Claudio ROSENBERG
Professeur - ISTeP - UMR 7193
Case 109 T46E3 Campus Jussieu
F-75252 PARIS cedex 05
tel : 00 33 1 44 27 51 36
fax : 00 33 1 44 27 50 85
mail : claudio.rosenberg@upmc.fr

Paris, 25/09/2016

Report on the Habilitation thesis of Dr. Petr Jeřábek

The habilitation thesis of Dr. Petr Jeřábek consists of 12 papers, 5 of which as a first author, all published in international journals between 2007 and 2016. This testifies his very significant scientific activity.

Numerous and different techniques of quantitative structural geology are used, in addition to petrographic observations, thermodynamic modelling, experimental petrology, and geochronology. Both regional studies and process-oriented ones are carried out. All this shows that Dr. Petr Jeřábek covers a very broad spectrum of techniques and topics of Earth Science research. I wish to stress that it is vary rare to see such an interdisciplinary knowledge in our scientific community and the present thesis shows that this multiple competence is necessary if a step forward is to be made in the field of basement tectonics.

Three major topics are addressed by the papers of this thesis: 1. Tectono-metamorphic history of the Vepor Unit, Western Carpathians; 2. Deformation mechanisms, and in particular the relationship between metamorphic reactions and deformation; 3. The growth kinetics of minerals. I do not feel very competent on the last subject, therefore I will comment mainly the publications related to the first two topics mentioned above.

Burial and exhumation of the Vepor Units, Western Carpathians

Seven papers of this habilitation thesis focus on the tectono-metamorphic history of the Vepor Unit, West Carpathians. The first publication (Jeřábek et al., 2007) uses microstructures of deformed rocks to constrain its large-scale tectonic history. I am impressed by the very quantitative approach of this paper, which collects data of different nature, but all perfectly quantified, and synthesizes them into a conclusion on the regional tectonics. Quartz and feldspar textures are quantified both with EBSD and CIP techniques, grain sizes are quantified by EBSD analyses and extrapolated on the map scale over several 10's of km. It is the first grain-size map on the orogenic scale that I ever saw! Aggregate outlines of quartz are also measured in order to calculate the shape of the strain ellipsoid. Finally, quantitative paleo-piezometry is used in combination with extrapolated flow laws to constrain paleo strain-rates.

Because all data are so carefully documented and quantified, they form a very solid base to discuss the regional tectonics of the Vepor Units. I believe that the tectonic significance of the described fabrics and metamorphic gradients may remain a subject of debate, but this debate will surely continue to be founded on the sound data described and quantified in this paper.

One interpretation that is very important for the other papers of this thesis that address the exhumation of the Vepor Unit, is the pure shear character of the DA1 deformation event. I believe that this interpretation could have been more cautious, given that 1) it is based on quartz textures that are mainly derived from orthogneisses, and only partly from quartz veins. Local effects, due to stronger feldspars are expected to induce local changes of shear sense, as frequently observed around boudins; 2) where present, shear senses from EBSD data are always sinistral. Why is the discrepancy to the CIP data not discussed?

An additional body of evidence, that provides strong constraints on the burial and exhumation of the Vepor Units comes from the second paper (Jeřábek et al., 2008), where the prograde character of metamorphism during the DA1 deformation phase is shown convincingly, based on very careful petrological/microstructural analyses. This paper also reinterprets previous temperature gradients in map view, although I have difficulties understanding how the iso-T contours can possibly be constrained given the small number of data. The nicely sketched block diagram of figure 12 shows a perfect matching between the shape of the isotherms and the structures, as illustrated in the cross section of figure 2. This is a very interesting result, but in view of the speculative character of the iso-T pattern in map view, I am not sure whether the interpretation is reliable.

The studies on the exhumation of the Vepor Unit are completed by a paper on the thermo-chronology of this area (Vojtko et al., 2016). It is very important to have this additional constraint on the timing of exhumation, and to integrate it with the structural/petrological work. The new thermo-chronological data point to a “passive, en-bloc” exhumation of the whole area after 80 Ma. As a consequence, the DA2 folding event is inferred to be earlier and correlated to previous literature ages spanning between 90 and 80 Ma. However, if DA2 folding is responsible for the differential exhumation of Alpine metamorphic rocks, age gradients, younging towards the eroded hinges of DA2 antiforms would be expected. Existing ages do not seem to confirm this and a discussion on this subject would be apreciated.

