Quaternary Science Reviews 97 (2014) 121–135

Contents lists available at ScienceDirect

Quaternary Science Reviews

journal homepage: www.elsevier.com/locate/quascirev

Ice-load induced tectonics controlled tunnel valley evolution – instances from the southwestern Baltic Sea

M. Al Hseinat*, C. Hübscher

Institute of Geophysics, Center for Earth System Research and Sustainability, University of Hamburg, Bundesstrasse 55, 20146 Hamburg, Germany

ARTICLE INFO

Article history:
Received 13 January 2014
Received in revised form
11 May 2014
Accepted 15 May 2014
Available online

Keywords:
Reflection seismics
Tunnel valleys
Glaciogenic unconformity
Bay of Kiel
Cretaceous pockmarks
Glückstadt graben

ABSTRACT

Advancing ice sheets have a strong impact on the earth's topography. For example, they leave behind an erosional unconformity, bulldozer the underlying strata and form tunnel valleys, primarily by subglacial melt-water erosion and secondarily by direct glacial erosion. The conceptual models of the reactivation of faults within the upper crust, due to the ice sheets' load, are also established. However, this phenomenon is also rather under-explored. Here, we propose a causal link between ice-load induced tectonics, the generation of near-vertical faults in the upper crust above an inherited deep-rooted fault and the evolution of tunnel valleys. The Kossau tunnel valley in the southeastern Bay of Kiel has been surveyed by means of high-resolution multi-channel seismic and echosounder data. It strikes almost south to north and can be mapped over a distance of ca 50 km. It is 1200–8000 m wide with a valley of up to 200 m deep. Quaternary deposits fill the valley and cover the adjacent glaciogenic unconformity. A near-vertical fault system with an apparent dip angle of >80°, which reaches from the top Zechstein upwards into the Quaternary, underlies the valley. The fault partially pierces the seafloor and growth is observed within the uppermost Quaternary strata only. Consequently, the fault evolved in the Late Quaternary. The fault is associated with an anticline that is between 700 and 3000 m wide and about 20–40 m high. The fault–anticline assemblage neither resembles any typical extensional, compressional or strike-slip deformation pattern, nor is it related to salt tectonics. Based on the observed position and deformation pattern of the fault–anticline assemblage, we suggest that these structures formed as a consequence of the differential ice-load induced tectonics above an inherited deep-rooted sub-salt fault related to the Glückstadt Graben. Lateral variations in the ice-load during the ice sheet's advance caused differential subsidence, thus rejuvenating the deep-rooted fault. As a result, the inherited fault propagated upwards across the Zechstein and post-Permian overburden and further grew during the ice sheet's retreat. The developing fault and anticline system under the ice sheet created a weakness zone that facilitated erosion by pressurized glacial and subglacial melt-water, as well as by the glaciers themselves. Near-vertical faults cutting through the post-Permian are abundant in the southwestern Baltic realm, which implies that the ice-load induced tectonic activity described above was not an isolated incident.

© 2014 Elsevier Ltd. All rights reserved.

1. Introduction

Three major ice advances affected northern and northwestern Europe during the Late Pleistocene period: the Elsterian, Saalian and Weichselian advances (Liedtke, 1981; Ehlers, 1996). Tunnel valleys originated as subglacial channels and are defined as deep channel-form features incised into the Pleistocene at glaciated sites all over the world, but particularly in the Northern Hemisphere. These erosional valleys were intensively studied over the past two decades (Cofaigh, 1996; van Dijke and Veldkamp, 1996; Huuse and Lykke-Andersen, 2000; Praeg, 2003; Jørgensen and Sandersen, 2004; BurVal Working Group, 2006; Rattas, 2007), since they hold significant amounts of groundwater or, rarely, economic shallow gas. They may also contain aggregate for construction.

The valleys' formation is primarily attributed to subglacial melt-water erosion, and secondarily to direct glacial erosion, incising the underlying Tertiary strata during the glacial coverage (for a critical discussion see, e.g., Huuse and Lykke-Andersen, 2000). In addition, several authors mentioned the spatial correlation between the tunnel valleys and the faults beneath (Bruun-Petersen, 1987; Lykke-Andersen et al., 1993; Salomonsen, 1993, 1995; Schwarz,

* Corresponding author. Tel.: +49 40 428385060; fax: +49 40 428385441.
E-mail addresses: muayyad.al-hseinat@zmaw.de, mo2ead2005@yahoo.com (M. Al Hseinat).

http://dx.doi.org/10.1016/j.quascirev.2014.05.011
0277-3791/© 2014 Elsevier Ltd. All rights reserved.

1996; Huuse and Lykke-Andersen, 2000; Sandersen and Jørgensen, 2002; BurVal Working Group, 2006). However, a causative interrelation was never established.

The tunnel valleys were investigated in the western Baltic realm over the course of several studies. Huuse and Lykke-Andersen (2000) mapped the onshore distribution of these valleys in Denmark and northern Germany (Fig. 1). Stackebrandt et al. (2001) showed a spatial correlation between the tunnel valleys and the fault systems related to the major tectonic elements in the region that had not previously been discussed. Based on some very high-resolution single-channel seismic data, Atzler (1995) mapped the offshore prolongation of the Kossau valley into the Bay of Kiel by means of Boomer data of 0.5–11 kHz (−6 db interval) with up to 30 ms two-way travel time (TWT) signal penetration (Figs. 2 and 3). The full width of the valley is not resolved in the bathymetry; however, a narrow channel is presented (Fig. 4).

