Geophysical Research Abstracts, Vol. 7, 02442, 2005
SRef-ID: 1607-7962/gra/EGU05-A-02442

Chemenda-type exhumation during non-steady state subduction: the Late Cretaceous evolution of Eastern Alps

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The structure of classical collisional orogenic belts is essentially dominated by an often flat-lying, metamorphic wedge with increasing metamorphic overprint towards the rear end. This structure is formed by accretion of units derived from the lower plate through extensive thick-skinned and thin-skinned thrusting and synorogenic exhumation of previously subducted metamorphosed units within a medium-angle subduction zone. The Chemenda model (Chemenda et al., 1995, EPSL, 132: 225–232) now predicts exhumation of previously subducted and continental crust metamorphosed at UHP/HP metamorphic conditions mainly driven by both (1) buoyancy of subducted material, and (2) associated surface erosion of the subducted wedge. Thrust surfaces in the footwall and a major normal fault in the hangingwall confine, therefore, the uplifting UHP/HP metamorphic wedge. Clastic material mainly derived from the surface of the uplifting subductional wedge infill a synorogenic flexural sedimentary basin located on top of the lower plate in front of the UHP/HP wedge. Material mainly derives from the surface of the uplifting previously subducted wedge, which commonly form a mountain range at this stage. A cross-section through an orogen exposes, therefore, the following units: (1) the non-subducted lower plate rocks with a collapse basin at the top, (2) the exhumed, previously subducted wedge with a nappe stack, which is dominated by cover rocks at the leading edge front and exhumed metamorphic, mostly polymetamorphic basement rocks, all metamorphosed at HP/UHP conditions at the rear front – all units were accreted from the footwall plate – and (3) the upper plate with collapse-type basins at top only in the case when extension-induced subsidence exceeds uplift. This is not the case in setting of steady-state subduction The subhorizontal attitude of nappes originates from subsequent processes.

The Austroalpine nappe complex of the Eastern Alps likely represent a superb field example for studying these relationships between all these processes, and consequently, the Chemenda model can be tested easily and modified by existing field and laboratory data. The Austroalpine nappe complex is continental basement-cover nappe complex with southward increasing, Cretaceous-age metamorphic overprint, which received its final internal structure largely by middle–late Cretaceous tectonic processes. During this time, subduction of the Piemontais-Ligurian Ocean beneath the Austroalpine units started. In detail, the Lower Austroalpine and lower part of Middle Austroalpine basement-cover nappes represent the footwall of the UHP/HP wedge and were accreted to the exhuming complex at ca. 80 Ma during a pronounced stage of thrusting. The Middle Austroalpine eclogite-gneiss units represent the exhuming UHP/HP wedge, which was subducted to depths corresponding to max. ca. 3.0 GPa in southernmost exposures (Janak et al., 2004, Tectonics, 23, TC5014) at ca. 95-90 Ma (Thöni, 1999, Schweiz. Mineral. Petrogr. Mitt., 79, 209–230). In the north, the pressure is ca. 1 GPa. Most pronounced exhumation of the UHP/HP wedge occurred at 90–80 Ma, as cooling ages indicate. In the hangingwall, a series of ductile low-angle normal faults separates the UHP/HP wedge from uppermost Middle Austroalpine and Upper Austroalpine nappes representing the upper plate. Low angle normal faults were most active between 87–80 Ma as published thermochronologic data indicate. Normal faulting occurred in a sinistral transtensional setting. In consequence of the transtension, collapse basins (Central Alpine Gosau basins) formed on top of the upper plate bear, which we explain by disturbance of steady-state subduction by oceanward retreat of the subduction zone. The tectonic unroofing of the UHP/HP wedge continuously increased to and was most pronounced at the rear end of the wedge, so that more than 50 km of overburden was cut out. The overall tempo of exhumation can be confronted with the infill history of flexural and collapse basins. These data show rapid exhumation between ca. 87 – 84 Ma and subsequent down-slowing motion. Subsequent footwall accretion of Lower Austroalpine nappes at ca. 80–78 Ma formed a duplex, which finally led to updoming of the exhuming UHP/HP wedge.

The model of non-steady Chemenda-type exhumation with oceanward retreat of the subduction zone can also explain the Tertiary exhumation of Cycladic HP metamorphic units of the Cycladic islands in the Aegean Sea above the Hellenic subduction zone.