The Jeřábek et al. (2012) paper, addresses many of the question that I had after reading the previous three papers on the tectono-metamorphic history of the Vepor Unit, namely the feasibility of orogen-parallel flow in a crust that is characterized by a rather cold geothermal gradient (16,5deg/km). In addition, orogen-parallel flow is not inferred to be post-, but rather syn-burial, hence starting early in the history of thickening, hence making lateral gradients of temperature and pressure more difficult. The authors lean their interpretation on the experimental work of Mariani et al. (2006), to conclude that metapelites in the Vepor Unit must have had an extremely low viscosity. This is an interesting point, but it should be mentioned that the experiment of Mariani were performed on samples entirely consisting of mica, and that no evidence from thin sections from the Vepor Units shown in this thesis document a significant localization of deformation within the mica rich layers.

C-S fabrics and deformation mechanisms

Two papers are devoted to the study of C-S fabrics. This classical topic of structural geology is rivisited by Bukovska et al. (2013) and Bukovska et al. (2016). Bukovska et al., (2013) describe a case study from the Veporic Unit, in which the C-planes are inferred to be kinematically un-related to the S planes, based on distinct quartz microstructures and distinct metamorphic assemblages of these two planes of anisotropy. This conclusion is very interesting, because it goes against the classical interpretation, widely accepted by all text-books. Inspired by these conclusions, the authors re-investigated the original outcrops of the South Armorican Shear Zone (Brittany, France), where S-C fabrics were first described in 1979, and never questioned since that time. Similarly to the case study of the Veporic area, the authors assess that the temperature of the mineral assemblage forming the C-planes is lower than that of the S planes (300-350°C vs. >550°C, respectively). In addition they describe the absence of transitional microstructures of quartz between the S and C planes. Thus they conclude that two distinct periods of deformation affected the rocks. As in the previous papers the data collection and interpretation is precise and sound, and so are the conclusions based on these data. Nevertheless I wonder why, if a time gap exists between S and C planes, but they are still inferred to correspond to one and the same tectonic event, why do we find this characteristic angle that can be reproduced experimentally? Why in both papers the C planes formed at lower T? Is it just a coincidence? And, if the S planes are not active during the lower T deformation occurring along the C planes, where is slip accommodated between the C shear bands?

The latter paper also discusses the evolution and nucleation of shear bands in the granitoids of the S-Armorican Shear Zone, showing a brittle initiation, followed by dislocation creep and finally grain boundary sliding. This evolution is also very interesting, and sheds new light on a subject (S-C mylonites) that seemed to be completely established, by initiating a discussion that includes rheological changes.

Another interesting paper of this thesis concerns the study of the transition from high-temperature fracturing to grain-size sensitive creep in the lower crust (Okudaira et al., 2015). The idea is not entirely new, but the documentation of the microstructures and their metamorphic stability make this case study to one (*The*?) of the best, to show that these transitions are possible even deep in the crust. In addition, the boundary conditions for these processes are soundly constrained, to a degree of detail that did not exist in previous literature. Indeed, not only P and T were determined, but also the conditions (dry) of fracturing, the water quantity, the stress level, and the porosity of the deformed samples. This is a great achievement!

In summary I am very positively impressed by this thesis. There are certainly a number of interpretations that may be questioned, but this is always the case and the papers have already gone through the review of international experts. The key points that I would like to emphasize are the very high quality of documentation of the data, the systematic, quantitative approach adopted in each of the papers, and the inter-disciplinary work performed, showing an amazing understanding of numerous analytical techniques and the capacity of investigating processes in fields spanning from experimental petrology and thermodynamic modeling, to deformation processes from the large-scale to the thin-section scale, including geochronological data. I warmly recommend the habilitation committee to accept this thesis for the habilitation of Dr. Petr Jeřábek.

Sincerely,

Claudio Rosenberg