Geophysical Research Abstracts, Vol. 7, 03367, 2005
SRef-ID: 1607-7962/gra/EGU05-A-03367

The Role of Indenter Rheology in the Evolution of the Eastern Alps

J. Robl

K. Stüwe

Department of Earth Sciences

joerg.robl@uni-graz.at

Introduction

The eastern part of the European Alps has been described as a typical example of an orogen formed by indenting one continent into another. Within this model, the southern, Adriatic plate is assumed to be rigid and to have indented obliquely into a softer region along the southern margin of the European plate [Ratschbacher et al., 1991a,b; Frisch et al., 1998]. However, structural data indicate that ever since the Eocene - the deformation was variably partitioned between the two colliding plates. Clearly, this shows that the Adriatic plate cannot be assumed as a rigid indenter and that both the rheology changes of the indenting plate and changes in the kinematic boundary conditions play an important role in shaping the orogen.

Here we use observations on the partitioning of deformation between the European and the Adriatic plates to infer aspects of the rheology contrast between the two plates and its changes since the Miocene, using a two-dimensional numerical thin viscous sheet model in plan view [*Robl and Stüwe,*2005b in print].

The Model

The modeling is done by assuming a viscous rheology and using the finite element code BASIL of *Barr and Houseman*, [1996]. The code has also been used successfully to describe other orogens with indenter geometry, in particular the India-Asia collision zone [*England and Houseman*, 1989; *Houseman and England*, 1986]. Contrary to previous studies, the indenter is defined as region of finite rheology contrast to foreland so that partition of deformation between indenter and foreland can be observed [*Robl and Stüwe 2005a*, in print].

However, in order to apply the finite element code to describe the Alps, we have performed several additional adaptations.

Firstly, we have implemented a routine that allows us to pre-allocate a crustal thickness to every grid node, so that the instantaneous deformation field of the orogen can be calculated on the basis of an existing distribution of potential energy. As a second adaptation, the finite element code was adapted to perform thin viscous sheet calculations in spherical coordinates. Finally, we generalized the model by implementing a facility that allows the insertion of regions of general shape and variable rheology into the finite element mesh.

For our model calculations the northern, western and eastern boundaries of the modeled region are assumed to have zero normal velocity relative to the European foreland. To minimize boundary effects, zero stress is set in tangential direction along these boundaries. For the southern boundary we assume a velocity distribution that reflects the counterclockwise rotation of the Adriatic plate as described by *Nocquet and Calais*, [2003].

Inside the model region a potential energy function was predefined by interpolating a digital elevation model onto the finite element mesh. Four zones of different rheology are defined inside the model region: the European foreland, the Pannonian basin, the Adriatic plate and the Eastern Alps. The European foreland is set to be hard enough so that the modeled strain rates are negligible. This is about 10 times as viscous as the Eastern Alps. The crust of the Pannonian basin is weakened by the elevated average heat flow [*Bada et al*., 1999]. The effective viscosity of this region is set to 0.8 times the viscosity of the Eastern Alps. The viscosity contrast of the Adriatic plate with the Eastern Alps is of interest here and is used as a variable in the model calculations.

Model Results

The stress- and velocity field of the Alpine- Pannonian realm can be successfully reproduced with a two dimensional thin viscous sheet model and boundary conditions that reflect the present day collision geometry between the Adriatic and European plates. The orientation of the intra-plate stress field is strongly dependent on these boundary conditions and is therefore used as an independent test for our assumed boundary conditions. However, the orientation of the intra-plate stress field is robust towards internal rheology contrasts between different geological domains.

In contrast to the orientation of the stress field, the velocity field is strongly dependent on internal rheology contrasts between different geological domains in the Alpine -

Pannonian realm. The GPS-determined velocity field in the model region can only be reproduced if the Adriatic indenter is less than 3 times as strong as the Eastern Alps and is described with a Newtonian rheology. This estimate is largely independent of the Argand number. A stronger rheology is not consistent with the extensive deformation within the Adriatic domain. The high seismicity within the Adriatic domain and the absence of seismicity in the Eastern Alps suggests that crustal deformation propagated to the proximal domains of the orogen driven by gradients in the potential energy.

The overall geometry of the Eastern Alps, the shape of the Adriatic indenter, as well as the timing and distribution of crustal thickness and topography imply that the similar viscosity of Adriatic plate and Eastern Alps is a recent feature and that this contrast was significantly higher in the Miocene.

10% of the lateral velocity of the Eastern Alps is due to gravitational collapse and 90% due to lateral escape. This ratio is for an Argand number of the orogen of 1. For this Argand number, the viscosity of the Eastern Alps scales to about 10^{23}Pa s and the gravitational collapse alone would take more than 1000 my to remove the topography. In the Miocene the viscosity would have been around 10^{22}Pa s. These values scale linearly with Argand number.

References

Bada, G., F. Horváth, P. Gerner, and I. Fejes, Review of the present-day geodynamics of the Pannonian basin: progress and problems, *J. Geodyn., 27*, 501-527, 1999.

Barr, T.D., and G.A. Houseman, Deformation fields around a fault embedded in a non-linear ductile medium, *Geophys. J. Internat., 125*, 473-490, 1996.

England, P.C., and G.A. Houseman, Extension during continental convergence, with Application to the Tibetan Plateau, *J. Geophys. Res., 96*, 17561-17579, 1989.

Frisch, W., J. Kuhlemann, I. Dunkl, and A. Brügel, Palinspastic reconstruction and topographic evolution of the Eastern Alps during late Tertiary tectonic extrusion, *Tectonophys., 297*, 1-15, 1998.

Houseman, G.A., and P.C. England, Finite strain calculations of continental deformation, 1. Method and general results for convergent zones, *J. Geophys. Res., 91*, 3651-3663, 1986.

Nocquet, J.-M., and E. Calais, Crustal velocity field of western Europe from permanent GPS array solutions, 1996-2001, *Geophys. J. Internat., 154*, 72-88, 2003.

Ratschbacher, L., W. Frisch, H.G. Linzer, and O. Merle, Lateral extrusion in the Eastern Alps, Part 2: Structural Analysis, *Tectonics*, *10*, 257-271, 1991a.

Ratschbacher L., O. Merle, P. Davy und P. Cobbold, Lateral extrusion in the Eastern Alps; Part 1, Boundary conditions and experiments scaled for gravity *Tectonics, 10*, 245-256, 1991b.

Robl, J., and K. Stüwe, The Role of Indenter rheology during continental collision: I. Concept and model formulation, *Tectonics*, in print

Robl, J., and K. Stüwe, The Role of Indenter rheology during continental collision: II. Concept and model formulation, *Tectonics*, in print