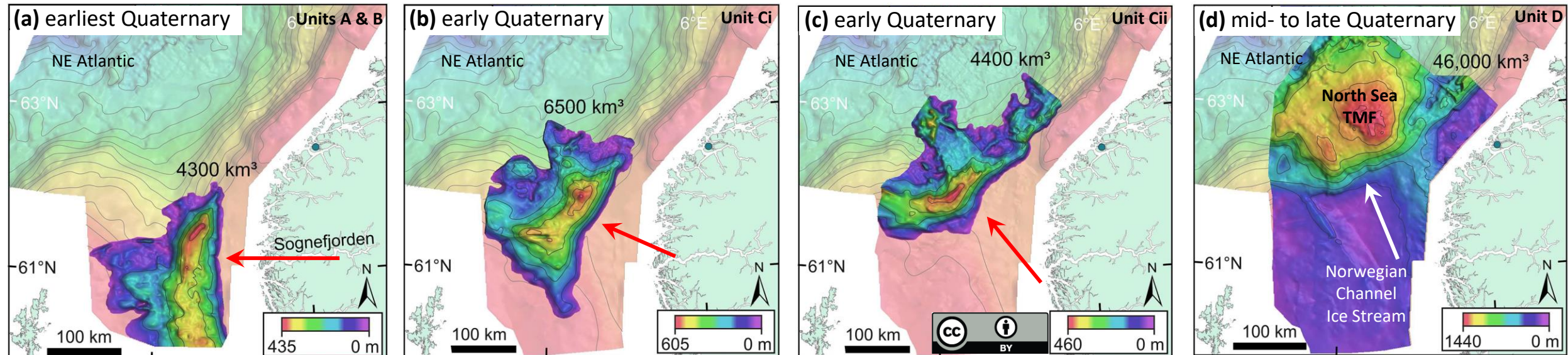
**Fig. 3.** (a) Interpreted seismic profile of the northern North Sea. (b) Example of GDFs on an early Quaternary palaeo-slope. (c) Isopach map showing the thickness and distribution of Quaternary Units A and B beyond Sognefjord, Norway. Adapted from Batchelor *et al.* (2017).



## 4. Infilling of the northern North Sea Basin led to:

- ... reduced accommodation, which caused the focus of sediment deposition to shift northwards towards the Northeast Atlantic Ocean (**Fig. 4**).
- ... shallower water in the northern North Sea, which enabled confluence of the Scandinavian and British-Irish ice sheets

Ice-sheet expansion and confluence in the North Sea probably encouraged initiation of the Norwegian Channel Ice Stream, which eroded the Norwegian Channel and formed the North Sea trough-mouth fan (TMF) (**Fig. 4d**).



**Fig. 4.** Isopach maps of the distribution and thickness of Quaternary units in the northern North Sea. **(a)** Units A and B (earliest Quaternary), **(b)** Unit Ci (early Quaternary), **(c)** Unit Cii (early Quaternary), **(d)** Unit D (mid- to late Quaternary). Adapted from Batchelor *et al.* (2017).

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