Formation of Carbon and Hydrogen Species in Magmas at low Oxygen Fugacity

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A variety of evidence exists to support the idea that at least part of the upper mantle is reduced enough to stabilize carbon, CH₄ and H₂ at depth (Ballhaus, 1993; Kadik, 1997) and that the Earth’s mantle was originally very reduced and has become progressively more oxidized, resulting perhaps in the multistage mechanism of accretion production of the upper mantle oxidized iron via the auto-redox process (Allègre et al, 1995; Javoy, 1995). Accretional models imply the depletion of the original volatiles of the Earth. Within the framework of these representations the presence of a primary fluid phase in mantle is rather doubtful. Although this area is still one of the active debate and inquiry, it seems likely that the range of oxidation states from relatively oxidized (fO₂ ~FMQ) to reduced (fO₂ ~IW) is applicable to the upper mantle. Volatiles in the reduced part of the system C-O-H may therefore be of considerable importance in igneous petrogenesis (Taylor and Green, 1987; Ballhaus, 1993; Holloway and Jakobsson, 1996; Kadik, 1997).

Our major concern is to demonstrate that carbon and hydrogen solubility in the melt may have important implication for the upper mantle evolution and the formation of carbon and hydrogen species in the terrestrial magmas during the early differentiation of the Earth. Our further purpose is to elaborate the role of fluid-absent melting in the generation of the oxidized C-O-H volatiles from reduced carbon-bearing upper mantle source. The iron-bearing silicate melt (ferro-basalt) is represented by CH₄ and other C-H groups. The spectroscopic constraint greatly limits the choice of a reduced component. It is suggested that the most likely candidates are the network units containing Si-C bonds and non-stoichiometric network component containing units having 0/Si ratio less than 2. It is supposed also, that a part of carbon and hydrogen could be dissolved in the atomic form. The interaction of carbon and hydrogen with silicate melts at low fO₂'s has a number of features, which could play a key role in CO₂ and the H₂O formation at the early stages of mantle evolution. We argue that fluid-absent partial melting of the reducing carbon-bearing planetary mantle will form magmas that yield the “oxidized” forms of carbon and hydrogen in melt that should be more oxidizing than the mantle source. The transport of primary magmas from the planetary interiors to the surface provides the primary supply of H₂O and CO₂ of volcanic gases. It is supposed, that the major factor controlling transport of oxygen in the large-scale melting zone at low fO₂ should be the auto-redox process that would release O₂ to oxidize the proto-mantle (Allègre et al, 1995; Javoy, 1995).