Uplift metamorphism and late orogenic fluids in the upper crust

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In the late stages of orogeny, most metamorphic rocks return to the surface along P-T paths which cross dehydration equilibria in a retrograde sense. As a result, remaining pore fluids are rapidly consumed in hydrous minerals and the cooled metamorphic rocks are essentially dry and therefore strong. Retrograde metamorphism is usually minor and related to fluid infiltration.

Under some circumstances however, rocks undergoing uplift can experience further dehydration, resulting in the generation of aqueous fluid in the upper crust. This is possible as a result of drop in pressure without the addition of heat and is analogous to the process of boiling water by “flashing”. As with flashing, the extent of reaction is limited by the heat already available in the system, since dehydration reactions are also endothermic. Equilibrium conditions must be overstepped to trigger reaction, and once the reaction starts it results in a drop in temperature until the P-T conditions of the reacting rock are buffered along the relevant dehydration equilibrium. The circumstances which favour such “uplift metamorphism” include: rapid uplift and erosion so that conditions are near to adiabatic, the presence of rocks with a suitable mineral assemblage and P-T conditions such that the relevant dehydration equilibria are strongly pressure-sensitive. These are most likely to be encountered where low grade pelitic rocks are undergoing uplift in the top c. 10 km of the crust. The continuing drop in pressure in such systems, coupled with the dehydration reactions, favours progressive hydraulic fracturing of the reactive lithology and the development of veins.

The potential for uplift metamorphism is strictly limited by the available heat, and this may be why few examples are described; the best documented are from late orogenic gold-quartz vein systems in low grade metamorphic belts. By the same token however, rapid uplift is a mechanism for driving regional-scale metamorphism at a much faster rate than is possible where heat input is required. Where uplift metamorphism does take place, it generates a volume of rock at depth that contains overpressured fluid. This provides a barrier to deep penetration of surface waters until the pressure decays, but subsequently the newly-generated fractures may promote deep circulation.