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Mechanics versus chemistry: three cases of abnormal fluid behaviour

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Field evidence shows that the preferential mode of metamorphic fluid flow is channelized. There are two limiting scenarios for the cause of channelization, reactive transport instabilities that arise because the solubility of a component of the solid matrix increases in the direction of fluid flow, and mechanically induced instabilities that arise as a consequence of deformation (1). Although the cause of channelization may be purely mechanical, chemical interaction between the fluid and rock matrix is an inevitable consequence of fluid flow. Here we consider three paradoxical examples of deep crustal fluid flow and argue that these examples can only be explained as the chemical consequences of mechanical flow instabilities. I) Hydrous eclogitized ductile shear zones in the largely dry, undeformed grabbroic rocks of the Western Gneiss Region of Norway. These features are enigmatic because ductile shearing would not reduce the mean stress, the mechanism most commonly invoked to explain fluid flow localization; moreover shearing is expected to reduce permeability, an effect that should make shear zones unattractive conductive features. Fluid infiltration into these shear zones can be explained in terms of a model in which the localized fluid pressure build up is the reason for the shear deformation (2). II) The development of almost pure garnet veins in eclogites of the Zambezi Belt (Zambia) and reaction selvages in the Tianshan (China) and Pouébo Eclogite Melanges (New Caledonia) require transport of supposedly immobile chemical components towards veins that are presumed to have acted as fluid conduits. Viewed as a purely metasomatic process this transport requires uphill chemical diffusion, but can be explained as a consequence of

normal diffusion if the pressure perturbations caused by compaction instabilities (3) are taken into account. III) Bathymetric and seismic evidence suggests that fluids released at fore-arc depths from the subducted oceanic crust serpentinize the underlying cold mantle part of the subducting slab on a kilometer spatial scale. Yet the hydration process should raise mean stress and decrease permeability. We discuss how the fluids overcome their claustrophobia and abhorrence for high mean stress in the context of reactive downward fluid flow during plate bending.

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