Tectonic evolution of the Western Eger rift: a tale of two faults

Jan Tomasek[1], Jonas Kley[1], Tomáš Fischer[2] and Petra Štěpančíková[3]

[1] Georg-August-University of Göttingen, Geoscience Centre, Department of Structural Geology and Geodynamics, Goldschmidtstr.3, 37077 Göttingen, Germany

[2] Faculty of Science, Charles University, Prague, Czech Republic

[3] Institute of Rock Structure and Mechanics, Academy of Science, Prague, Czech Republic

1 Introduction

The Eger Rift and Cheb basin in northwestern Bohemia are part of the European Cenozoic Rift System. They are associated with earthquake swarms, voluminous CO2 outgassing and Quaternary mantle-derived volcanism. The structure of the extensional system is dominated by two large faults:
(1) the ENE-striking **Krušné Hory Fault (KHF)**, which delimits the northwestern shoulder of the Eger rift and has accommodated tilting and uplift of the Erzgebirge (Krušné Hory), creating a present day elevation difference of 700 m;
(2) the NNW-striking **Mariánské Lázně Fault (MLF)**, which is the master fault of the Cheb basin and crosscuts the KHF.

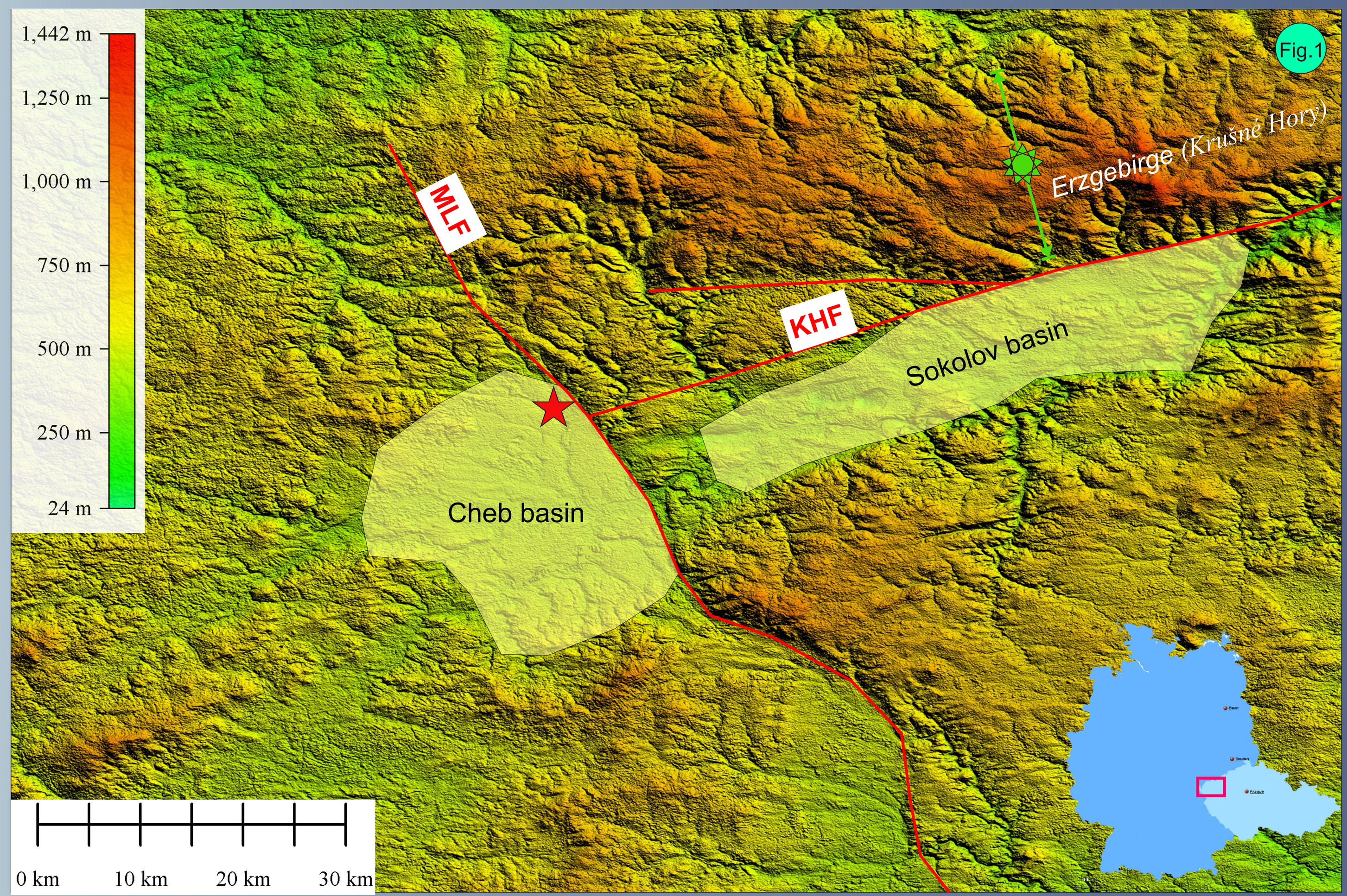

Figure 1: ASTER digital elevation image - red star indicates the swarm earthquake cluster near Nový Kostel (NKC). Green star indicates elevation profile for apatite (U-Th)/He samples.

