Molecular-scale vision of geochemical processes: a world without frontiers?

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Minerals, including the nanos, glasses and melts, mineral surfaces interacting with aqueous solutions or biological organisms, may be conveniently described at the atomic scale using similar structural descriptions provided by a large wealth of instrumental, experimental and theoretical approaches. This unified approach is at variance with the older concepts of crystalline vs. amorphous materials, which have shown their limitations in many instances and do not conveniently correspond to the reality. Among the new tools available to the Geoscience community, synchrotron radiation has been progressively used to develop countless innovative techniques, broadening considerably the usefulness of x-rays for solving geochemical problems. As a consequence, synchrotron radiation centers are nowadays largely populated by geoscientists, worldwide. Gordon Brown popularized the unique properties of synchrotron radiation, which he used for solving questions ranging from environmental and geochemical sciences to materials sciences.

We will focus on how the molecular-scale approaches provide a unifying view of the geochemistry of a given element, comparing element speciation in fluids, minerals, mineral surfaces and interfaces, biological systems, glasses and melts. Based on the example of a few elements, we will show how molecular scale factors play a role in governing the stability of geomaterials and man-made environmental materials (e.g. nuclear glasses), as well as they may explain element transfer during mineral formation and dissolution. These observations give substance to the concept of geochemistry of solids, already advocated by Bill Fyfe more than 50 years ago in his premonitory book. In environmental sciences, often facing urgent demands, observations at atomic scale bring a basic understanding to rationalize risk assessment, management and reduction of the impacts of contaminants and pollutants at field, landscape, and global scales.