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3D seismic analysis of buried tunnel valleys in the central North Sea: morphology, cross-cutting generations and glacial history

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ABSTRACT

This work presents the results of morpho-stratigraphic analyses carried out on more than 180 buried tunnel valleys imaged in the central North Sea using 3D seismic data at a variety of resolutions. The buried tunnel valleys form complex networks of multiple cross-cutting generations. In the northern part of the study area, cross-cutting relationships within higher resolution 3D seismic data are used to extrapolate seven generations of tunnel valleys over an area of 14,400 km^2. Three generations of cross-cutting tunnel valleys are also observed within higher resolution 3D seismic data in the southern part of the study area. Detailed morphological measurements of individual tunnel valleys reveal average widths between 300 m and 3000 m, lengths in the region of tens of kilometres, and relatively straight and simple planform geometries. The majority of the tunnel valleys display undulating basal profiles which provide evidence for the uphill movement of water over distances greater than 10 km and indicate formation by meltwater under pressure. Tunnel valley geometries vary between generations and defy a simple link between formation process and end form. Detailed orientation measurements for the tunnel valley generations reveal an overall NE–SW trend in the northern part of the study area, and a NW–SE directionality in the south. When considered in light of palaeoglaciological models for the British and Scandinavian ice sheets during the Pleistocene, tunnel valley orientation and distribution are consistent with the majority of tunnel valley generations forming perpendicular to a retreating British ice sheet. Changes in orientations between generations (in both northern and southern study areas) provide evidence for changes in the dynamics of the British and Scandinavian ice sheets between subsequent glaciations of the central North Sea.

1. Introduction

Tunnel valleys are linear, channel-like incised landforms closely associated with the continental glaciation of sedimentary lowlands and basins where they are often used to delineate former ice margins. Tunnel valleys of Quaternary and older age are documented both on land and offshore, buried and at surface. They are recognised as important conduits for meltwater underneath continental ice sheets and are generally considered to be erosional landforms associated with subglacial drainage, although the exact process of their formation remains contentious (O'Cofaigh, 1996; Huuse and Lykke-Andersen, 2000; Van der Vegt et al., 2012).

Tunnel valleys have been used for over a hundred years as part of a suite of glacial landforms (including moraines, eskers and ploughmarks) to identify the locations of former ice-sheet margins in NW Europe (see reviews in O'Cofaigh, 1996; Huuse and Lykke-Andersen, 2000; Kehew et al., 2012; Van der Vegt et al., 2012). As meltwater features, tunnel valleys are generally considered to be oriented roughly parallel to ice flow direction, where they channel water from areas of high pressure (thicker ice) to lower pressure (thinner ice) (e.g. see Fig. 1 of Kehew et al., 2012). A common characteristic of tunnel valleys, and in some cases, a criteria for their identification, is the presence of an undulating thalweg along tunnel valley reach, which provides evidence for the uphill flow of pressurised meltwater as a mode of formation, as opposed to subaerial processes (O'Cofaigh, 1996; Huuse and Lykke-Andersen, 2000; Kehew et al., 2012; Van der Vegt et al., 2012).

Recent reviews by Kehew et al. (2012), Van der Vegt et al. (2012), O'Cofaigh (1996) and Huuse and Lykke-Andersen (2000), provide a thorough outline of the ongoing controversy regarding the formation of tunnel valleys beneath continental ice-sheets. Currently,

