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Integrated study on the topographic and shallow subsurface expression of the Grote Brogel Fault at the boundary of the Roer Valley Graben, Belgium

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ABSTRACT

The Grote Brogel Fault (GBF) is a major WNW-ESE striking normal fault in Belgium that diverges westward from the NW-SE striking western border fault system of the Roer Valley Graben. The GBF delimits the topographically higher Campine Block from the subsiding Roer Valley Graben, and is expressed in the Digital Terrain Model (DTM) by relief gradients or scarps. By integrating DTM, Electrical Resistivity Tomography (ERT), Cone Penetration Test (CPT) and borehole data, we studied the Quaternary activity of the GBF and its effects on local hydrogeology. In the shallow subsurface (< 50 m) underneath these scarps, fault splays of the GBF were interpreted on newly acquired ERT profiles at two investigation sites: one on the eastern section and the other on the western section, near the limit of the visible surface trace of the fault. Borehole and CPT data enabled stratigraphic interpretations of the ERT profiles and thereby allowed measuring vertical fault offsets at the base of Pleistocene fluvial deposits of up to 12 m. Groundwater measurements in the boreholes and CPTs indicate that the GBF acts as a hydrologic boundary that prevents groundwater flow from the elevated footwall towards the hangingwall, resulting in hydraulic head differences of up to 12.7 m. For the two investigation sites, the hydraulic head changes correlate with the relief gradient, which in turn correlates with the Quaternary vertical offset of the GBF. ERT profiles at the eastern site also revealed a local soft-linked stepover in the shallow subsurface, which affects groundwater levels in the different fault blocks, and illustrates the complex small-scale geometry of the GBF.

1. Introduction

The Roer Valley Rift System (RVRS, also referred to as the Lower Rhine Graben) developed during the late Oligocene as the northwestern branch of the Rhine Graben system, which is part of the European Cenozoic Rift System extending from west of the Alps to the North Sea (Ziegler, 1988; Fig. 1). The Roer Valley Graben (RVG) is the central graben of the RVRS and is flanked by the Campine Block in the west and the Peel Block in the east. The RVG is ~ 145 km long, trends northwest-southeast, and has an asymmetric structure. To the northeast, it is bordered by a relatively straight and narrow NW-SE striking fault zone, the Peel Boundary Fault Zone, which has a throw of 400–800 m for the base of the Miocene (Geluk et al., 1994). To the southwest, the RVG is bordered by a NW-SE striking broad fault bundle, the Feldbiss Fault Zone (FFZ), which consists of a number of faults showing a left-stepping pattern, and with a throw for the base Miocene horizon in the order of ~ 400 m (Demyttenaere and Laga, 1988). In the central or Belgian sector of the RVG, the FFZ bifurcates into three fault branches (Fig. 1B): the NW-SE oriented Bocholt and Reppel faults, and the WNW-ESE striking Grote Brogel fault (further noted as GBF). According to Demyttenaere and Laga (1988), the GBF bends NW, parallel to the other two faults. However, this bend is poorly constrained, making the precise role of the GBF in the overall graben geometry speculative. It is not clear whether the fault represents a large-scale left step in the border fault system or simply splits off from the border fault and dies out to the west. Despite its importance for the border fault geometry and local stratigraphy, little research was thus far performed on the geologically recent (Quaternary) activity of the GBF.

As a result of their Quaternary to recent activity, the large border faults of the RVRS reach the surface and have generated topographic relief, which promotes groundwater flow from the footwall to the hangingwall. Since most of the faults in the RVRS act as a hydrological barrier in the unconsolidated sediments (Bense et al., 2003a), they prevent groundwater to flow from elevated to low areas, causing a

