A case study on grain coarsening in polymineralic rocks under static conditions

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Increasing temperature, which occurs for example during contact metamorphism, leads to grain growth in monomineralic as well as polymineralic crystalline rocks. This is due to the ambition to reduce the surface energy of the grain aggregates. Whereas in monomineralic rocks normal grain growth can mathematically be treated in form of a simple grain gowth law, grain coarsening in polymineralic rocks - such as we analysed in this study - is more complex. To investigate grain coarsening in polymineralic systems, we studied contact metamorphic, polymineralic carbonate rocks (Calcare di Angolo: impure carbonates alternating with marly layers). In addition, we performed in-situ rock analogue experiments using rigid second phases embedded in a norcamphor matrix.
The results indicate a rather complex grain coarsening behaviour in such systems, which is mainly due to the interaction between the rock's matrix phase (>50 Vol%) and the second phases. Parameters that control the grain growth in such composite systems are the mineralogy, quantity, distribution, and grain size of the second phases. Generally two different types of growth behaviours can be distinguished for polymineralic rocks: (i) A large quantity, dense distribution, and large grain size of the second phases pin the grain boundaries of the matrix grains as long as the their driving forces for grain growth are smaller than the pinning forces induced by the second phases. Depending on T and the time available, mass transfer between second phases can occur allowing the second phases to further grow. (ii) For enhanced grain growth (e.g. elevated T), the matrix grain size can overgrow the second phases leading to inclusions of them in the matrix grain.
In light of a P-T-t evolution of a rock, both growth processes can occur depending on the mobility of the grain boundaries of the matrix phase and the pinning forces of the second phase. This fact can be used to gain a time-resolved insight into the changes in the grain coarsening behaviour of a polymineralic rock. For example, grains with included second phases, document stages of high grain boundary mobility/low pinning forces. The fact that these phases are chemically isolated allows to infer the conditions of grain growth at the time of the overgrowth. Second phases at grain boundaries, however, are indicative for the pinning of the matrix grain boundaries by the second phases. In contrast to included ones, these second phases are located on the interconnected grain boundary network allowing mass transfer between the different second phases. In this way, second phases can either further grow at given mineral stability or they can undergo mineral reactions. Particularly in the first case, an increase in the size of second phases leads to a decreasing number of phases per unit volume, enhancing the interparticle distance between the second phases what enables the matrix grains to further grow until they are pinned again. This coupled grain growth in combination with (ii) is responsible for enhanced grain sizes of polymineralic rocks with increasing metamorphic conditions.