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Slip rate and mode of the Feldbiss normal fault (Roer Valley Graben) after removal of groundwater effects

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Abstract

The Feldbiss fault is the main active fault bounding to the southwest the Roer Valley Graben of NW Europe. In order to investigate the reasons of the discrepancy between its short- and long-term slip rate estimates, we have repeatedly surveyed a 2.3 km-long line by levelling at Sittard (The Netherlands) from April 2001 to December 2004. Simultaneously, three superposed aquifers were monitored on both sides of the fault. The across-fault differential groundwater variations are shown to be responsible for a seasonal 0.87 mm/m vertical motion of the fault, mainly through the effect of pore pressure changes in confined aquifers. After removal of this effect, I get a residual trend of -0.60 ± 0.11 mm/yr for the relative motion of the hangingwall. This trend was disturbed in the summer of 2002 by transient millimetre-level up and down motions temporally associated with the small Eschweiler earthquake that occurred on July 22, 2002 on the Feldbiss fault at a distance of 35 km from Sittard. I explain this as a creep event triggered by the passage of trapped seismic waves. The subsisting discrepancy between the long-term slip rate of 0.06 mm/yr and short-term rates of ~ 1.5 mm/yr (from 1962 to 2001) and 0.6 mm/yr (from 2001 to 2004) is tentatively interpreted as resulting from the current occurrence of a decade-long episode of aseismic slip involving a large part of the fault plane. Occasionally associated with minor seismicity, this aseismic slip event could betray a thickening of the transitional region located below the upper crustal zone of stable sliding. It causes a total fault slip of 5–10 cm in a few tens of years, releasing smoothly all, or a great part of, the strain accumulated during the previous 1–2 ky of fault quiescence.

Keywords: Roer Valley Graben; Feldbiss fault; fault slip rate; fault creep; aseismic slip; precise levelling

1. Introduction

The Roer Valley Graben (**RVG**) is a region of moderate seismicity [1], struck by the Roermond, 1992, earthquake of $M_L \sim 5.9$. It has also been shown that the Feldbiss fault is one of the main seismogenic sources in the area, with Late Quaternary paleoearthquakes of estimated M_w 6.0–6.5 [2], calling for detailed studies of the present-day behaviour of the fault in order to support the regional earthquake hazard assessment.

Extending across densely populated areas of W Germany, the Netherlands and NE Belgium, the **RVG** is continuously subsiding since the Late Oligocene [3] and is still currently the most active tectonic unit within the Lower Rhine segment of the European Cenozoic Rift

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System (ECRS). It is limited to the northeast by the Rurrand–Peel Boundary fault zone and to the southwest by the NNW- to NW-striking Feldbiss fault zone. To the south of the latter, the southern shoulder of the graben is comprised, from SE to NW, of the uplifting Paleozoic NE Ardenne massif, the S Limburg block and the Campine Plateau (Fig. 1).

The incision of the Meuse valley in the uplifted shoulder, including the footwall of the Feldbiss fault, and the development of a flight of fluvial terraces provide ample evidence of the Quaternary activity of the fault zone [4,5]. Displacement rate estimates for various segments of the Feldbiss fault system during varying periods of the Middle and Late Quaternary do not exceed 0.05–0.06 mm/yr [4–7]. A similar rate of 0.07 mm/yr has been deduced for the last 45 ky from paleoseismological investigations of the Bree segment of the fault in Belgium [8]. However, Van den Berg [5] suggests that this rate had strongly decreased during the last 200 ky.

By contrast, precise levelling surveys of the Dutch first order network repeated over more than 50 yrs yield a displacement rate of ~ 1.5 mm/yr for the Feldbiss fault [9]. The discrepancy between low paleoseismological and one order of magnitude higher geodetic rates has been suggested to indicate that only a limited amount of the total strain is released seismically [8]. But, even in this case, the inconsistency remains between the present-day and Quaternary slip rates.

One possible explanation of the problem could lie in that the geodetic rate estimates, in particular for the very low rates of intraplate normal faults, are often biased by groundwater-dependent vertical movements of the ground [10]. Relying on almost four years of repeated precise levelling surveys across the Feldbiss fault at Sittard (Fig. 1), the aim of this article is therefore (1) to identify, to model and to remove every groundwater effect on surface vertical displacements in order (2) to isolate the possible tectonic component of motion and to determine the true present-day slip rate and mode of the fault.

2. Geological setting of the study area

Belonging to the Lower Rhine segment of the ECRS, the NNW- to NW-trending Roer Valley Graben is inherited from a Carboniferous foreland basin reactivated in various ways during several periods of the Mesozoic and the Cenozoic. After a last inversion phase during the Late Eocene-Early Oligocene [7], it has been continuously subsiding since the Late Oligocene. In its southeastern part, the RVG is almost symmetric, with ~ 1000–1500 m-thick Cenozoic and ~ 2500 m-thick Mesozoic sediments overlying the Paleozoic basement [11].

The normal fault systems bounding the RVG, in particular the Feldbiss fault zone (FFZ) to the southwest, are

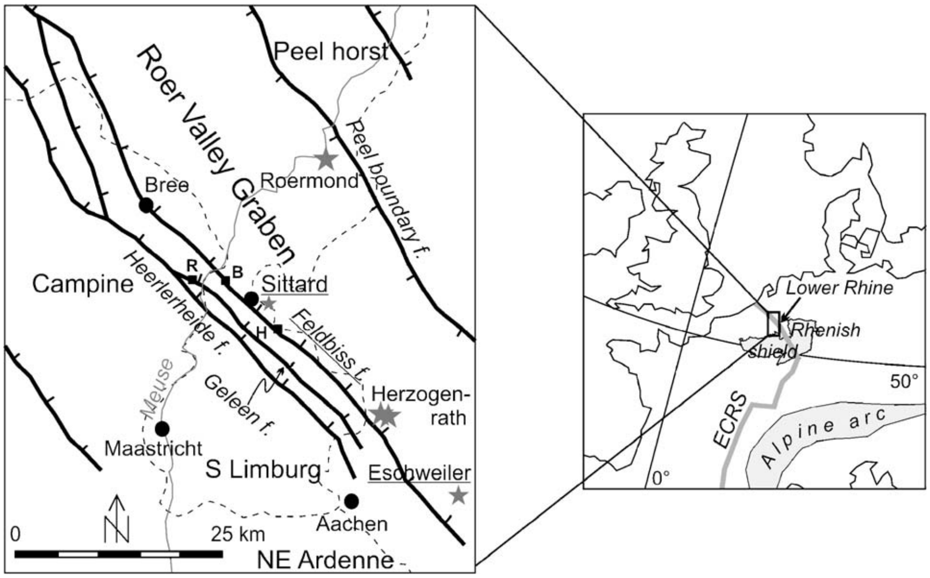

Fig. 1. Sketch map of the Roer Valley Graben showing the location of the surveyed line across the Sittard segment of the Feldbiss fault. The Sittard segment extends from Born (**B**) to Hillensberg (**H**). (**R**) Rotem. The stars locate the earthquakes mentioned in the text. (**ECRS**) European Cenozoic Rift System.