

The Rhinegraben – Bresse Graben System, European Crust and Topo Europe

Verena Gennes

(294781)

M.Sc. Georesources Management

Supervisors: Prof. Janos Urai and Prof. Ralf Littke

RWTH Aachen University

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1. Introduction

Europe and especially Central Europe are characterised by its high mountain belts: The Pyrenees, the Alps, the Apennines and the Carpathians. Furthermore, there are the Balkan Mountains, the Ural Mountains and the Scandes that play an important role in Europe's geography and affect a lot of factors such as climatic conditions. However, Europe includes many basins and rift structures that were built during the Earth's history and remain still active today. Their impact is not less than the impact of the mountain belts and sometimes they are even associated with each other. An example of the coherence between a rift structure and an orogeny can be seen in Central Europe. Due to the collision of the European and the African plate in the late Cretaceous period and the resulting compressional regime the alpine orogeny began to form a high mountain belt. As the lithosphere responded to the compression with an extensional regime perpendicular to the compression, some rift structures in Central Europe were built, e.g. the Bresse Graben and the Upper Rhine Graben. These two graben belong to a major rift system called the European Cenozoic Rift System. (Pfiffner, 2009)

2. The European Cenozoic Rift System

The European Cenozoic Rift System (ECRIS) is an 1100 km long rift system between the Mediterranean Sea and the North Sea that began to form during the late Eocene. There are six different rifts in Central Europe that belong to the Cenozoic Rift System: Limagne Graben, Bresse Graben, Upper and Lower Rhine Graben, Eger Graben and the two Hessian Grabens (see Fig. 1). Some parts of this system are still active today. The forming is believed to be a response of the lithosphere to the compression in the Alps and Pyrenees so that the E-W extension appears perpendicular to the compression and consequently the rift structures evolve. While the graben structures in the South are older than the graben in the North, there is a preferred NNE-SSW to N-S orientation of all graben that indicates a coherent rift belt. The tensional reactivation of Permo-Carboniferous and Mesozoic shear systems played an important role in the localization of the ECRIS as all rift valleys have followed pre-existent weakness zones. The development of the rift system was accompanied by seismic and volcanic activities which are controlled by mantle rise. This rising and upwelling of the mantle leads to a rising of the Mohorovičić discontinuity so that the crust-mantle boundary can be found in a depth of only 25 km to 30 km. The reaction of the domed crust by rifting and gravity sliding away from the bulge lead to a propagation of a linear rift valley. (Illies, 1977) Given that this paper is written in context to a field trip of the RWTH University, Aachen in August 2013 to the Alps, the focus is laid on the Upper Rhine Graben and the Bresse Graben as they are mainly influenced by the Alpine Orogeny.

