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On the Dynamics of the Swiss Alps along the Geotraverse Basel–Chiasso *)

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Abstract

The geodynamics of the Alps, and of the Northern and Southern Foreland will be modelled along the Swiss Geotraverse by computer calculations utilizing the finite element technique. The geological and geophysical constraints which determine the input parameters of the model are discussed. Special attention is payed to modelling the rheology of the lithosphere. The model solution sought must be in accordance with observed present-day crustal movements and spatial stress patterns.

The observed rates of relative vertical crustal movements along the Swiss Geotraverse can be correlated with certain geological features and geophysical observations (Rybach et al., 1977). To determine the influence of possible explanations on these phenomena, the dynamics of the area will be studied by means of numerical calculations. An appropriate approximation of both, the structural and rheological data of the crust and upper mantle along the Geotraverse will be obtained by the use of the finite element technique.

The finite element representation of the cross section through the Swiss Alps requires a generalization of the structure (Fig. 1). This scheme has been deduced from geological and seismic data (Truempy, 1975; Mueller and Talwani, 1971; Kahle et al., 1976). The subdivision is chosen such, that structural features of an extension of about two kilometers will be resolved by finite elements. So, beside the upper and lower crust, we distinguished the Jura mountains and the Molasse basin in the north and the Mesozoic sediments and the Po basin in the south. The Insubric fault will be incorporated into the model structure as a zone of variable strength and variable extension into the crust.

Mueller, Egloff and Ansorge (1976) reported on the basis of studies of

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the dispersion of surface waves (SPRECHER, 1976) a downdip tendency of the transition zone between the lithosphere and the asthenosphere from north to south along the Swiss Geotraverse.

The structural pattern of Fig. 1 represents simultaneously an approach to the variation of the rheology of the earth's crust and uppermost mantle. It has been found from experimental data that the deformation mechanism of the material changes with increasing temperature and pressure. The stress-strain rate relations for different rheological models of polycristalline aggregates are shown in the lower right of Fig. 1.

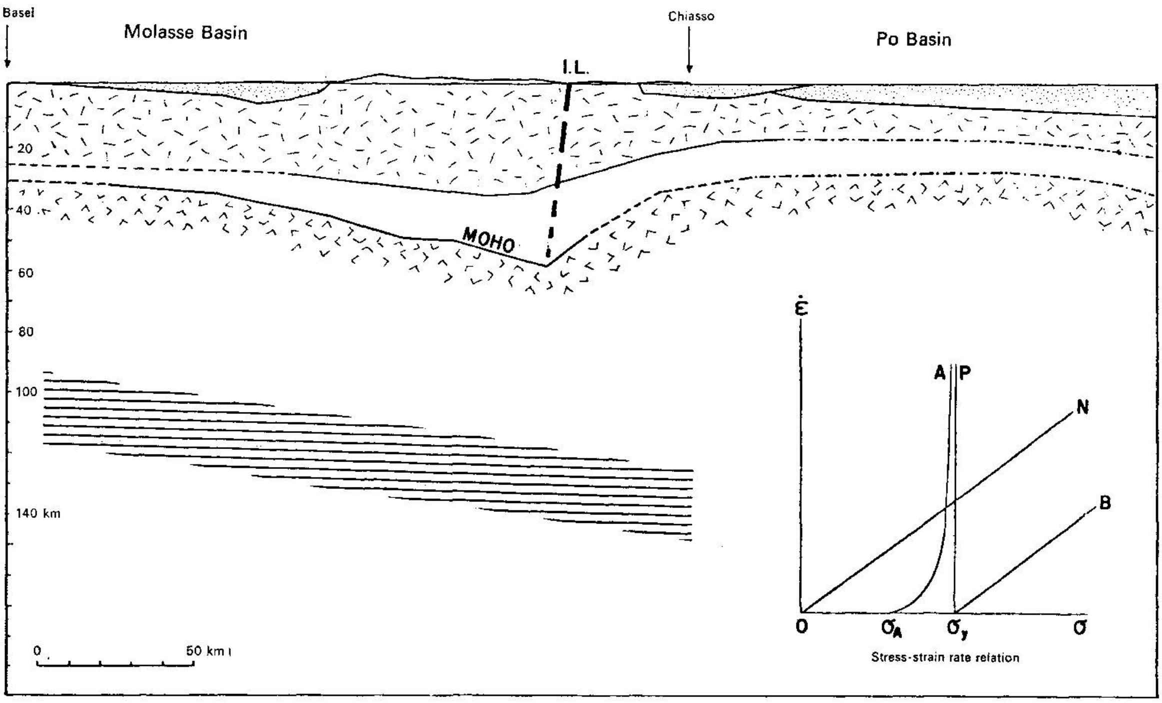

Fig. 1. Two-dimensional structural model of the crust and upper mantle along the Swiss Geotraverse Basel–Chiasso. Dynamical aspects require an extension of the section to the south. The hatched area below indicates schematically the transition lithosphere – asthenosphere. For explanation of the stress – strain rate relations (lower right) see text. IL: Insubric line.

The upper crust is brittle and will be represented very well by a BINGHAM material $0-\sigma_Y-B$ (for explanation see Fig. 1). If the creep strength σ_Y is overcome, the material flows with constant viscosity. With increasing pressure and/or temperature a transition from brittle to ductile behaviour is observed. This zone can be placed in the lower crust. Therefore, the rheological response of the lithosphere, with exception of the upper crust, can be represented by a non-linear creep law $0-\sigma_A-A$ at stresses above the creep strength σ_A. This is even valid for the asthenosphere. In this case the deformation rate depends on the thermal regime of the structure which will be prescribed by the ratio of the in-situ temperature – to the melting temperature – depth curve along the Geotraverse. Newtonian viscous behaviour O-N and purely plastic behaviour $0-\sigma_y-P$ are unlikely dominant deformation mechanisms.

The numerical approach of finite elements used here will be a powerful tool to describe both, the outlined structural and rheological representation of the model (NEUGEBAUER and BREITMAYER, 1975; NEUGEBAUER, 1976).

The purpose of our studies is to relate the calculations on the dynamics of the modelled region to various geological and geophysical parameters in the hope of learning more of the driving forces of vertical movements affecting the earth's crust. KAHLE et al. (1976a, 1976b) found coincidence of the isostatic low with the zone of crustal uplift along the Geotraverse. Assuming an under-compensation of this Alpine region, the effect of thermal expansion, crustal unloading by erosion and migration of phase transitions in the lower crust and/or upper mantle might be possible explanations for the observed uplift. Thermal expansion is suggested by different studies on the temperature-depth distribution of the Alps, providing higher temperature for the central Alps against the surrounding area. The migration of possible phase transition boundaries will be affected directly by nonequilibrium crustal loads as well as by crustal unloading by erosion.

Following the concept of plate tectonics and orogeny, a possible subduction model can be introduced. Negative buoyancy forces due to the remaining thermal regime of a former subducted lithospheric slab can be deduced (RYBACH, 1976). Beside this thermal effect, there is some evidence for an additional horizontal movement of the crustal layer north of the Alps. Indication is possibly given by the results of earthquake focal mechanism studies and in-situ stress measurements for the Alps and the surrounding area (PAVONI, 1976).

For the numerical calculations emphasis will be placed on the effect of these different processes on the calculated parameters and the resulting kinematics. Correlations of the calculated spatial stress patterns with geophysical and geological observations will be made.

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