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# Exhumation of oceanic blueschists and eclogites in subduction zones: Timing and mechanisms

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ABSTRACT

High-pressure low-temperature (HP–LT) metamorphic rocks provide invaluable constraints on the evolution of convergent zones. Based on a worldwide compilation of key information pertaining to fossil subduction zones (shape of exhumation *P–T–t* paths, exhumation velocities, timing of exhumation with respect to the convergence process, convergence velocities, volume of exhumed rocks,…), this contribution reappraises the burial and exhumation of oceanic blueschists and eclogites, which have received much less attention than continental ones during the last two decades.

Whereas the buoyancy-driven exhumation of continental rocks proceeds at relatively fast rates at mantle depths (≥cm/yr), oceanic exhumation velocities for HP–LT oceanic rocks, whether sedimentary or crustal, are usually on the order of the mm/yr. For the sediments, characterized by the continuity of the *P–T* conditions and the importance of accretionary processes, the driving exhumation mechanisms are underthrusting, detachment faulting and erosion. In contrast, blueschist and eclogite mafic bodies are systematically associated with serpentinites and/or a mechanically weak matrix and crop out in an internal position in the orogen.

Oceanic crust rarely records *P* conditions >2.0–2.3 GPa, which suggests the existence of maximum depths for the sampling of slab-derived oceanic crust. On the basis of natural observations and calculations of the net buoyancy of the oceanic crust, we conclude that beyond depths around 70 km there are either not enough serpentinites and/or they are not light enough to compensate the negative buoyancy of the crust.

Most importantly, this survey demonstrates that short-lived (<~15 My), discontinuous exhumation is the rule for the oceanic crust and associated mantle rocks: exhumation takes place either early (group 1: Franciscan, Chile), late (group 2: New Caledonia, W. Alps) or incidentally (group 3: SE Zagros, Himalayas, Andes, N. Cuba) during the subduction history. This discontinuous exhumation is likely permitted by the specific thermal regime following the onset of a young, warm subduction (group 1), by continental subduction (group 2) or by a major, geodynamic modification of convergence across the subduction zone (group 3; change of kinematics, subduction of asperities, etc).

Understanding what controls this short-lived exhumation and the detachment and migration of oceanic crustal slices along the subduction channel will provide useful insights into the interplate mechanical coupling in subduction zones.



**Contents**



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## 1. Introduction

Subduction zones are crucial areas to constrain interplate coupling (Hyndman et al., 1997; Conrad et al., 2004; Heuret and Lallemand, 2005), recycling processes to the mantle (Bebout, 1996; Schmidt and Poli, 1998; Bebout, 2007) and thermal structures of arc-magmatism (Iwamori, 1998; Peacock and Wang, 1999). They are also the distinctive locus of high-pressure low-temperature metamorphism (HP–LT; Ernst, 1970, 1972; Goffé and Chopin, 1986; Okay, 1989; Maruyama et al., 1996), as confirmed by deep drilling in active trenches (Maekawa et al., 1993; Fryer et al., 1999).

Over the past twenty years, many studies have dealt with exhumation processes of HP–LT rocks, chiefly because: (1) compared to subduction forces burying rocks at depth, processes that return rocks towards the surface are still poorly understood (for example Platt, 1993; Jolivet et al., 1998b; Ring et al., 1999; Jolivet et al., 2003), (2) the discovery that continental crust could be buried deeper than previously thought (>100 km; Chopin, 1984; Smith, 1984) challenged the research community, (3) exhumation velocities derived from *P–T–t* paths, though spanning a wide range from <mm/yr to a few cm/yr (Ernst, 1988; Rubatto and Hermann, 2001; Baldwin et al., 2004), are generally surprisingly lower than subduction plate velocities (except for Philippot et al., 2001), (4) the metamorphic evolution of HP–LT rocks brings invaluable insights into deep crustal processes (Green, 2005).

For the sake of clarity and terminology, the tectonic setting of exhumation in subduction zones is recalled in Fig. 1a. The prevalent view is that, during a period of oceanic subduction, the oceanic crust and the overlying sediments, part of which can be decoupled from the crust and accreted to form the accretionary wedge, are dragged at depth along the subduction plane into the so-called subduction channel (Fig. 1a; Shreve and Cloos, 1986; Cloos and Shreve, 1988). Exhumation of some of these rocks metamorphosed under HP–LT conditions may then take place in the wedge and/or in the channel (e.g. Jolivet et al., 2003). When a large continental piece (i.e., a passive margin or an isolated block) enters the subduction zone it may also be dragged by 'continental subduction', but generally only during a restricted period of time (c. 10 My; e.g. Ernst, 2001; Chopin, 2003), after which collision develops. The introduction of the low-density continental material is generally thought to be responsible for the choking of subduction, which then stops or jumps outboard of the continental block (e.g. Stern, 2004).

