Glacigenic debris-flows observed in 3D seismic high-resolution seafloor imagery, Faroe–Shetland Channel, NE Atlantic

H. A. STEWART* & D. LONG

British Geological Survey, The Lyell Centre, Research Avenue South, Edinburgh EH14 4AP, UK

*Corresponding author (e-mail: hast@bgs.ac.uk)

Glacigenic debris-flows represent successive mass-flow deposits that build out a prograding wedge of sediment beyond the grounding zone of an ice sheet (e.g. Laberg & Vorren 1995; King *et al.* 1998). A prograding sedimentary depocentre extending from the outer shelf to the upper slope has been observed in geophysical datasets from the West Shetland margin of the Faroe–Shetland Channel, NW of the UK in the NE Atlantic. Overlapping, glacigenic debris-flows comprise the Rona and Foula wedges and provide insight into the extent and stability of the northern sector of the British Ice Sheet during the last full-glacial period (Stoker & Varming 2011).

Description

The Rona and Foula sedimentary wedges dominate the West Shetland margin south of 61° N (Fig. 1a) and overlap to form an elongate, outer-shelf to upper-slope depocentre up to 300 m in thickness (Stoker & Varming 2011). Typically elongate and sinuous lobe-like landforms are observed on seafloor imagery (Fig. 1a), and form a stacked association of lobes in seismic-reflection profiles (Fig. 1f). The sedimentary lobes of the Rona Wedge occur in water depths from approximately 400 to 1000 m, partly cover the floor of the Faroe–Shetland Channel and infill part of the Judd Deeps (Fig. 1a). The lobes of the Foula Wedge occur in a more restricted water depth range of between 400 and 700 m (Fig. 1a).

Both the Foula and Rona wedges comprise lobe-like landforms 3–5 km in width and up to 20 km in length located on the outer shelf and upper- to mid-slope (Fig. 1a). The lobes of the Foula Wedge can be traced onto the lower slope with most terminating abruptly between 650 and 700 m water depth (Fig. 1e). The lobes of the Rona Wedge occur immediately downslope of a scour-hole complex around 250 m in width and 10–15 m deep (Fig. 1a, c). At around 600 m water depth, the Rona lobes begin to lose their distinctive form (Fig. 1a).

A number of downslope gullies are also incised into the West Shetland slope extending down from 465 m water depth to the channel floor between 940 and 995 m (Stewart & Long 2012). Here, they connect with a number of basin-floor debris fans (Fig. 1e). The debris fans are up to 10 km across and the westernmost fan appears to partially infill an erosional hollow located on the channel floor (Fig. 1a). Abundant channels are also evident on the Rona Wedge between 600 m and around 900 m water depth, but are less incised than those observed on the Foula Wedge. A number of the lobe-like features of the Rona Wedge continue onto the lower slope. As the lobes reach the floor of the channel their morphology changes; the lobes widen and coalesce to form a series of fans that are about 2–3 km wide (Fig. 1a, d). These fans extend up to 15 km onto the channel floor with some showing a crest-line channel along the middle of the fan (indicated by white arrows in Fig. 1c).

Boreholes and shallow sediment core data from both the Foula and Rona wedges recover diamictons separated by thinner, acoustically layered packages that contain a mixture of cold and temperate, shelf and deep-water marine microfossils (Stoker & Varming 2011). British Geological Survey borehole 99/03 (Fig. 1a) penetrated a 56.3 m section of the Rona Wedge preserved on the lower slope and recovered massive diamictons up to 17 m in thickness within the acoustically structureless mass-flow deposits (Davison & Stoker 2002).

Interpretation

The stacked, lobe-like features of the Rona and Foula wedges are interpreted as glacigenic debris-flows that have occurred multiple times during the Late Quaternary, separated by periods of alongslope sedimentation. Such debris flows are comparable morphologically to those observed within Late Quaternary sequences of the Bear Island and North Sea fans (e.g. Laberg & Vorren 1995; King *et al.* 1998). Borehole data demonstrate that the debris-flow deposits are predominantly of glacigenic origin, with thin, layered packages separating the deposits suggested to be indicative of an interstadial or interglacial phase (Davison & Stoker 2002). These debris-flow deposits are located immediately downslope from moraines observed on the outer West Shetland shelf, linking them to former ice streams that extended across the northern UK shelf (Bradwell *et al.* 2008).

