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THE TEMPERATURE AND PRESSURE CONDITIONS OF THE REGIONAL DYNAMOTHERMAL METAMORPHISM

The experimental data on the diverse metamorphic mineral reactions studied to date will be compiled in this chapter with the goal of specifying the temperature and pressure conditions of the greenschist and amphibolite facies. Only certain mineral assemblages are found repeatedly in metamorphites, and it is the conditions of formation of these assemblages and the conditions under which one commonly occurring mineral assemblage changes to another one that permit elucidation of metamorphic conditions. Only certain imaginable reactions that can be explored by experimental means are useful for this purpose. A prerequisite for the application of experimental data to petrological interpretations is that a particular reaction has been really observed to have taken place in the rocks. For this reason, we shall have to consider reactions taking place in naturally occurring mineral assemblages. It is also necessary to recognize from petrographic observation the reactions taking place at particular facies or subfacies boundaries or else within a particular facies under different pressures. Of special importance for this purpose is a knowledge of the various metamorphic facies series. This branch of petrogenetic research is rather new and quite a lot is yet to be achieved. Still, we are now in a position to provide some concrete data to replace the earlier presumptions. Examples of these have been given in Sections 4.1, 4.2, 6.2, and in Chapter 14.
15.1 Physical Conditions of Metamorphism in the Greenschist Facies

Let us first inquire whether there are some minerals that make their appearance for the first time in the greenschist facies. Albite, chlorite, actinolite, for instance, are common in the greenschist facies; however, they are present as well at lower temperature, in the prehnite-pumpellyite-quartz facies in the lawsonite-albite facies, and even in sediments. The actual transition from these facies to the greenschist facies or the glaucophanitic greenschist facies is marked by the disappearance of certain assemblages. The beginning of the greenschist facies is characterized by the complete disappearance of prehnite and pumpellyite, at the cost of which, primarily zoisite/epidote and actinolite are formed. At the entrance to the glaucophanitic greenschist facies, lawsonite and pumpellyite disappear and are replaced by zoisite/epidote and actinolite. The actual reactions and their equilibrium relations have not yet been explored experimentally, though it is to be expected from consistent petrographic observations that these reactions would yield very good temperature marks for the beginning of the two facies. From the data bearing on the upper stability limit of isolated lawsonite, it is known that temperatures somewhat lower than the upper stability of that mineral, that is, temperatures of the order of 400°C, must be reached for the onset of the glaucophanitic greenschist facies. Moreover, from petrographic observations, we know for certain that typical sedimentary minerals such as kaolinite, glauconite, celadonite, and saponite vanish completely only at the beginning of the greenschist facies.¹

The upper stability limits of these minerals alone or in common reactions are reached at the lower boundary of the greenschist facies. This boundary is thus characterized, for instance, by the reaction of kaolinite and quartz, which is usually present in profusion in the kaolinitic clays, to give rise to pyrophyllite according to the reaction $\text{kaolinite} + \text{quartz} \rightarrow \text{pyrophyllite} + \text{H}_2\text{O}$. Important likewise is the formation of paragonite from $\text{kaolinite} + \text{albite}$ and from Na-montmorillonite. Hydrothermal runs of long duration carried out by ALTHAUS with the latter mineral yielded, apart from chlorite, albite and quartz, an ordered paragonite-montmorillonite mixed-layer structure at 2000 bars $\text{H}_2\text{O}$-pressure from 370°C on (not, however, at 355°C). This mixed-layer mineral is probably metastable and will presumably give rise to paragonite.

¹This does not, however, exclude the possibility that at still lower temperatures kaolinite may enter into reactions with other minerals, for instance, with calcite.