**REVIEW**

**FLUIDS IN THE CRUST**

The chemical behavior of fluids released during deep subduction based on fluid inclusions†

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**ABSTRACT**

This review combines fluid inclusion data from (HP-)UHP rocks with experimental research and thermodynamic models to investigate the chemical and physical properties of fluids released during deep subduction, their solvent and element transport capacity, and the subsequent implications for the element recycling in the mantle wedge. An impressive number of fluid inclusion studies indicate three main populations of fluid inclusions in HP and UHP metamorphic rocks: (1) aqueous and/or non-polar gaseous fluid inclusions (FI); (2) multiphase solid inclusions (MSI); and (3) melt inclusions (MI). Chemical data from preserved fluid inclusions in rocks match with and implement “model” fluids by experiments and thermodynamics, revealing a continuity behind the extreme variations of physico-chemical properties of subduction-zone fluids. From fore-arc to sub-arc depths, fluids released by progressive devolatilization reactions from slab lithologies change from relatively diluted chloride-bearing aqueous solutions (±N₂), mainly influenced by halide ligands, to (alkali) aluminosilicate-rich aqueous fluids, in which polymerization probably governs the solubility and transport of major (e.g., Si and Al) and trace elements (including C). Fluid inclusion studies point to a reconsideration of the petrological models explaining deep volatile liberation, and their flux into the mantle wedge.

**Keywords:** Subduction zones, fluid inclusions, UHP metamorphic rocks, volatile cycling, mantle wedge, deep subduction, Review

**INTRODUCTION**

The chemical behavior of fluids in deep subduction zones and their implications for element cycling and flux melting in the mantle wedge, which causes the formation of arc magmas, has been a subject of growing interest in the last 20 years (e.g., Manning 2004; Bebout 2007, 2013). Experimental and theoretical research represents a major tool for understanding the chemical and physical properties of slab-derived fluids, and for modeling the metamorphic evolution of deep subducting rocks (e.g., Ulmer 2001; Poli and Schmidt 2002; Manning 2004; Sanchez-Valle 2013; and references cited).

Closely related to theoretical and experimental research are studies of fluid inclusions in metamorphic rocks. High-pressure (HP) and ultrahigh-pressure (UHP) eclogite-facies rocks of crustal origin represent an excellent natural laboratory for the study of subduction-zone fluids, since they underwent pressure and temperature conditions comparable to those hypothesized to occur in deep subducting slabs (Carswell and Compagnoni 2003). A large number of fluid inclusion studies in eclogites and related rocks have reported a remarkable variety of fluid types: aqueous fluids with variable halide content ± non-polar gases (e.g., N₂, CO₂, CH₄), aluminosilicate-rich aqueous fluids, intermediate between silicate melt and water, and hydrous silicate melts (cf. Scambelluri and Philippot 2001; Frezzotti and Touret 2003; Ferrando et al. 2005b; and references cited). Many among these inclusions have lost their original composition, but some still preserve the chemistry of fluid trapped during prograde and peak UHP metamorphic conditions, despite subsequent exhumation from extreme depths. In this paper, we highlight how fluids in inclusions can constrain and explain deep subduction processes. After providing a review of current research on fluid inclusions in (HP-)UHP metamorphic rocks, we express our view on the chemical and physical characteristics of subduction-zone fluids preserved as inclusions, including solvent and element transport capacity, and implications to cycling of volatiles. Further recent discussion on fluid inclusions in UHP metamorphic rocks can be found in Scambelluri and Philippot (2001), Touret and Frezzotti (2003), Ferrando et al. (2005b), Zheng et al. (2011), Klemd (2013), and Hermann et al. (2013).

**FLUID INCLUSIONS IN HP-UHP METAMORPHIC ROCKS**

Fluid inclusions are tiny volumes of mobile volatile-rich phases trapped in minerals during, or after their growth (Roedder 1984). For this reason, they represent the only possible way to acquire firsthand information on naturally occurring fluids. A digest of current main research on fluid inclusions in UHP eclogite-facies metamorphic suites is provided in Table 1. It summarizes different pieces of information, including inclusions’ main textural (stage of trapping, inclusion type, and

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† Special collection papers can be found on GSW at http://ammin.geoscienceworld.org/site/misc/specialissuelist.xhtml.