Although the bulk of sediment deposited in these prograding sediment wedges is glacial in origin, the initiation of the wedges pre-dates the onset of glaciation. This suggests that although tectonic uplift initiated change, isostatic uplift sustained the build-out of the continental margin by up to 40 km since the late Neogene (Stoker & Varming 2011).

The stacked glacigenic debris-flows are evidence that Pleistocene ice sheets reached the edge of the West Shetland shelf multiple times, delivering large volumes of sediment directly to the shelf edge and upper slope (Davison & Stoker 2002). These deposits became unstable, forming debris flows that transported sediments to the deep-water environment of the Faroe-Shetland Channel.

References

Bradwell, T., Stoker, M.S. *et al.* 2008. The northern sector of the last British Ice Sheet: maximum extent and demise. *Earth-Science Reviews*, **88**, 207–226.

Bulat, J. & Long, D. 2001. Images of the seabed in the Faroe-Shetland Channel from commercial 3D seismic data. *Marine Geophysical Researches*, **22**, 345–367.

Davison, S. & Stoker, M.S. 2002. Late Pleistocene glacially influenced deep-marine sedimentation off NW Britain: implications for the rock record. *In*: Ó Cofaigh, C. & Dowdeswell, J.A. (eds) *Glacier-Influenced Sedimentation on High-Latitude Continental Margins*. Geological Society, London, Special Publications, **203**, 129–147, http://doi.org/10.1144/GSL.SP.2002.203.01.08

King, E.L., Haflidason, H., Sejrup, H.P. & Løvlie, R. 1998. Glacigenic debris flows on the North Sea trough-mouth fan during ice-stream maxima. *Marine Geology*, **152**, 217–246.

Laberg, J.S. & Vorren, T.O. 1995. Late Weichselian submarine debris flow deposits on the Bear Island trough-mouth fan. *Marine Geology*, **127**, 45–72.

Stewart, H.A. & Long, D. 2012. The timing and significance of gully incision on the eastern flank of the Faroe–Shetland Channel and its impact on seafloor infrastructure. *Near Surface Geophysics*, **10**, 317–331.

Stoker, M.S. & Varming, T. 2011. Cenozoic (sedimentary). *In*: Ritchie, J.D., Ziska, H., Johnson, H. & Evans, D. (eds) *Geology of the Faroe–Shetland Basin and Adjacent Areas*. British Geological Survey Research Report, RR/11/01, Jarðfeingi Research Report, RR/11/01, HMSO for the British Geological Survey, London, 151–208.

From: Dowdeswell, J. A., Canals, M., Jakobsson, M., Todd, B. J., Dowdeswell, E. K. & Hogan, K. A. (eds) 2016. *Atlas of Submarine Glacial Landforms: Modern, Quaternary and Ancient*. Geological Society, London, Memoirs, **46**, 361–362, http://doi.org/10.1144/M46.94