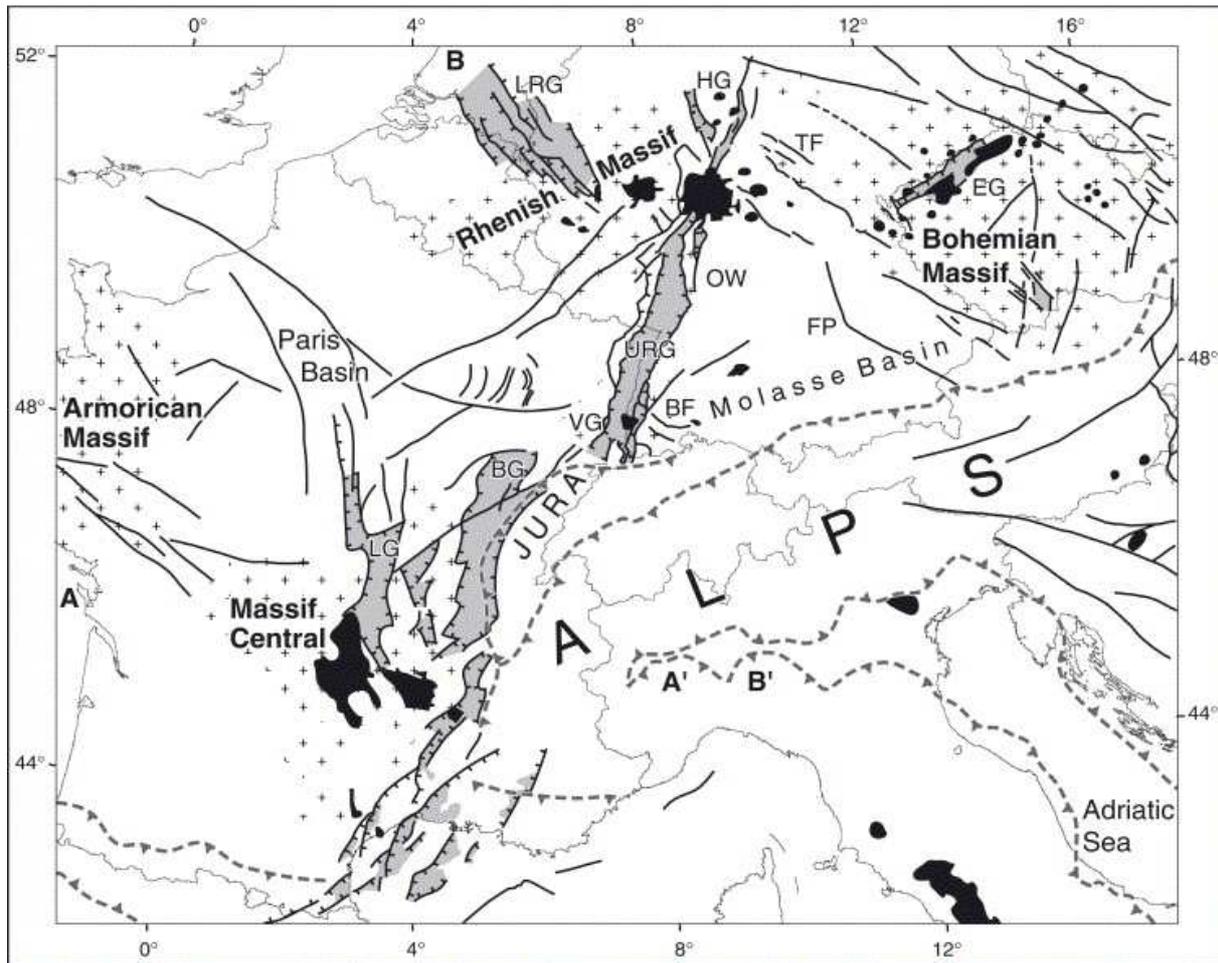


Figure 1: European Cenozoic Rift System in Central Europe with the Alps and surrounding mountains (Cloetingh, 2005)

3. The Upper Rhine Graben

The Upper Rhine Graben (URG) between the cities Frankfurt and Basel is about 350 km long and 30 – 40 km wide. This central part of the ECRIS shows a preferred NNE-SSW orientation which reflects the so-called Rhenish trend that was established during the Paleozoic Variscan Orogeny. Nowadays, scientists divide the evolution of the URG into two phases. The first phase occurred in the Oligocene where Permo-Carboniferous and Mesozoic weakness zones were reactivated so that an E-W oriented extension opened a rift structure. The second phase began in the Miocene and is constantly moving until present. A change to a NE-SW oriented extension combined with a NW-SE oriented compression led to a sinistral shearing. Sedimentation in the graben occurred at all times but an uplift and erosion phase during the Early Miocene inhibited sedimentation in the central and southern parts. The Vosges mountain range in the West and the Black Forest in the East build the rift flanks of the URG (see Fig.2). Their uplift is an isostatic response of the crust due to the formation of the rift. The differences between the URG and the rift flanks vary. While the Vosges mountain range was about 4000 m higher than the graben, the difference between the middle of the basin and the Black Forest was about 3000 m. The major percentage of the flanks has been eroded to