Research on the exhumation of HP–LT rocks mainly focused so far on continental high- to ultrahigh-pressure rocks (UHP; for example, Wain, 1997; Kurz and Froitzheim, 2002; Chopin, 2003; Hacker et al., 2003a), partly due to the diagnostic occurrence of the quartz polymorph, coesite (as noted by Bucher et al., 2005) and to the finding of UHP rocks from ever increasing depths (Fig. 1b). The new paradigm suggests that the buoyant UHP continental rocks return at plate velocities from mantle depths (1–5 cm/yr; Duchêne et al., 1997a;

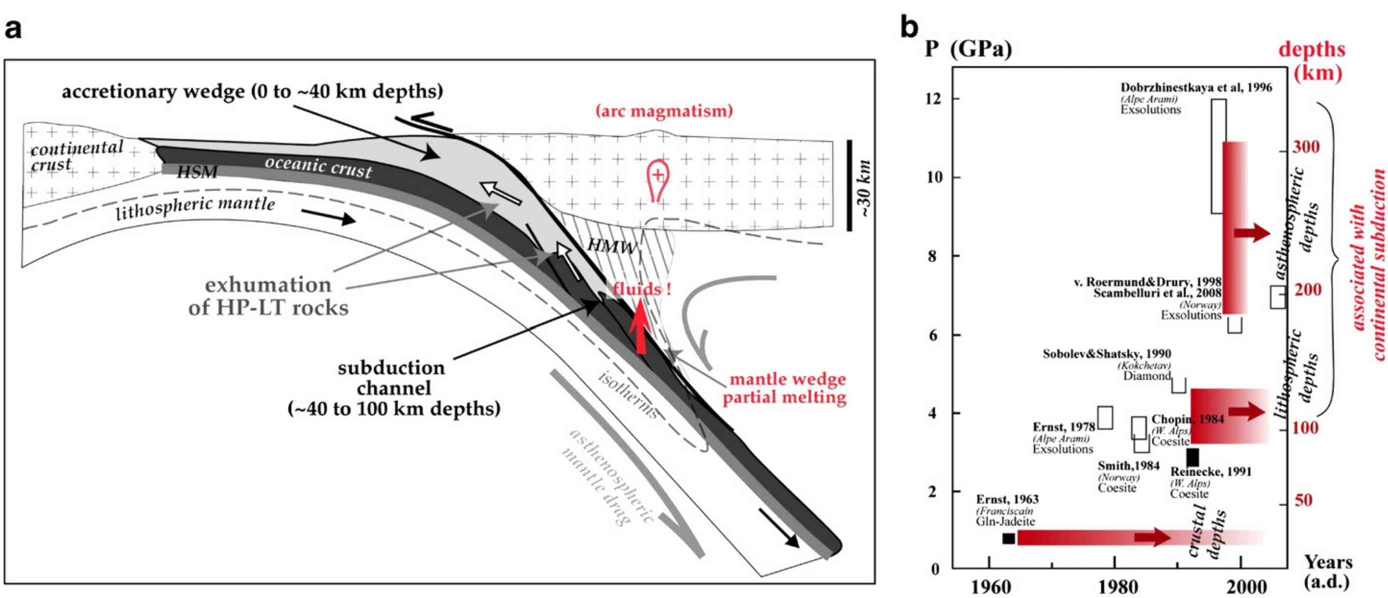


**Fig. 1.** (a) Sketch depicting the tectonic setting of the exhumation of high-pressure low-temperature (HP–LT) rocks in subduction zones. HMW: hydrated mantle wedge; HSM: hydrothermalized slab mantle. (b) Compilation of the main steps of discovery of HP–LT rocks illustrating the recovery of rock samples returned from increasing depths with time (Ernst, 1963, 1978; Chopin, 1984; Smith, 1984; Sobolev and Shatsky, 1990; Reinecke, 1991; Dobrzhinetskaya et al., 1996; van Roermund and Drury, 1998; Scambelluri et al., 2008). Empty boxes: continental material; black boxes: oceanic material. Note that no oceanic material has been documented from pressures >2.8 GPa so far (Reinecke, 1991, 1998).