# Deformation assisted fluid migration in rocks

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The layman's notion that a solid rock is impenetrable to fluid flow is probably in many cases a more correct conception than the view expressed by geophysical textbooks listing finite, but often ridiculously small permeabilities for metamorphic and igneous rocks. In the absence of tectonically produced deformation with associated dilation and porosity generation, or porosity inflation due to devolatilization, most metamorphic and igneous rocks are probably impermeable. This also applies to well consolidated sedimentary rocks such as carbonates and evaporites as well as to many shales. Even in the presence of a finite porosity, the wetting properties of many natural fluid-rock systems prevent the formation of a connected porosity in the absence of cracks.Yet, introduction of external fluids to dry and impermeable volumes of the Earth's crust is a prerequisite for retrogressive metamorphism and may cause significant changes of the crust's physical properties, notably its density, rheology, and elastic properties. Clearly fluid migration through impermeable rocks must be intimately associated with porosity generation.

We present field observations and modelling results illustrating fluid migration promoted by hydrofracturing and reaction enhanced permeability respectively.

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# The early evolution of the Earth : core formation, mantle differentiation and volatile evolution.

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The early evolution of the completed Earth has been conditioned both by the building material and by the great impact which led to the formation of the Moon. This event has marked the final differentiation of the core and produced the mantle differentiation by the formation of a magma ocean. The present expression of that magma ocean is the upper mantle: the problem is to identify the present limits of this upper mantle. In a simple model it could be the fraction "above 650 km". However this probably conflicts with some characteristics of the present Earth as well as with energy fluxes and chemical mass balance considerations and with the result of recent two-level convection experiments.

The present trace of the early upper-lower mantle boundary is more likely to be identified with the tomographic surface at around 1000km depth, which corresponds to mantle mass fractions of 0.44 and 0.56 respectively for the upper and lower mantle. That separation corresponds to a chemical boundary for major elements, the upper mantle being silica-depleted. This difference is also apparent in isotopic signatures of some trace elements, notably the rare gases.

The silica depletion of the upper mantle is due both to the uptake of silicon, between ~10 and 24 Gpa, by the metal migrating to the core, and to the effect of partial melting on silicates, enriching the liquid in magnesium.

The Earth has been completed by a late veneer of material bringing the siderophile element content of the upper mantle and also part of the volatile elements . If we believe recent osmium isotopic data, that veneer resembled ordinary and enstatite chondrites but was unable to bring all the terrestrial volatile inventory, especially the water.

Hence it had to be followed by another veneer, probably of cometary origin, of much smaller size, which brought about half of the water and part of the terrestrial carbon and nitrogen.

The main differences between the Earth and Venus lay in the absence of a great impact, hence of a doubly convecting mantle, whic led to complete mantle outgassing, and to the very small size of the cometary veneer.