Figure 2: Map of the Upper Rhine Graben and its rift flanks the Vosges mountain range in the West and the Black Forest in the east. The Kaiserstuhl volcano can be seen in the central graben (Turner, 2008)

this day. The rift flanks disinter the same types of rocks as the graben but there are no cretaceous, tertiary or quaternary formations because the rift flanks experienced erosion. Major zones with normal faults define the boundaries between the graben and the rift flanks. The URG consists of a Variscan basement, a Mesozoic cover and a Cenozoic sedimentary fill at the top. The Variscan basement is exposed by erosion in the Vosges mountain range and the Black Forest. (Peters, 2007)

The magmatic activity in south-western Germany was little and occurred mainly in the Middle Eocene before the evolution of the URG. A second phase in the Miocene led to the formation of the Kaiserstuhl in South Baden which is about 15 km long and 12.5 km wide. This range of hills has a Jurassic, sedimentary basement that built a horst during the formation of the URG. Due to the volcanic eruptions the sedimentary layers are covered by feldspars and olivine rich rocks that form a complex strato-volcano. Since a few hundred metres of this volcano have been eroded, this day the highest point of the Kaiserstuhl region is the Totenkopf (556.6 m). At the present time and since the last ice age the Kaiserstuhl is covered by a Quaternary

loess layer. (Schwarz, 2005)

Beside the volcanic activity of the URG there was always seismic activity since the evolution of the rift structure and there is still activity measurable today. While the seismic activities in the central and southern part of the URG are higher than the activity in the northern area, no earthquake with a magnitude higher than $M_L=4.0$ cropped up in the last 80 years. (Reicherter, 2012)

4. The Bresse Graben

The Bresse Graben lies to the southwest of the URG and to the East of the Limagne Graben in the countries France and Switzerland. The French city Lyon lies in the south-western part of the Bresse Graben. It began to form simultaneously with the URG and strikes sub-parallel to the deformation front of the Western Alps with a NNE-SSW orientation of its axis. The localization of the graben structure can be related to Stephanian-Autunian and Mesozoic fracture systems that got reactivated. After the initial rifting during the Eocene the process of extensional movement came to a full-stop in a period from the Late Oligocene to the Middle Miocene. The rifting resumed in the Late Miocene and the graben experiences uplift at present. The main tectonic subsidence phase occurred in the age of the Late Eocene and the Early Oligocene. A specific characteristic of the Bresse Graben is that the eastern margin was overridden by thrust faults of the Swiss Jura Mountains that features west-vergent folds. This led to an asymmetric fill of the rift structure with

maximum values of 5000 m of which the main part has been eroded until today. The eastern part is covered by Pliocene sediments. The rock formations in the entire graben show a marine influence with deposits of carbonates and evaporitic sequences but there is one unit of Early Miocene age that did not experience marine influence as the Massif Central and the Rhenish Massif were thermally uplifted and consequently blocked the access to the sea. Especially the Massif Central which lies to the southwest of the Bresse Graben experienced high volcanic activities. They commenced during the Late Palaeocene and Miocene and peaked during the Pliocene and Pleistocene age. The last volcanic eruption in this region occurred around 4000 years ago and the Massif Central experiences transtensional deformation at present. Nowadays the Bresse Graben contains about 2500 m of Cenozoic sediments. (Ziegler, 1993)

5. The Burgundy Transfer Zone

The URG and the Bresse Graben are linked by the so-called Burgundy Transfer Zone, also known as the Rhine-Bresse Transfer Zone (RBTZ) which shows a sinistral strike-slip orientation (see Fig. 3). The Late Palaeozoic Burgundy Through System has been reactivated in the Palaeogene and Neogene because of an extensional stress regime. ENE-SWS striking normal faults occur mainly and led to the formation of complex fault patterns especially nearby a pre-existing Palaeozoic horst structure. Since the Pliocene a rock uplift is recorded which is forced by the inversion of the transfer zone. Present-day seismicity in the Burgundy Transfer Zone indicates ongoing activity and may reflect tectonic underplating in this part of the Alpine foreland. (Laubscher, 2001)