In this study, we examine the interplay between ice sheet loading/unloading and the resulting vertical movement of an inherited fault system related to the southeastern segment of the Glückstadt Graben (GG) in controlling the formation and evolution of the Kossau tunnel valley. The Universities of Aarhus and Hamburg collected the information for the dataset that we used within the framework of the BaltSeis and NeoBaltic projects (Hübscher et al., 2004; Hansen et al., 2005; Hübscher et al., 2010). It is also supplemented by information from four surrounding exploration wells (Fig. 3).

2. Setting and previous work

The study area – the Bay of Kiel in the southwest Baltic Sea – is part of the Northeast German Basin (NEGB) and represents the NE part of the South Permian Basin (Fig. 2). The NEGB belongs to a series of Carboniferous-Permian intercontinental basins extending from the North Sea to northern Poland, such as the GG, which is located in the southern corner of the study area (Fig. 2). The GG represents an NNE–SSW trending post-Permian sub-basin of the Central European Basin System (Maystrenko et al., 2005). The GG is one of the sedimentary basins where the sedimentary cover has been strongly affected by salt tectonics. The GG can be subdivided into three main domains (Fig. 2): (i) the Central GG; (ii) the marginal Eastholstein, Westholstein and Hamburg Troughs; and (iii) the outer Eastholstein, Westholstein and Mecklenburg blocks at the western GG flanks (Maystrenko et al., 2008). The onset of the regional E–W directed extension at the transition between the Middle and Late Triassic created N–S trending depocentres, as well as the associated salt structures, such as the GG. The eastern SW–NE trending marginal Eastholstein Trough evolved during the Jurassic period (Maystrenko et al., 2011).

Hansen et al. (2005) extensively studied the stratigraphy and structural evolution of the Bay of Kiel. According to these authors, the E–W directed regional extension during the Late Triassic and Early Jurassic, which created the GG, corresponds with the E–W striking fault system on top of a salt pillow in the Bay of Kiel. The development of the Central North Sea Dome, due to plutonic activity (Ziegler, 1990; Underhill, 1998), caused a period of uplift and erosion in the Middle Jurassic to Early Cretaceous, which removed parts of the Lower Jurassic and Upper Triassic successions. Sedimentation resumed towards the end of the Early Cretaceous and the subsidence continued without major tectonic activity.

On the Cretaceous to Cenozoic transition, the Alpine Orogenesis started and the regional stress field changed from extensional to compressional (Ziegler, 1990), causing a reactivation of vertical salt tectonics. Hansen et al. (2005, 2007) and Hübscher et al. (2010) stated that the post-Palaeozoic stratigraphic boundaries generally follow along the top of the Zechstein salt throughout the southwest Baltic realm.

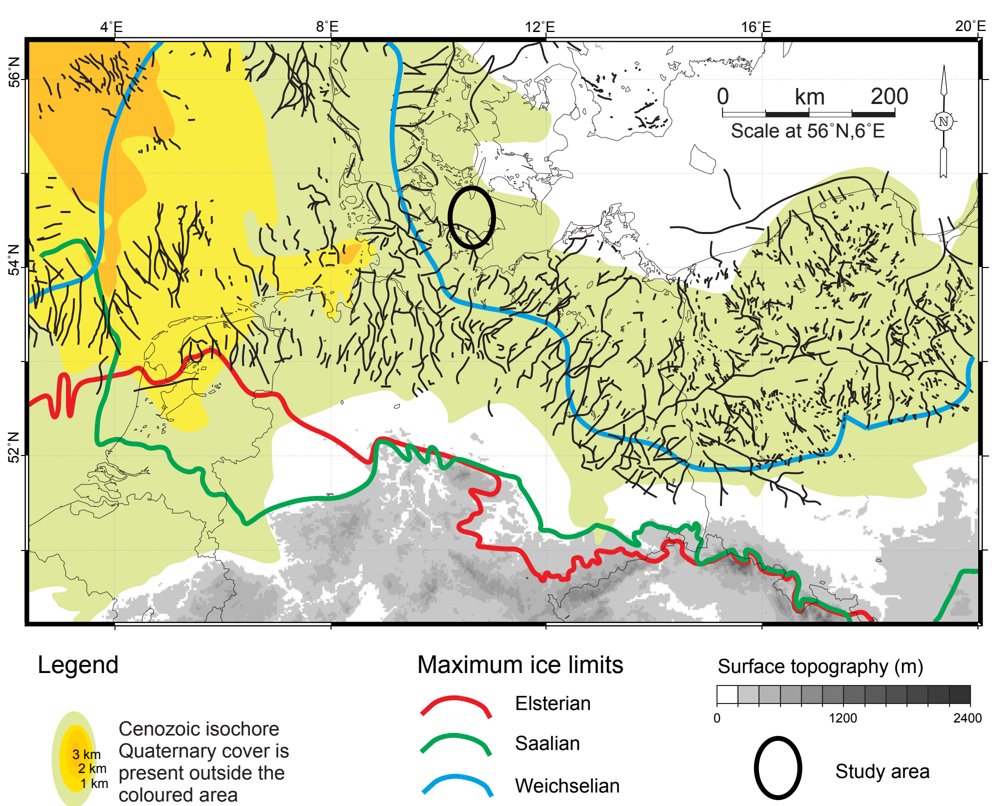

Fig. 1. Overview of Quaternary tunnel valleys in northwest Europe (modified after Huuse and Lykke-Andersen, 2000).

Download English Version:

https://daneshyari.com/en/article/6445675

Download Persian Version:

https://daneshyari.com/article/6445675

Daneshyari.com