

Reactive fluid flow in slabs – A metamorphic view on the origin of the slab component

TIMM JOHN

Physics of Geological Processes PGP, University of Oslo,
0316 Oslo, Norway (timm.john@fys.uio.no)

Subduction zones are the places on Earth where quantitatively the largest mass transfer rates exist and element fractionation occurs between crust and mantle. The agents, which are central to these processes, are aqueous fluids, supercritical fluids, and melts. Field evidence found in formerly subducted rocks shows that the preferential flow field of released slab fluids is highly channelized and that these fluids tend to react with parts of their wall rocks. Thereby they are able to serve as agents for mobilization and transport for most trace elements. I will describe a model for fluid flow within slabs that suggests that slab melting must not necessarily be invoked for mobilization of so-called fluid-immobile trace elements. For this model it is critical that permeabilities in the subducting slab appear to be too low and dihedral angles between fluid and relevant minerals too high to allow for pervasive porous flow, hence the fluids tend to localize while flowing. I will outline how fluid channelization controls reaction rates and element redistributions during metamorphism of the subducting plate as well as trace element composition of subduction-related fluids during flow. Channelized fluid flow predicts that most formerly subducted material will show only very limited evidence for fluid flow, consistent with the rarity of observed high fluid fluxes in subduction-related rocks. Aqueous fluid produced by dehydration reactions will not percolate through large rock volumes, but rather will be carried away from the dehydration sites by a veining network. Indeed evidence for significant aqueous-fluid fluxes have been found in high-pressure veins with adjacent selvages. In such selvages, LILE's generally show the highest mobilities, followed by light REE's and then heavy REE's and HFSE's. Equilibrium between aqueous fluid and surrounding rock will only be approached at sites of fluid production and mineral reaction. However, this fluid can be significantly modified while moving upwards through a veining network where the wallrocks are out of equilibrium with the passing fluid. In a subducting slab, such reactive fluid flow can preferentially dissolve minerals and release their trace elements. The degree of change in aqueous fluid composition will depend on the fluid composition itself, the amount of fluid–mineral surface interaction and the ratio between the kinetics of the mineral reactions and the velocity of the passing fluid. In this talk I will focus on field evidence for reactive fluid flow in localized channel networks in high-pressure metamorphic terranes and its distinct chemical signature that is a direct counterpart to that in arc magmatism.

Interplay of deformation, fluid infiltration and eclogitization

TIMM JOHN, HÅKON AUSTRHEIM, DANIEL W. SCHMID,
LARS RÜPKE AND YURI PODLADCHIKOV

Physics of Geological Processes PGP, University of Oslo,
0316 Oslo, Norway (timm.john@fys.uio.no)

It is a common observation that during increasing metamorphic conditions dry coarse-grained rocks often fail to react because of sluggish mineral reactions. The crucial trigger mechanism to start the delayed metamorphic reactions is the infiltration of fluids. But how do fluids flow within dry rocks with very low permeability and how fast do the system react? The Kråkenes Gabbro is a partially deformed and transformed igneous body located in the Western Gneiss Region (Norway). The body is transected by a swarm of cm-wide hydrous eclogite-facies shear zones. The shear zones have cores of intensely deformed material surrounded by a dm-wide reaction halo where deformation is less obvious. The water-bearing minerals are highly concentrated in shear zones and their modal abundance progressively decreases with increasing distance to the deformation front. Fluid infiltration into the undeformed parts apparently occurred both along grain boundaries and through reactive minerals. Thereby, olivine appears to have been too reactive and thus shielded by corona formation, whereas clinopyroxene mainly reacted along its grain boundary and the magmatic plagioclase reacted to a micron-sized hydrous symplectite. It is interesting to note that these symplectites lack deformation features, indicating that they formed under static conditions. The subdomains can be regarded as tiny batch-experiments in which the fluid was rapidly supersaturated in the precipitating mineral phases, so that the replacement products inherited the chemical variations of the subdomains. In this manner magmatic zoning of plagioclase grains have been preserved. These findings imply that the kinetics of the reactions were faster than the fluid flow. From less transformed subdomains it is evident that element transfer was controlled by discrete transport pathways. At the terminations of such transport pathways the stable mineral assemblage precipitated. Real eclogite formed only if the element exchange between different subdomains was efficient, otherwise “metastable” phases formed. Obviously, the dynamic formation of porosity and permeability is crucial for the described observations, because it allows fluid access to the reaction interfaces and mass transfer even in undeformed parts. However, even though the suggested fluid pathways are wide, in cases up to several hundred microns, the final effective porosity is low. Thus, beside the deformation enhanced fluid infiltration along the shear zones effective porosities only exist while minerals react – then the newly formed mineral assemblage closes the pathways. Formation of porosities is either reaction enhanced along grain boundaries or occurs in form of porosity waves associated with mineral reactions through reactive domains.