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Editorial: Advances in subduction zone fluids and their geochemical effects

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Editorial on the Research Topic
Advances in subduction zone fluids and their geochemical effects

Introduction

Subduction zone fluids, including aqueous solutions, hydrous melts and supercritical fluids, are key agents for mass transfer and element exchange between the subducting slab and the adjacent oceanic or continental lithosphere. These fluids being released due to metamorphic reactions greatly affect the chemical composition of the subducted slab, the overlying mantle wedge, and arc magmas. They are of fundamental importance for the geochemical cycle in subduction zones, which play a vital role in subduction zone magmatism and in the secular evolution of Earth's crust-mantle system.

Fluid processes in subduction zones are controlled by protolith composition, geothermal structure, pressure-temperature (*P*-*T*) conditions, and fluid-rock interaction. In a cold subduction zone, aqueous solution would dominate, mainly carrying fluid mobile large ion lithophile elements (LILEs). When the temperature increases, partial melting of the subducting crust can occur forming hydrous melts. This type of fluid exhibits an elevated transport capacity of LILEs and light rare earth elements (LREEs). However, due to the complexity of subduction zones and fluid-rock systems, the detailed fluid-related processes and the associated elemental and isotopic compositions of subduction zone fluids are not yet entirely known. In addition, it is not clear how the slab derived fluids/melts enter the deep mantle and modify the mantle source related melts for various types of magma formation. This Research Topic aims to advance our understanding of how the fluid forms at various *P*-*T* conditions and of geochemical fingerprints of fluids in subduction zones. Furthermore, the geochemical effects of such fluids on subducting slab, mantle wedge, and related magmas are highlighted.

Contributions of this topic

This Research Topic is composed of six papers focusing on metamorphic processes in oceanic and continental subduction zones, geochemical compositions of slab-derived fluids, recycling of oceanic and continental crustal materials, as well compositional variations during differentiation of silicic melts.

Metamorphic process in subduction zones

Metamorphism is closely linked with dehydration and the composition of fluids in subduction zones. Thus, it is important to constrain the *P-T* path experienced by respective metamorphic rocks. The petrogenesis and metamorphic evolution of quartzo-feldspathic metasedimentary rocks is usually difficult to constrain, although such rocks widely occur in high pressure (HP) to ultrahigh pressure (UHP) metamorphic belts. Zhang et al. studied felsic schists in the Western Tianshan metamorphic belt through petrological observations and phase equilibria modeling, and constrained *P-T* conditions of prograde, peak, as well as decompression stages. They obtained a clockwise *P-T* path similar to other lithologies of the same belt, suggesting a coherent subduction-exhumation history of the UHP unit in this locality. Fluid activity and late tectonic deformation were proposed to account for the final uplift of the Western Tianshan oceanic crust to the surface.

Lawsonite is one key mineral for understanding fluid activity, element migration and crust–mantle interactions in subduction zones. However, lawsonite is generally absent in nature HP/UHP rocks in continental subduction zones, although it is expected to occur as indicated by theoretical calculation. Lu et al. studied HP–LT eclogite from western Dabie to constrain the conditions for lawsonite formation and preservation during continental collision. They documented the occurrence of polymineralic aggregates that presumably represent lawsonite pseudomorphs, and constrained the *P-T* path of such rocks through phase equilibrium modelling. On this basis, they proposed that lawsonite can be present under H_2O present conditions along a low geothermal gradient during continental subduction, which may break down during exhumation.

Geochemical composition of slab-derived fluids

The geochemical composition of slab-derived fluids is a key for understanding crust-mantle interaction and redox evolution of Earth's interior. However, the species of redox-sensitive elements (like C-S-Fe) and the oxygen fugacity (f_{O2}) of slab-derived fluids are discussed very controversially. Li et al. conducted phase equilibria modeling on altered oceanic crust (AOC) and serpentinite for the C-S-bearing system over a pressure range of 0.5–6 GPa. The modeling results show that the redox species and f_{O2} of slab-derived fluids are mainly controlled by the redox state of the protolith composition with only a minor impact by the subduction-related thermal structure. Under average compositions, the subducted AOC and serpentinite can produce oxidizing fluids with oxidized carbon-sulfur species and high f_{O2}, which can effectively oxidize the subarc mantle over geological timescales.

The recycling of oceanic and continental materials in subduction zones

Crustal materials can be subducted to mantle depths inducing mantle heterogeneity, which is in turn reflected by the composition of mantle-derived magmatic rocks. For the Cenozoic basalt from Changbaishan, northeastern China, the origin of the enriched mantle source component is not clear. Zhao et al. used machine learning algorithms of Random Forest and Deep Neural Network to train models using global island arc and ocean island basalts data; the trained models suggest that Changbaishan basalts are highly influenced by slab-derived fluid. Based on the Sr-Nd isotope composition changes of basalt from 5 to 1 Ma ago, they proposed that a slab gap opened at ca. 5 Ma and the hot sub-slab oceanic asthenosphere rose through the gap after 1 Ma. For the post-collisional alkaline intrusive rocks from the Dabie orogen, Sun et al. conducted a comprehensive geochemical and zircon study to elucidate the mantle source and crust-mantle interaction in continental subduction zones. They found that the syn-magmatic zircons exhibit three groups of Hf-O isotope compositions comparable to those of UHP metamorphic rocks from different parts of the Dabie orogen. Based on this observation, they suggested that the melts derived from the subducted South China Block reacted with the lithospheric mantle wedge of the North China Block to form metasomatites, whose partial melting finally generated post-collisional alkaline intrusive rocks during the Early Cretaceous.

The melt composition change during leucocratic melt evolution

It is important to know how the melt composition could change during melt evolution. Gao et al. studied leucogranites from the Himalaya orogen, and found systematic variations in Nb/Ta and Zr/Hf ratios, which are considered to be linked with changes in the dissolution behavior of key accessory phases. These data in turn reflect the melt structural changes associated with fractional crystallization of the leucocratic melt. Such a great change in the melt structure would not only affect the viscosity and fractional crystallization of the granitic melts, but also promote the formation of rare elements enriched ores associated with leucogranites.

Clearly, many problems related to subduction zone processes remain and need future investigation. These problems include but are not limited to: 1) controlling factors of metamorphic dehydration and partial melting in subduction zones, e.g., the impact of protolith composition, thermal structure of subduction zones, differences in *P-T* path, and fluid-rock interaction during fluid migration; 2) conditions and mechanisms of partial melting in oceanic and continental subduction zones, and how they affect the geochemical composition of resultant partial melts; 3) conditions and geochemical composition of supercritical fluids in various rock systems; 4) impact of metamorphic dehydration and partial melting on element mobility and isotopic fractionation in subduction zones, which includes LILEs and volatile elements such as C-H-N-S; 5) differences of metamorphic dehydration and partial melting between oceanic subduction zones and continental subduction zones; 6) relationship between fluid action, element mobility, and

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crust-mantle interaction at the slab-mantle interface as well as subduction zone magmatism.

Author contributions

Y-XC wrote the draft with input from all the authors. All authors contributed to the article and approved the submitted version.

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Conflict of interest

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