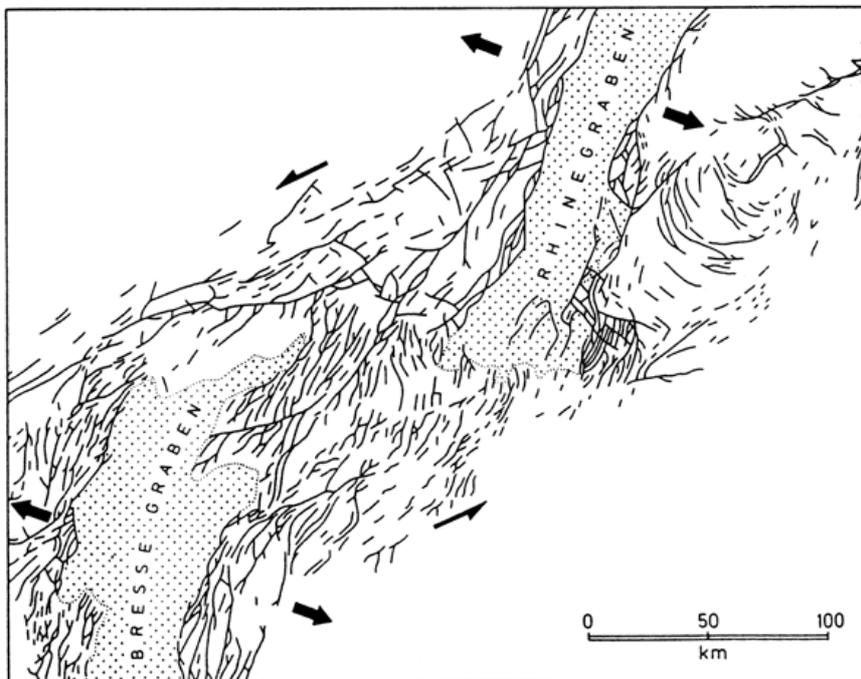


Figure 3: The northern part of the Bresse Graben and the southern part of the Upper Rhine Graben are linked by the Burgundy Transfer Zone with its complex fault systems. The zone shows a sinistral strike-slip orientation. The arrows show the sense of movement. (Illies, 1977)

6. European Crust and Topography Europe

The thickness of the earth's continental crust lies on average between 35 km to 40 km. This can be determined precisely as the seismic velocities of the crust and the mantle differ significantly. The boundary between the crust and the upper mantle is known as the Mohorovičić (henceforth referred to as Moho) discontinuity. The depth of this boundary between the mantle and the European crust varies highly (see Fig. 4). On the one hand, this phenomenon is a result of crustal thickening and lithospheric folding. These processes took place during the Alpine orogeny in conjunction with subduction and the Moho discontinuity was depressed to depths of 60 km to 75 km. Nowadays the maximum amount of the crustal thickness in the Alps region lies about 55 km. The thickening is accompanied by metamorphism and plutonic activity which caused the forming of crystalline rocks that are exposed at present. On the other hand, the crustal varieties follow from crustal thinning. Some parts of the European crust experienced extensional stresses and mechanical stretching which led to the evolution of graben structures. Volcanic activity can crop up due to mantle rise. This mantle rise results in an uplifted Moho discontinuity which lies in a depth of 25 km beneath the Upper Rhine Graben at present. (Amaru, 2007; Ziegler, 2005)

