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Autor: Burchart, Jan

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The Crystalline Core of the Tatra Mountains: a Case of Polymetamorphism and Polytectonism

by JAN BURCHART

Polish Academy of Science, Geologic Centre, Warsaw

ABSTRACT

Rb-Sr determinations of the crystalline rocks from the Tatra Mountains, Poland, yield evidence of two periods of metamorphism, at about 420 and 300 m.y. ago. On the strength of petrological and structural evidence, the event dated at 300 m.y. is shown to have consisted of two separate stages operating under different PT conditions. The older stage gave rise to granitic rocks, incipient melting of their cover and its anatectic differentiation. It was followed by K-metasomatism resulting in granitization phenomena and in the development of post-tectonic muscovite porphyroblasts. The Upper Cretaceous orogeny was not accompanied by metamorphism or isotopic redistribution of Sr.

Thus the polymetamorphic and polytectonic development of the area cannot be unravelled by geochronological studies alone, but only with the aid of structural geology, petrology, and petrofabric analysis. Each of these methods separately can detect only some episodes but is unable to recognize the other ones.

A history of a metamorphic area can be reported in several different ways, each of them based on a different set of data and line of reasoning. Structural geology, petrology, petrofabric analysis, and isotope dating differ not only in the methods applied but also in the processes they are able to trace and the various ways of approach result in finding out several sets of events not always easy to correlate with each other.

The crystalline core of the Tatra Mountains is deeply eroded and partly covered with the autochtonous sedimentary strata of Late Permian to Middle Cretaceous age. This is overlain by several nappes consisting of Triassic to Cretaceous deposits. At the base of the lower nappes there occur some slices of granites and metamorphic rocks cut off from the top of the core and thrust over the folded autochtonous or parautochtonous sedimentary unmetamorphosed series. Thus this general geology (for more detailed data see SOKOLOWSKI, 1959) indicates that the whole petrological development of the crystalline rocks was concluded by the Late Permian. The orogeny responsible for the folding of the sedimentary rocks and for the thrusting of the crystalline outliers occured during Coniacian-Santonian (KOTANSKI, 1961).

Detailed examinations of the mesostructures and petrofabrics of the biggest of the crystalline outliers known as the "Goryczkowa island", have shown that the Alpine orogeny resulted in cataclastic deformations, mylonitization, numerous slickensides and faults which cut across the older structures. The direction of movement along the slickensides was exactly parallel to the movements recorded in the sedimentary rocks and therefore it seems to have been caused by the main stage of the Alpine folding. The orogeny was not accompanied by metamorphic recrystallization. As shown by petrofabric analysis even such a sensitive mineral as quartz has not always been reoriented according to the Alpine stress system. Nevertheless some cases have been met in which the quartz fabric records the Alpine-age movements while the biotite fabric, in the same thin section, has been left and represents an older pattern. It has been also found that the pre-Alpine deformations represented by foliation and lineation consisted of more than one phase of movements.

In its eastern part (the High Tatra) the crystalline core is built of fairly homogeneous quartz diorites, in some zones secondarily enriched in microcline and thus passing into granodiorites, and only exceptionally approaching the composition of true granites. Its metamorphic cover has been almost completely removed by the pre-Late Permian denudation. In the west (the Western Tatra) the crystalline core consists of various gneisses and amphibolites and small bodies of alaskitic granites. The crystalline island of Goryczkowa having been cut off from the top of the main granitoid body seems to represent the horizons elsewhere removed by erosion.