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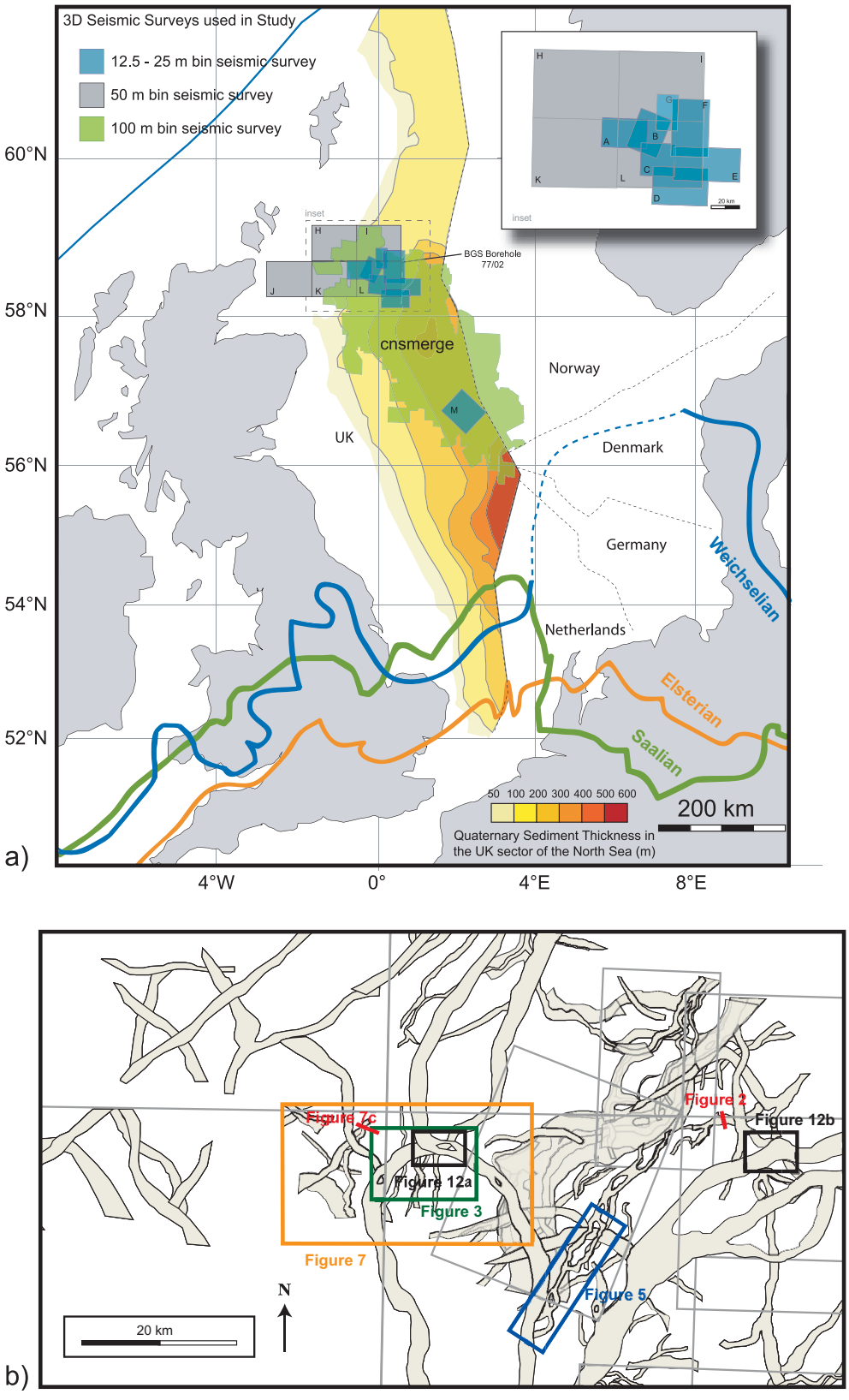

Fig. 1. (a). Location map of central North Sea study area with 3D seismic surveys A to M (inset shows detailed view of datasets A to G) and the regional dataset 'cnsmerge'. Seismic surveys are colour coded dependant on their bin spacing which is equivalent to the horizontal resolution of the data. Extent of the Elsterian (orange), Saalian (green) and Weichselian (blue) Pleistocene glaciations are from Ehlers and Gibbard (2004). Quaternary sediments into which the study tunnel valleys incise are up to 600 m thick towards the centre of the basin (Caston, 1977; Gatliff et al., 1994). Map Projection: Spherical Mercator. (b) Location of figures within northern part of study area on map of tunnel valley outlines (in grey). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)