2 Questions & Problems

Our project receives parallel funding from GAČR and DFG. The goal is to decipher the interaction between the two main faults, the adjacent basins and earthquake activity in space and time. We investigate recent seismicity (T.Fischer) and tectonic geomorphology (P.Štěpančíková, Fig. 6). The project part described here aims at the following questions:

- How do the KHF and MHF systems continue to depth ?
- What is the kinematic evolution of the Eger/Cheb system ?
- When were the faults active ? How fast did they move ?
- What is the role of inherited crustal or lithospheric anisotropies ?

3 Methods

- Structural modelling (restorable cross-sections and 3D)
- Thermochronology (high resolution apatite (U-Th)/He elevation profiles)
- Tectonic geomorphology and neotectonics (high resolution DEMs and satellite images, fieldwork, trenching)
- Fault-slip analyses, paleostress reconstruction

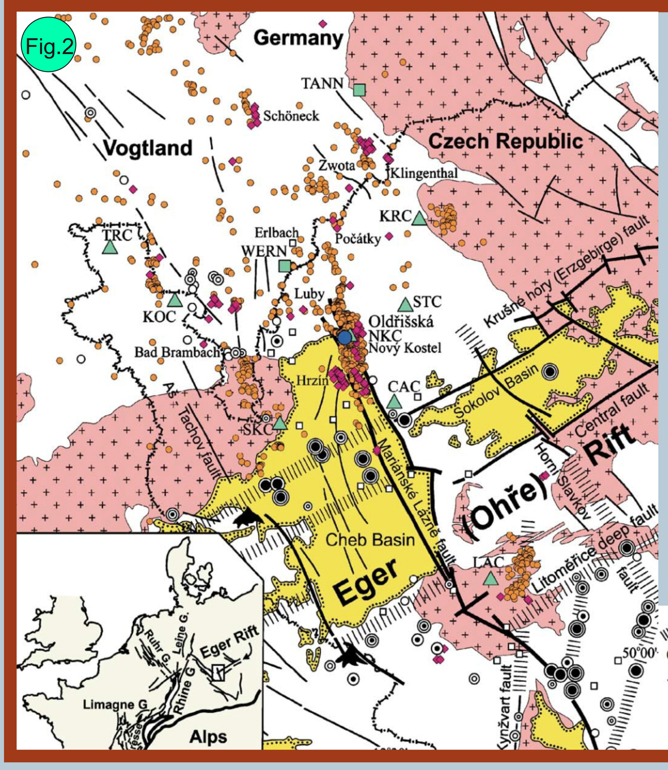

Figure 2: Geological map by Weinlich et al. 2006 showing the distribution pattern of swarm earthquakes and CO2 outgassing in the western Eger Rift. Quaternary volcanoes; north: Komorní Hůrka, south: Železná Hůrka.

