

## Onset of North Atlantic Deep Water production coincident with inception of the Cenozoic global cooling trend

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We are grateful for the opportunity to reply to the Comment by Stoker et al. (2013), who raise questions of interpretation regarding our paper (Hohbein et al., 2012). The main focus of the paper is the interpretation of the Eocene basinal succession of the Faerøe-Shetland Basin as a contourite drift body, using two-dimensional seismic and borehole data. This interpretation is exactly that: an interpretation, and as is the case with regional seismic stratigraphic interpretation in general, alternative views are often forthcoming, and to be encouraged.

Our interpretation of a drift is based on three key, purely seismic stratigraphic observations: recognition of a pronounced climbing onlap onto basinal structure; bidirectional downlap within a lensoid, slope parallel mounded body; and following Faugères et al. (1993), diagnostic thickening of onlapping units into the lapout position.

We address each of Stoker et al.'s three main points in turn:

1. Stoker et al. assert that the basal unconformity (Intra-Eocene Unconformity [IEU]) formed as “a subaerial or shallow marine erosion surface” and cannot therefore have been a deep-sea hiatus. However, because the position of 99/3 is at the updip limit of the contourite system, this does not preclude a deeper water environment of formation basinward. The lack of borehole calibration of the drift in the deeper basin leads to some uncertainty in either interpretation. Hence, the onus of the case made by Stoker et al. that this is not a drift body rests with the seismic stratigraphic evidence.

2. Stoker et al. argue that the IEU should be restored to a “flatter disposition prior to folding.” Applying their restoration to the onlap surface onto the Judd Anticline (Hohbein et al., 2012, our figure 2A) would turn the onlap relationship into a downlap. We consider this improbable, because it would require successive southwestward migration of lapouts with no aggradation of bottomsets in a more distal position. Base of slope clinofolds do give rise to downlap relationships, but in muddy systems, the lapout geometry is much more commonly asymptotic rather than an abrupt termination (Cartwright et al., 1993).

Stoker et al. acknowledge a period of folding for the Judd Anticline since the mid-Eocene, which would clearly allow the creation of topography in time to control the onlap relationship shown in our figure 2 (Hohbein et al., 2012). Robinson (2004) also showed convincing evidence for middle Eocene folding on the Judd Anticline. We therefore see no reason to modify our interpretation of the seismic-stratigraphic relationships on the grounds suggested by Stoker et al.

3. Stoker et al.'s statement that “no true deep connection (through the Greenland-Scotland Ridge) existed before the mid-Miocene” is, unfortunately, misleading; it reflects the prevailing view from the early to mid-1990s. Prior to our paper (Hohbein et al., 2012), work from the past two decades had already indicated significant deep-water flow through

the Greenland-Scotland Ridge from the earliest Oligocene onward (e.g., Wold, 1994; Davies et al., 2001).

Stoker et al. also question whether the existence of a northern component Atlantic deep water mass is oceanographically realistic for the minimally glaciated Eocene. Yet, contrary to Stoker et al.'s reasoning, large ice sheets do not directly influence North Atlantic Deep Water formation today nor likely did they during the Eocene. North Atlantic Deep Water is formed by winter cooling of already relatively saline surface waters. However, at warmer temperatures, surface cooling is even more effective than salinization at densifying fresh polar waters and initiating convection (de Boer et al., 2007). Presumably, despite upper abyssal waters during the early Eocene reaching 14 °C (Sexton et al., 2006), deep waters could still be sourced from the most northerly (and therefore likely coolest) surface waters of a given basin in a thermohaline manner. Furthermore, numerical models support the stability of thermohaline circulation across a wide range of “greenhouse” background climatic regimes (e.g., Huber and Sloan, 2001).

Our dating of the onset of sediment drift deposition in the northeast Atlantic now closely matches new results from Integrated Ocean Drilling Program Expedition 342 that indicate that the onset of drift sedimentation around the Newfoundland Ridges (that lie in the path of today's deep western boundary current) also occurred across the early to middle Eocene boundary (Expedition 342 Scientists, 2012).

In summary, we find no basis in Stoker et al.'s arguments to abandon our original conclusion that a major change in ocean circulation occurred across the early to middle Eocene boundary.

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