Tracing deep volatiles from the crust to the core

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Carbon, hydrogen, and nitrogen are among the essential volatile elements for life on our habitable planet. The reservoirs and cycling of those volatiles at depth are crucial for our understanding of the physiochemical processes and evolution of Earth's deep interior, as well as its interaction with the surface. The formation of the metallic core in Earth's early history and the gradient in the redox state of the differentiated deep interiors of the planet are believed to dictate the occurrence and cycling of deep volatiles. Here I will report our recent mineral physics studies on the elastic and viscoelastic properties of Fe-Ni liquids alloyed with a considerable amount of carbon, thermoelastic properties of Fe-C-N alloys, and melting and phase relations of the Fe-C-H systems at high pressure-temperature conditions. The alloying of carbon was found to substantially influence the properties of the Fe-Ni liquids, providing constraints on the presence and abundance of carbon in the cores of the Earth and the Moon. Our experimentally and computationally determined structures, phase stability, and thermoelastic properties of Fe-C-N alloys at high pressure-temperature conditions indicate that iron carbonitrides may be the main nitrogen host in the mantle and core, informing a better understanding of the composition of Earth's core. The eutectic melting temperatures of both Fe-C and Fe-C-H systems were found to be below the mantle geotherm, which facilitates the cycling of subducted crustal carbon and hydrogen as molten iron alloys. The depressed melting temperatures of iron alloyed with subducted carbon and hydrogen may lead to the formation of metallic melt pockets for superdeep diamond formation in the deep mantle. In summary, tracing volatiles from the crust to the core could shed new light on the core chemistry, pathways of volatiles at depth from planet formation to present Earth, and the thermochemical evolution of our habitable planet and other worlds.