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Structure and mode of exhumation of subduction channels in continent-continent and island arc-continent collisional orogens

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The structure and mode of exhumation of subduction channels with high-pressure and ultra-high-pressure (UHP/HP) metamorphic rocks preserved in orogens is still far from full understanding (e.g., Agard et al., 2009 and references therein). Field observations, petrologic, thermochronologic and numeric studies are used to constrain the geodynamic setting, velocity of exhumation and rheological controls on the final structure. Not so many recent studies exist on tectonic boundaries of the subduction channel and on sedimentary basins related to exhumation. Based on new observations from Alps, Aegean Sea and island arc systems (e. g., Escambray Massif and Northern Ophiolite belt on Cuba), we report a number of structural features and geodynamic relationships not commonly used in tectonic models on subduction channels in continent-continent and island arc-continent collisional orogens. Many models of continent-continent collisional orogens predict that exhumation of UHP/HP units is mainly driven by (1) rheological weakening of subducted material, (2) buoyancy of the subducted material, and (3) associated surface erosion of the subducted metamorphic wedge. The uplifting metamorphic wedge (subduction channel) is confined, therefore, by (i) a thrust system in the footwall and (ii) a major ductile low-angle normal fault in the hangingwall, and both shear system are operating synchronously. Consequently, nearby sedimentary basins are filled with material mainly derived from the surface of the uplifting, previously subducted wedge, which commonly form a mountain range at this stage. Associated sedimentary basins include a synorogenic flexural basin on top of the lower plate and in front of the orogenic wedge, and, in the case of extension, collapse-type basins and retro-wedge basins on the upper plate. A cross-section through an orogen exposes, therefore, the following units: (1) the non-subducted lower plate rocks with a flexural basin in the front of the orogenic wedge; (2) the exhumed, previously subducted continental lower plate within a nappe stack, which is dominated by cover rocks at the leading edge and exhumed UHP/HP (poly-)metamorphic basement rocks at the rear end – all units were accreted from the footwall plate; and (3) the upper plate with collapse basins at top, when extension-induced subsidence exceeds there uplift. This is the case in a setting of non-steady-state subduction, e.g., when extension is induced by retreat lower-plate slab. The subhorizontal attitude of nappes originates from subsequent processes. A common observation is that the grade of metamorphism is increasing towards the rear end of the orogenic wedge including the subduction channel (e. g. in Cretaceous Eastern Alps from ca. 8 to 30 kbar). Consequently, the composition and the age signal of eroded material deposited in adjacent sedimentary basins is a good measure for exhumation of the orogenic wedge using the lag time concept. Lag time is duration of the interval between cooling of a mineral in a metamorphic rock through the appropriate isotopic closure temperature of the mineral and its deposition in a sedimentary sequence. As erosion and sediment transport are rapid processes, the lag time is mainly controlled by exhumation rates, and this is monitored in associated sedimentary basins.

In our study of the Cretaceous Eastern Alps, we compare the temporal development detrital signal from foreland and collapse basins, and found a very rapid Mid to early Late Cretaceous exhumation to shallow crustal levels consistent with thermochronologic studies of rocks the subduction channel.

Interestingly, and in contrast to continent-continent collision orogens, the island arc-continent collision setting may result in two HP wedges in different tectonic levels. These include, here exemplified largely after the case of Cuba: relatively old, Cretaceous-aged high-pressure rocks in a high structural level (e.g., in the Northern Ophiolite belt), which is accreted onto the North American craton and which is underlain by unmetamorphic to medium-grade metamorphic island arc successions. The island arc system is again underlain by the eclogite-rich Escambray dome with earliest Paleogene amphibole and white mica Ar-Ar cooling ages (65 – 62 Ma). These ages proof synchronous exhumation and dome formation with final collision of the Cuban orogenic wedge with the North American craton. These relationships suggest that the upper HP wedge represents on older stage of oceanic subduction whereas the younger and structurally HP wedge testifies syncollisional emplacement of a detached piece of lower plate rocks.

Reference

Agard, P. Yamato, P. Jolivet, L. Burov, E., 2009. Exhumation of oceanic blueschists and eclogites in subduction zones: Timing and mechanisms. Earth-Science Reviews, 92, 53–79.