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# Exhumation of HP/UHP tectonic units

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Many models for tectonic exhumation of HP/UHP units have been proposed in the past 20 years. Sometimes different models cannot be differentiated on the basis of structural, metamorphic and geochronological observations in the field, so the subject is coloured by personal preferences and by the predictions of geodynamic models (which are only as good as the assumptions within them).

The Alps contain mafic eclogite-facies rocks in the Zermatt-Saas zone (ZS) associated with a blueschist facies overprint. They lie below a greenschist facies shear zone at least a km thick which runs from the Grand Combin area in the NW, beneath the Dent Blanche klippe, over the peaks between Val Tournanche and Val Gressoney, and is last seen dipping SE beneath the Sesia zone, and across-strike length of at least 70 km. This, the Gressoney Shear Zone (GSZ), has abundant top-SE kinematic indicators (Reddy et al. 1999) and is inferred to have had truly "normal-sense" movement, although it is now folded so some parts have apparent thrust orientation (Wheeler & Butler 1993). Structural criteria make it a candidate for unroofing the eclogites, then, but timing information is essential to test such a proposal. Could it be a "late" structure postdating eclogite exhumation? Rb/Sr ages from the GSZ span a range 45-36 Ma which overlaps with the age of UHP metamorphism in the footwall, and ends when both footwall and hangingwall were at greenschist facies. This provides substantial evidence that the GSZ was the structure responsible for unroofing. Nevertheless the base of the GSZ, a rather sharp structure truncating fabrics in the hangingwall and folds in the footwall, really is late – the folds it truncates are themselves greenschist facies. Structural and geochronological data are both essential to test the exhumation model.

It is useful to distinguish the kinematics of the process from the dynamics. The kinematics are what can – ideally – be deduced from observations. Generally they must be integrated across a whole orogen, to distinguish in particular whether thrusting was contemporaneous with extension. In recent literature it is extremely common to see hinterland directed extension proposed as being contemporaneous with foreland directed thrusting, giving a model variously referred to as the "Chemenda model" or "channel flow" etc., though so far as I can tell these are kinematically very similar. I would urge that the dates of thrusting are always considered – in several orogens such dates are not available, so the possibility of net orogenic extension should not be dismissed. For example in Norway exhumation during net transtension associated with plate divergence has been proposed (Foreman et al. 2005, Krabbendam & Dewey 1998). In the Alps, foreland basin migration provides strong evidence for thrusting in the more external zones during internal zone extension (Wheeler et al. 2001). Contemporaneous thrusting and extension mut be driven by internal buoyancy forces. Though the eclogites are dense, they lie above quartzofeldspathic rocks of the Monte Rosa unit and may have been carried up on the back of those less dense rocks.

Exhumation models must be tested by detailed structural mapping to constrain the setting of eclogites and the kinematics of possible unroofing structures, as well as by synthesis on the scale of the whole orogen. A dating program is essential and should involve, ideally, crystallisation ages, and not just for the eclogites but for the deformed rocks around them.

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