Geophysical Research Abstracts, Vol. 7, 09517, 2005
SRef-ID: 1607-7962/gra/EGU05-A-09517

Styles of active orogenic shortening in the Eastern Alps

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A comparison of reconstructed Miocene convergence rates with GPS data serving as a snapshot on recent plate motion indicates continuous convergence across the Eastern Alps with a velocity and direction similar to the Miocene average. Miocene shortening was compensated by a combination of north-directed thrusting, shortening of the upper plate by crustal-scale folding, and lateral extrusion out of the collision zone. Current data such as the distribution of seismicity, orientations of nodal planes of focal solutions, geomorphologic and geodetic measurements indicates that most of the presently known active faults correspond to reactivated Miocene structures, and that present kinematics grossly resemble the Miocene ones. Data further support marked differences in the styles of active shortening between the eastern and western parts of the Eastern Alps.

(1) Shortening of the eastern part of the Eastern Alps is accommodated by the (north)eastward lateral escape of wedges along major reactivated strike-slip fault systems. Active kinematics of these faults closely resemble the Miocene ones as can be demonstrated by data from the Vienna Basin Transfer fault, the Salzach-Ennstal Fault (Plan et al., 2005), and the Lavanttal Fault. For the Vienna Basin Transform fault active sinistral movement is indicated by moderate seismic activity in a NE-striking zone paralleling the fault, focal plane solutions and recent stress measurements. By analogy to the Miocene kinematics we propose that the sinistral strike-slip fault delimits a major crustal wedge carrying parts of Styria, the western Pannonian Basin and the western Inner Carpathians. According to geologically and geodetically derived data this wedge moves NE at a velocity of 1.5 to 2 mm/a. The geological data obtained so far indicate that most of the listed escape-related faults have significant seismic potentials, although many of them do not show up as loci of observed earthquakes.

(1) In the western and central part of the Eastern Alps shortening is compensated by a combination crustal-scale folding and/or thrusting below the Tauern antiform and south-directed back-thrusting in the Southern Alps. The interpretation of active up-ramping and folding of the Tauern range in deep crustal levels is in line with the measured surface uplift (up to 2.5 mm/a) and the observed tilting of young ($<$ 7 Ma) structural markers, which were rotated for about 25° in both the northern and southern limb of the Tauern antiform. According to gravimetric data (Steinhauser, 1997) the observed uplift cannot be attributed to isostatic processes. The absence of seismicity below the uplifting region suggests that thrusting / folding occurs at depths below the brittle-ductile transition. Deep crustal stacking in the Tauern region is presently not connected to active thrusting along the northern floor thrusts of the Alps but rather to south-directed back-thrusting in the Southern Alps. This is shown by the apparent absence of thrust-related seismicity along the northern margin of the Eastern Alps and by correlations of Quternary sediments and landforms along rivers crossing the northern floor thrusts of the Eastern Alps. Sediments and landforms have not been offset during the last 200 ky (Van Husen, 1971). In contrast to the north, the thrusts in the Southern Alps including the Friuli region are marked by substantial seismicity. Along-river sections in the northern Eastern Alps, however, do indicate that thrusting along the northern floor thrusts occurred prior to about 400 ky. Geomorphologic markers of prae-Mindel age are vertically offset across the thrust for c. 30 m (Van Husen, 1971). We may conclude that during the Pleistocene kinematics of the Alpine thrust wedge changed from a period of thrusting towards the European foreland (prea-Mindel) to present-day crustal thickening in the center of the orogen (Tauern area) and back-thrusting in the Southern Alps. Such suggested kinematic changes on the orogen-scale compare to orogenic wedge models, which indicate repeated switches between basal accretion, wedge steepening and back-thrusting, and foreland imbrication (Huhn, 2002). Such models may be useful for seismic hazard assessments as they could aid to support the improbability of thrust-related earthquakes in the northern Eastern Alps.