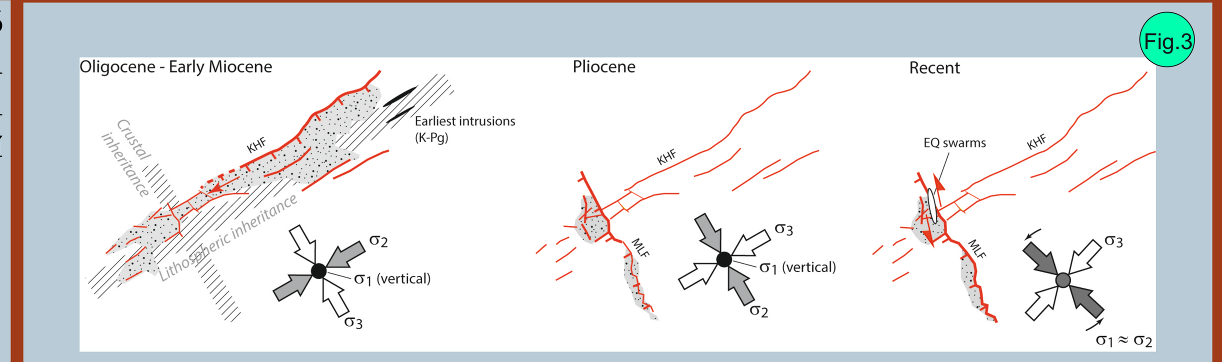

Figure 3: Working hypothesis for the evolution of the Eger rift and Cheb basin. The indicated stress fields are broad generalizations, inferred from the overall architecture and subsidence patterns of the Eger and Cheb basin. They are likely to encompass higher-frequency variations of the stress field and may be separated by pulses of compression as summarized in Ulrych et al. (2011).