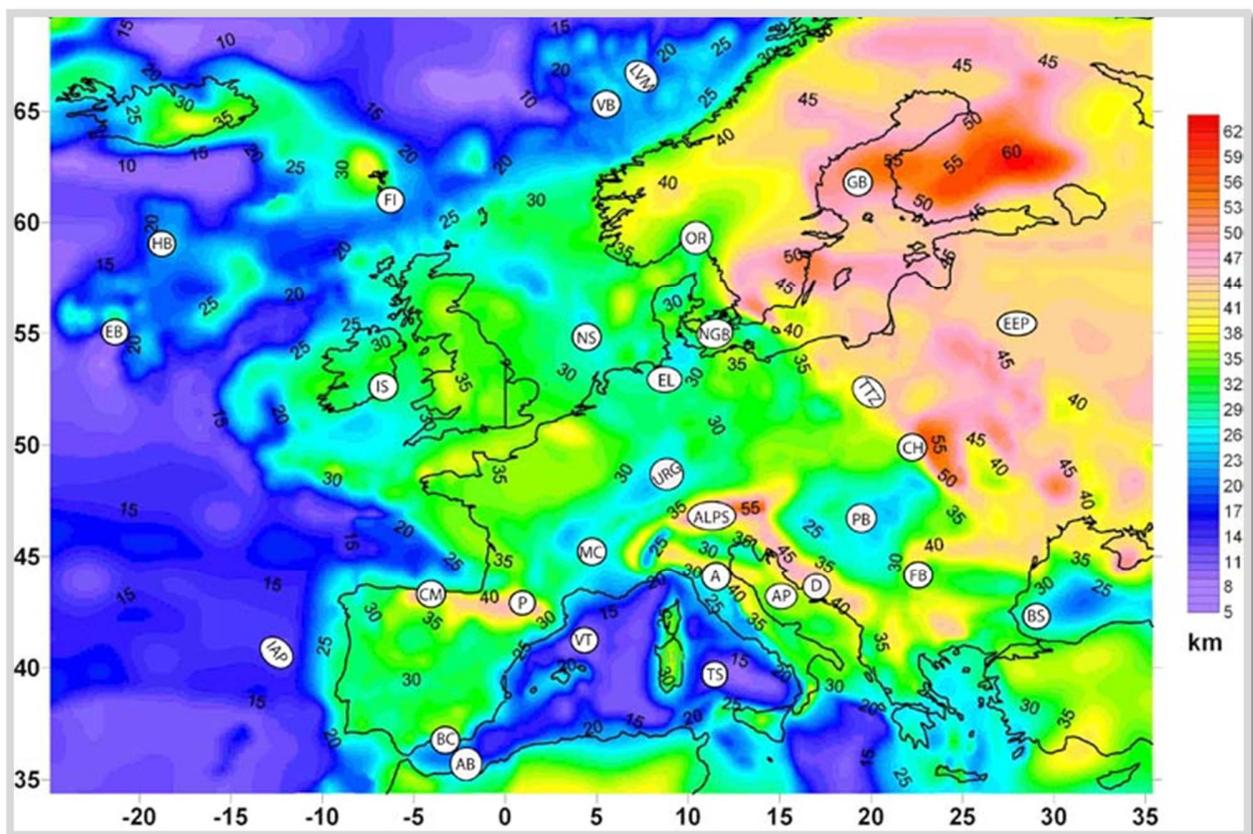


Figure 4: Europe and the thickness of the oceanic and continental crust in kilometres. Rift structures and mountains are marked by abbreviations. (Topo-Europe, 2013)

7. Conclusion

The collision between the continents of Europe and Africa in the late Cretaceous period was an essential event that changed the geomorphology and geology of Europe perseverative. The evolution of the Alpine mountain range which stretches 1200 km across eight countries is of prime importance for Central Europe at present. The resulting evolution of the 1100 km long European Cenozoic Rift System with its central parts the Bresse Graben and the Upper Rhine Graben changed the geologic framework and led for example to intraplate volcanic activities. Seismic events occur frequently and the Basel earthquake of 1356 showed that these events can reach a magnitude of $M_w=7.1$. In addition, the continent collision induced the building of high varieties in the thickness of the European continental crust so that differences of about 30 km in thickness can be found within a surface length of only 200 km. In the end, the topography of Europe is mostly influenced by the alpine orogeny and experiences change and transformation due to the continent-continent collision which remains still active today.

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