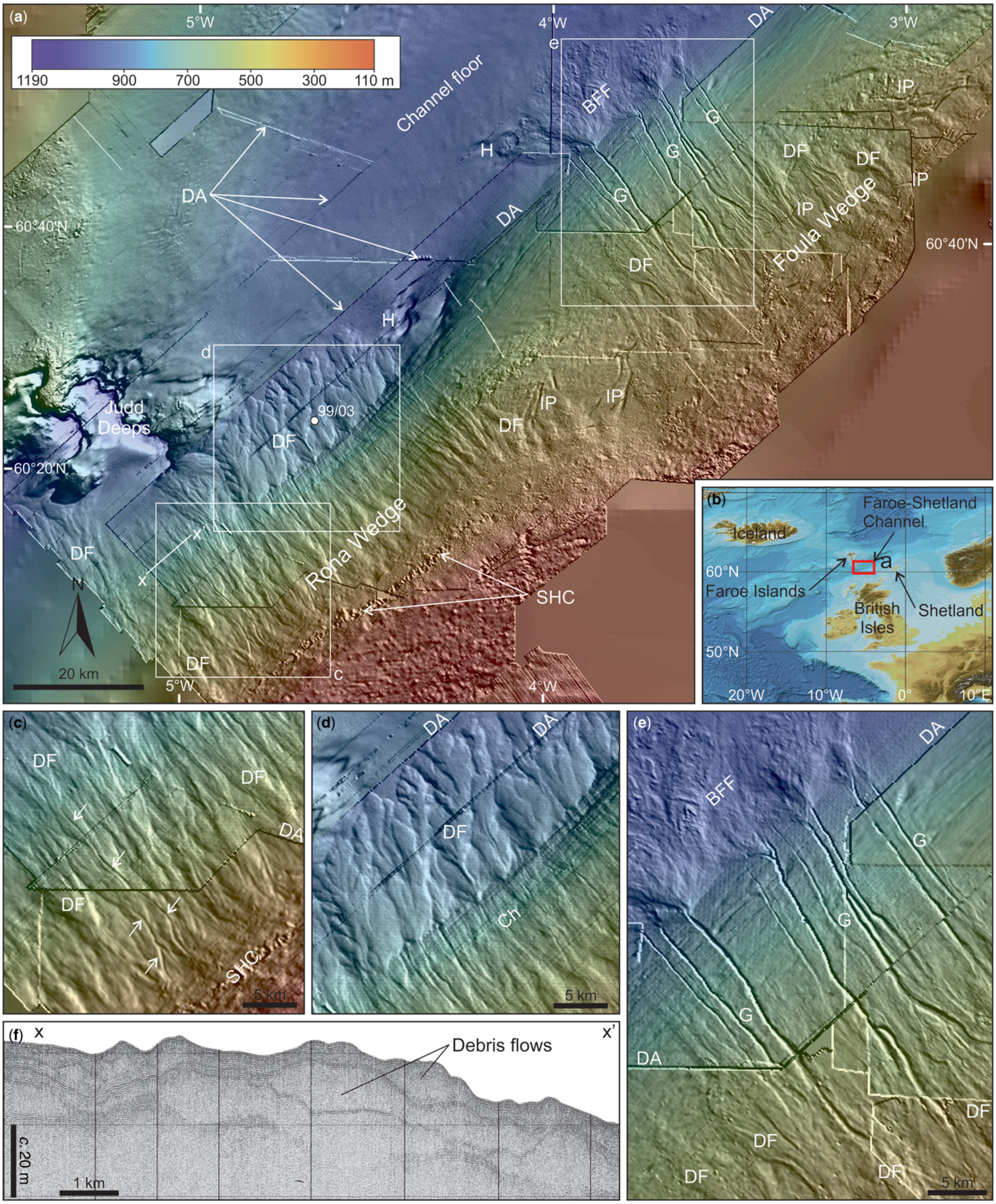

Fig. 1. Seafloor images and seismic-reflection profile of glacigenic debris-flows on the West Shetland margin. (**a**) Seafloor image showing the glacigenic debris-flows of Rona and Foula wedges. Image derived from first returns from commercial 3D seismic surveys (methodology in Bulat & Long 2001) combined into a mosaic grid with 100 m node line-spacing and depth converted assuming a water velocity of 1500 m s^{-1}. The mosaic was merged with a bathymetric grid (100 m contour, GEBCO dataset). (**b**) Location of study area (red box; map from GEBCO_08). (**c**) Detailed image of Rona Wedge. A few debris flows have channels incised into their crests (white arrows). (**d**) Detailed image of Rona Wedge showing an abrupt change from channelized features to fans on the channel floor. (**e**) Detailed image of downslope gullies incised into the West Shetland slope. (**f**) Seismic-reflection profile 83/04-64 showing stacked debris-flows, depth converted assuming a velocity of 1500 m s^{-1}. Acquisition system Huntec Deep-Tow Sparker 2000 Joules. BFF, basin floor fans; Ch, channelized features; DA, data artefact; DF, debris flow; G, linear gullies; H, hollow; IP, iceberg ploughmarks; SHC, scour-hole complex.