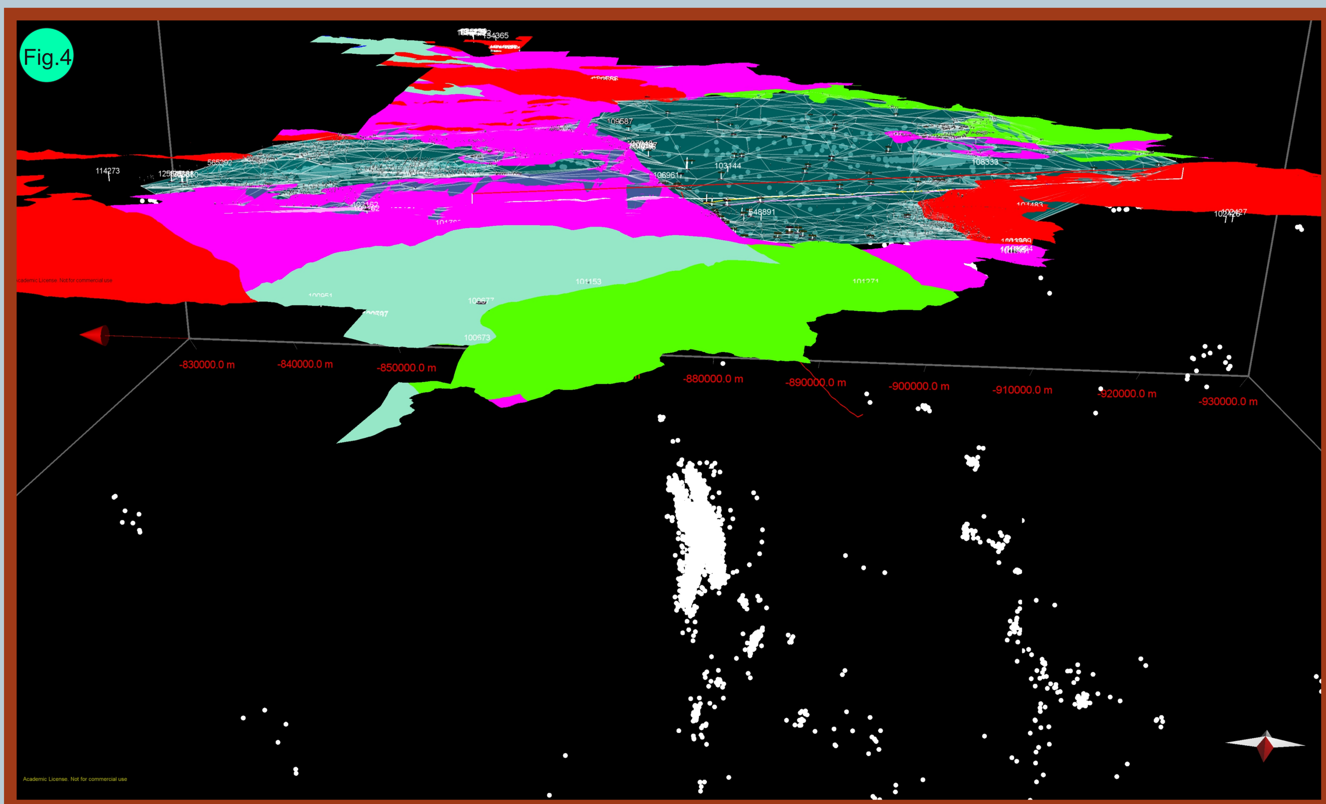

Figure 4: Side-view in south direction of the geological 3D model (3DMove by Midland Valley). White dots illustrate earthquake epicentres. Light blue mesh is the modelled subsurface top basement. All other colors indicate outcropping basement of various types (granites, schists etc.)

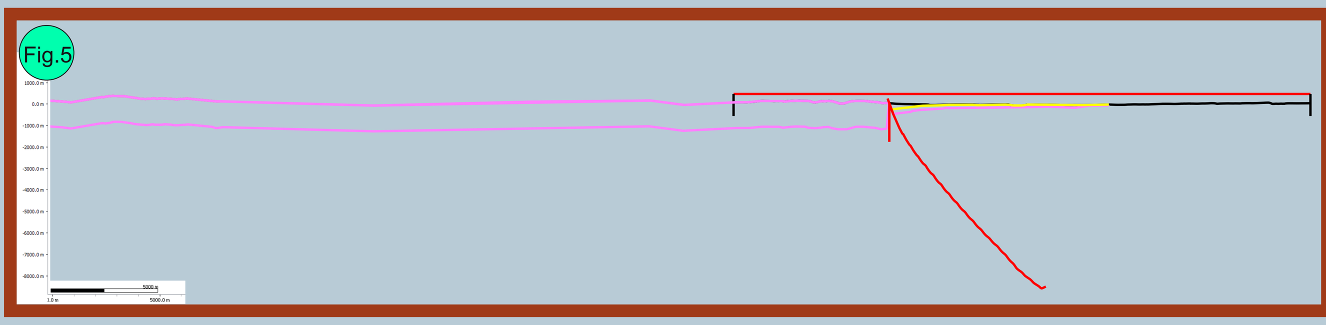

Figure 5: Cross-section view (see trace above).
pink: top basement, yellow: top Tertiary, red: listric MLF modelled from basement geometry

Figure 6: Photographs taken during a trenching campaign near Novy Kostel, Czech Republic, April 2017. Aerial pictures by courtesy of Petra Štěpančíková

3 Modelling and geochronology

New insight into tectonic structure is brought by an enhanced combination of a high-resolution LiDAR-derived digital elevation model (DMR 5G) covering an area of ~ 2000 km^2, and a modelled subsurface crystalline relief utilizing ~11.000 boreholes and 145 vertical electric sounding entries of the CGS Geofond database (Mlčoch & Skácelová 2009).

Up to today no apatite fission track or apatite (U-Th)/He ages were published for the southeastern, czech flank of the Erzgebirge, whereas for the German part a broad variety of age data exist. We sampled and analyzed 9 granitoid specimens spanning an elevation difference of 1100-400 m a.s.l across the KHF with the intent to reveal the uplift and erosion history of the rift shoulders.