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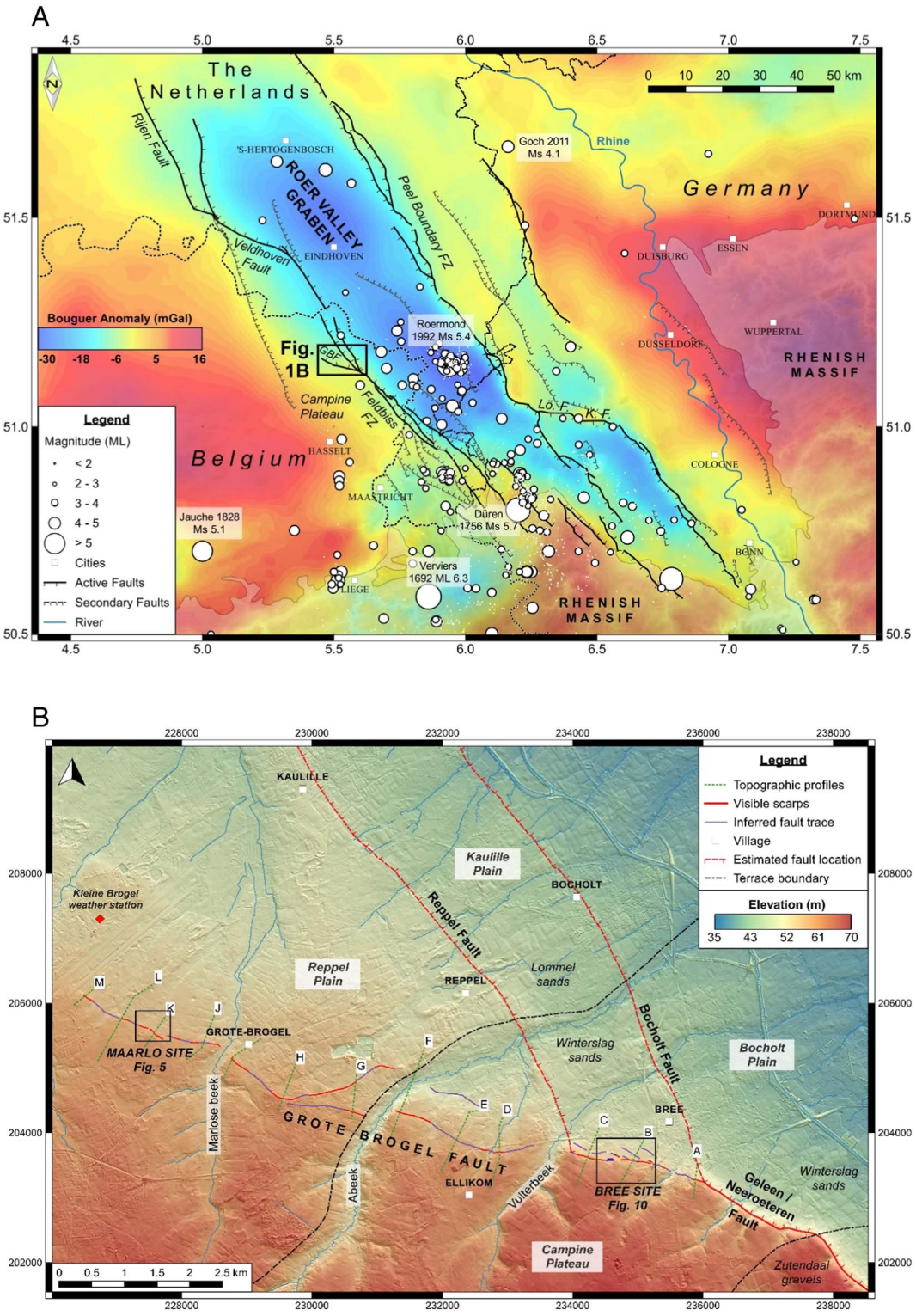

Fig. 1. A. Roer Valley Graben border fault configuration and seismicity in relation to the Bouguer anomaly. Note the lower Bouguer Anomaly values in the Roer Valley Graben related to a thick sequence of uncompacted sediments. The study area is explained in detail in panel B. Lö. F.: Lövenich Fault; K. F.: Kast Fault. Coordinates in WGS '84. Modified after Vanneste et al. (2013) with seismicity updated to Dec. 2016.

B. Detailed morphotectonic map of the border faults of the RVG and indication of the Maarlo and Bree Sites (Figs. 5 and 10) analyzed in this work. Note the fragmentation along the Grote Brogel Fault, and the large-scale complexity west of the Abeek. The Reppel and Bocholt fault traces are taken from the H3O-Roer Valley Graben project (Deckers et al., 2014), slightly modified to the geomorphology. Labels A to M correspond to topographic profiles shown in Fig. 3. Terrace boundaries are indicated after the Quaternary geological map of Beerten et al. (2005). DTM model from Agentschap Informatie Vlaanderen (2016). Coordinates in Lambert '72.