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Transport phenomena through Small-World fracture networks

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The description of the topological features of networks developed through the Earth's interiors (e.g. fracture networks) has been the subject of several studies. In the last decades, attempts have been made in order to describe quantitatively the scaling characteristics of such networks by using fractal geometry. Scale invariant fracture or conduit networks have been proposed, for instance, as theoretical models for the efficient delivery of magmatic liquids to the Earth's surface.

In this study I adopted the principles of Graph Theory in order to describe the geometry of a series of fracture networks occurring in geological media at different scales (micron to metre). Such natural networks are described in terms of connectivity between nodes and this is done by implementing a mathematical formalism based on the efficiency of the connections at global and local scale. By means of the 'efficiency' formalism, the well known concept of Small-World can be applied to real networks. The global and local efficiency parameters quantify, respectively, how promptly the information can be spread across the system, and its robustness in terms of fault tolerance (i.e. availability of alternative pathways whenever a certain node is interrupted).

I applied this idealized model to the transport of magmas through networks of fractures and porous channelways. It is suggested that network connectivity may affect the modes of melt delivery towards the surface (e.g. equilibrium vs. disequilibrium transport) depending on the global and local efficiency of the network.

Further studies and refinement of the model might render this approach applicable to a series of issues related to fluid transport through geological media, including mantle metasomatism, dispersion of pollutants through aquifers, oil recovery and CO2 geological sequestration.