4 Basin and fault geometry

The Cheb basin forms an approximate semi-ellipse in map view, suggesting it is a half-graben bounded by a listric, WSW-dipping MLF. The well-defined N-striking fracture plane traced by the swarm earthquakes of 2000 and 2008 generally lies in the footwall of the MLF, but might branch from the deeper parts of the listric MLF. A key parameter for the kinematic modelling is the original elevation on the graben shoulders of the basement underlying the basin fill. Kaolonitic relicts (at altitudes 600-650 m and 900-950 m), silcretes (550-635 m) and ferricretes (600-650 m) outside the basin indicate paleosurfaces defining regional levels of the top basement surface and a throw of at least 400 m for the MLF.

We hypothesize the following four-stage scenario for the Cenozoic evolution (Fig. 3):
(1) From 42 to ca. 24 Ma, low-magnitude N-S extension oblique to the modern morphological axis of the Eger rift is accompanied by voluminous mafic magmatism indicating effective connection to an ENE-trending mantle anomaly already evidenced by pre-rift magmatism since 76 Ma. This anomaly probably represents a Variscan subduction or transform plate boundary (U.Kroner, oral comm.).
(2) From about 24 Ma, a sudden mechanical decoupling of the rift and its northwestern shoulder occurs. The new KHF, possibly propagating upwards from the mantle, dissects the Variscan crustal grain and earlier Cenozoic structures and initiates rapid uplift and northwestward tilting of the Erzgebirge. Around the same time, the eastward tilting half-graben configuration of the Cheb basin is established, suggesting activation of the MLF as a normal fault.
(3) After a period of non-deposition, extension on the MLF resumes in Pliocene time.
(4) At a later stage, possibly through a gradual change from (3), the NNW-SSE-orientated intermediate principal stress σ2 increases to attain a magnitude similar to the overburden stress σ1. This corresponds to the present-day situation where a sinistral transtensional fault plane is active, accommodating NNW-directed shortening and ENE-directed extension as evidenced by focal mechanisms of the swarm EQ.

5 And what about the ages ?

Three apatite (U/Th)/He samples result in a bulk span of 76 to 257 Ma, with the oldest age 300,0 ± 27,6 Ma, and the youngest age 54,6 ± 5,9 Ma (errors are 2σ).The results are in accordance with previous studies from the German part of the Erzgebirge, which reveal FT ages with a span of 210-45 Ma. So far the youngest, Cenozoic ages are located close to the KHF. They are still older than the assumed fault activity, but may indicate partial resetting if the pattern is confirmed by additional ages.

6 Conclusions and preview

- first results of kinematic modelling suggest that the MLF flattens at ca. 7 km in the northern Cheb Basin and 11km in its central part similar to the earthquake hypocenters which also deepen southwards from 7-10 km to 7-13 km
- stepwise restoration will constrain the magnitudes of fault offsets and possible fault slip directions
- further analyses constituting a high resolution apatite (U-Th)/He elevation profile ideally will allow to constrain the timing, rate and magnitude of exhumation and fault motion.

jan.tomasek@uni-goettingen.de

References

Mlčoch, B.; Skácelová, Z. (2009): Digital elevation model of the crystalline basement of the Cheb and Sokolov Basin areas (Western Bohemia, Central Europe). In: Z. geol. Wiss 3 (37), S. 145–152.
Ulrych, Jaromír; Dostal, Jaroslav; Adamovič, Jiří; Jelínek, Emil; Špaček, Petr; Hegner, Ernst; Balogh, Kadosa (2011): Recurrent Cenozoic volcanic activity in the Bohemian Massif (Czech Republic). In: Lithos 123 (1-4), S. 133–144. DOI: 10.1016/j.lithos.2010.12.008.
Weinlich, Falk H.; Faber, Eckhard; Boušková, Alena; Horálek, Josef; Teschner, Manfred; Poggenburg, Jürgen (2006): Seismically induced variations in Mariánské Lázně fault gas composition in the NW Bohemian swarm quake region, Czech Republic — A continuous gas monitoring. In: Tectonophysics 421 (1-2), S. 89–110. DOI: 10.1016/j.tecto.2006.04.012.