The lower part of the Goryczkowa crystalline series comprises biotite-rich foliated quartz diorites intercalated with concordant sheets of amphibolites, andesine gneisses, migmatites, and quartz-poor mica-sillimanite gneisses and schists. The metamorphic rocks form something like a framework filled with the quartz diorite ("ghost stratigraphy"). A reconstruction of the pre-Alpine structure reveals that oligoclase gneisses and quartzites occur mainly in higher horizons, while the top of the succession consists of alaskites, albite-microcline leucogneisses and microcline-enriched gneisses. In some schists occuring in the lowermost part of the series the biotite-sillimanite aggregates seem suggestive of a thermal break of mica. It seems particularly noteworthy that the composition of the alaskites closely corresponds to that of the matter which could be anatectically removed at the very beginning of melting according to the experimental data by LUTH, JAHNS and TUTTLE (1964). Therefore it seems reasonable to suppose that the contrasting compositional trends of the rocks of the area into alkali-poor andesine-biotite gneisses and amphibolites on one hand and to alkali-rich albite-microcline-muscovite rocks on the other are due to anatectic differentiation which followed an older stage of moderate temperature metamorphism.

The PT gradient in the column of the metamorphic rocks produced upward migrating fronts: a front of alkalis and silica closely followed by a front removing these constituents. The rocks, impoverished in alkalis and recrystallized at considerably high temperatures and pressures, estimated at 6 kb and at least 660 °C, became very sensitive to future potassium metasomatism, which did appear considerably later, after the deformations had ceased to operate. Potassium metasomatism acting under much lower temperatures resulted in crystallization of cross muscovites in gneisses and schists, and in granitization of quartz diorites (microcline feldspathization). The process affected also the quartz diorites of the High Tatra.

The Rb-Sr isotopic determinations (BURCHART, 1968) have yielded two main dates: 290–300 m.y. as the age of the main granitic body of the High Tatra, alaskites and quartz diorites of the Goryczkowa island, as well as the age of mineral metamorphism of the gneisses, and 410–430 m.y. as the date of some earlier isotopic homogenization found only by a whole-rock isochron for the Goryczkowa gneisses. Neither the post-tectonic muscovites nor the microcline porphyroblasts have yielded ages significantly younger than the minerals shown to be older by petrographic evidence. The Rb-Sr dating also failed to find any event corresponding to the Alpine disturbance. It should be added that K-Ar dating of some Alpine mylonites resulted in an apparent age of 165 m.y. (SEDLETSKII et al., 1966), which is obviously a value intermediate between the Carboniferous crystallization and Late Cretaceous mylonitization.

In their general structure and in the lithology of the Mesozoic the Tatra Mountains closely resemble the Alps. Sometimes they are even called "the Alps in miniature". The data reported above point out an important difference. The Alpine orogeny which resulted in similar structures in the Alps and in the Tatra brought about true metamorphism in the Alps, but it did not in the Tatra Mountains. Great orogeny without metamorphism – a phenomenon has been proved by the lack of metamorphic recrystallization in the folded and thrust sedimentary rocks, by purely cataclastic or mylonitic deformations unaccompanied by recrystallization in the granitic and metamorphic rocks, and also by the 300 m.y. ages found by the Rb-Sr study on the crystalline rocks of the area.

Numerous cases have been reported in which Sr isotopic ratios have been found extremely sensitive to geologic events, even to such events which have been indistiguishable by classic geologic or petrologic methods. The case of the Tatra Mountains serves as an example of just the opposite situation. Petrologic studies have revealed quite a long and complex history of Carboniferous metamorphism with two main separate stages, one involving high-temperature metamorphism and anatectic differentiation, and the other occurring under different PT conditions and resulting in post-tectonic K-metasomatism and granitization. The Rb-Sr studies have resulted in but one date for these stages, 300 m.y., which probably strictly corresponds to neither of them but to a cooling period. It is the last date traceable by the Sr isotopic studies though by no means the last in the geologic development of the Tatra Mountains. The earlier date, 420 m.y., indicated by the whole-rock isochron corresponds to some earlier events the petrological meaning of which is not easy to find.

The events detected by different methods are not always easy to correlate with each other. A major event according to petrologic record does not always leave its mark on isotopic dates. Even such a major event as an orogeny does not always bring about metamorphism or isotopic redistribution.

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