SEISMIC SLIP ESTIMATES AND 3-D STRUCTURAL MODELLING ALONG THE VIENNA BASIN TRANSFORM FAULT

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Introduction

Current seismic hazard estimates for the Vienna Basin Transform Fault area are solely based on probabilistic analyses of historical and instrumental earthquake data. The accuracy of resulting hazard estimates is limited by the nature of the data (e.g. ambiguous historical sources) and by the restriction of available earthquake catalogues to time scales of only few hundred years, which are geologically insignificant and not capable to describe the tectonic processes causing earthquakes. This is especially relevant to intraplate regions where faults show slow slip rates resulting in long average recurrence times for large earthquakes ($10^3$ to $10^6$ yrs).

The Vienna Basin Transform Fault system extends for about 450 km from the central Eastern Alps through the Mur-Mürz Valley, the Vienna basin and Moravia into the outer Carpathians of Polish Galicia. The fault developed during the Miocene, kinematically linked to eastward lateral extrusion of crustal blocks from the Eastern Alps to the Carpathian-Pannonian region. Seismicity along the fault proves that the fault system is still active. Recently published GPS derived velocities suggest about 1-2 mm/yr left lateral movement across the Vienna Basin (Grenerczy et al., 2000, 2002). Geometric balancing of a Quaternary Basin in the southern Vienna Basin comprises 1-2 mm/yr movement along the Vienna Basin Transform Fault system (Decker et al., 1998).

In order to understand the geodynamic processes and to enhance current seismic hazard estimates along the Vienna Basin Transform Fault we focus on two different approaches:

A) Calculating slip rates from the seismic energy release of available historical and instrumental earthquake data. Results are compared to geologically/geodetically obtained velocities and are discussed in order to evaluate possible seismic slip deficits.

B) Structural modelling of the subsurface of the Vienna Basin to enhance understanding of kinematics and geodynamics of the system.
**Seismic Slip estimates**

The database used is the national earthquake catalogue (ZAMG, 2001), which lists felt earthquakes since 1201 A.D. The following computations use only events after 1898, i.e., the start of instrumental recording. For calculating deformation rates from seismic moment release we define generalized faults and fault segments along the Vienna Basin Transform Fault system (Fig. 1). Magnitudes were converted to seismic moment and the seismic slip rate is determined following Brune (1968). A shear modulus of 30 GPa is used.

Scalar seismic moments are converted from catalogue magnitudes comparing two different empirical relationships (Hanks and Kanamori, 1979: $\log M_0 = 1.5M + 9.1$; Purcaru and Berckhemer, 1978: $\log M_0 = 18.8 + M_S$) giving a spectrum of results for the slip rate. Slip rates are plotted versus assumed fault depth, which is not precisely known.

Figure 1b show the results for the Austrian part of the Vienna Basin Transform Fault system. Estimated seismic slip rates for the whole fault system vary from 0.1 - 0.3 mm/yr for reasonable fault depth (6 - 10 km). Separating the system into two segments show that cumulative seismic moment at the Vienna Basin fault correspond to slightly higher rates than at the Mur-Mürz fault (c. 0.03 - 0.05 mm/yr faster, Fig. 2). For further investigation the generalized faults are broken into segments of approx. 21 km length. While there are segments without any substantial seismic moment release and corresponding seismic slip (less than 0.02 mm/yr) the segments with the highest seismic moment release show seismic slip rates as high 0.2 - 0.5 mm/yr for 10 or 4 km fault depth respectively. This heterogeneity might be explained by creep or locked segments.

We find that the rate of slip along the Vienna Basin Transform Fault System detected by geodetical measurements is significant higher than the rate calculated from the seismic moment release. There are several major reasons, which might account for the discrepancy between the different kind of estimated slip velocities.

A) Uncertainties in the calculation and inaccurate input parameters

B) Uncertainties regarding the slip velocities obtained from geological modelling and geodetical measurements

C) Changing mechanical conditions along the fault zone, i.e. aseismically creeping sections

D) Insignificant observation time covering only part of the seismic cycle along the fault, i.e., the considered 100 years record missed large earthquakes, which may occur at large time intervals.
Fig. 1. Austrian part of the Vienna Basin Fault System and earthquake epicentres (from ZAMG, 2001). Earthquakes within a distance of 20 km from the fault segments are selected for calculating seismic energy release.

Fig. 2. Seismic slip rates plotted vs. the depth of the fault zone. Results plot as areas because of the use of two different relations for converting magnitudes to seismic moment.

Fig. 3. Oblique view of the basement topography of the Miocene Vienna Basin (data from Kröll and Wessely, 1993).

Fig. 4. Simplified structural model of the 3D seismic Moosbrunn (courtesy of OMV Austria). The depicted negative flower structure is part of the seismically active fault system.
The calculated seismic moment release along the fault system is only a rough estimate with several uncertainties. However, calculated slip rates one order of magnitude below the regional strain accumulation rate indicates a reasonable seismic slip deficits. It may be concluded that not all earthquakes on fault system, which are necessary to balance regional long-term deformation, have occurred within the observation time. At the present state of knowledge it is not possible to give a more thorough quantification of the resulting slip deficit and its uncertainties. The results, however, are thought to be a strong argument for further investigations and the re-evaluation of seismic hazard in the area.

3-D Structural Modelling of the Subsurface of the Vienna Basin

The subsurface of the Vienna Basin is well investigated due to extensive hydrocarbon and fresh water exploration. The existing subcrop data are used to constrain the geometry of active faults and their possible segmentation as well as to build up 3-D structural models for subsequent dynamical modelling and testing of fault plane stabilities.

A 3-D model of the Pre-Neogene base of the Vienna Basin constructed from the map of Kröll et al. (1993) is shown to illustrate part of the crustal-scale geometry of the fault system (Fig. 3). The pull-apart geometry in combination with the distribution of seismicity indicates that the active fault system is characterized by a much smaller left-lateral step-over than the Miocene system. Accordingly, Quaternary pull-apart subsidence is restricted to the centre of the Miocene basin. A first preliminary structural model for the Quaternary pull-apart constructed from the OMV 3-D seismic block Moosbrunn is shown in Fig. 4. The mapped faults depict a negative flower structure underlying thick Quaternary sediments in the centre of the southern Vienna Basin.

References