

RECRYSTALLIZATION OF LIMESTONES AT IGNEOUS CONTACTS*

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At the outset I would like to make it clear that I do not enter this discussion in a controversial spirit, but in an attempt to contribute something helpful to an understanding of a difficult problem. I have too high regard for the sterling quality of the work of the men who have studied this subject in detail to offer anything in the way of essential contradiction to their statements of fact. Difference of opinion arises from differing valuation of the possible alternative hypotheses which these facts suggest.

Some degree of recrystallization in limestone contact zones has been recognized by many investigators. Earlier investigators, for the most part, assigned an important, if not the most important, role to recrystallization in development of these zones. With the growing recognition of introduction of ores and gangue materials into the contact zone from igneous rocks through the medium of primary magmatic solutions, there has been a tendency to ascribe to this process most, if not all, of the chemical and mineralogical characteristics of the contact zone. This has involved a correspondingly diminished emphasis on recrystallization of substances already there as a factor in the process, and in some cases even the complete elimination of this hypothesis. From detailed study of a few contacts, casual observation of others, and a general familiarity with the literature, some of us have been led in recent years to raise the question whether the pendulum has not swung too far away from recrystallization toward direct introduction from igneous sources, and to argue for more recognition of the part played by recrystallization. The inevitable sequence has been that those of us who have taken this view have been charged, at least by inference, with emphasizing recrystallization to the total exclusion of the alternative process. Scientists, like other men, like to classify and pigeon-hole views under simple and definite designations, leaving out qualifications which would tend to make the classification more difficult to state. This has made the problem seem more definite and simple, but has tended to obscure the fact that the disagreement is primarily not one relating to essential facts, but one of emphasis. The relative importance of processes seems to vary greatly in different districts. Until many other contacts have been carefully studied, agreement as to the relative importance of processes in general is perhaps not to be expected.

Evidences for recrystallization, briefly summarized and without qualification, are as follows:

1. So far as there is recrystallization it relates mainly to part of the silicate minerals and the residual carbonates of the contact zone. By no stretch can it explain the metallic minerals. The development of silicates from the lime or magnesia carbonates involves the elimination of all the carbon dioxide and some of the lime and magnesia, with recrystallization into silicates of part of the lime and magnesia together with other impurities which may be present, such as silica, iron, kaolin, and other substances. In certain districts the composition of part of the silicate zone (usually the outer part) corresponds approximately to the composition of the original carbonate rock, minus carbon dioxide and a part of the lime and magnesia. No analyzed

samples have shown exact correspondence. It would be difficult to find exact correspondence because of later replacements, because of original variation of beds, and because of difficulty of confining sampling only to the recrystallized zone; but in some cases there is a remarkable tendency toward the constancy of silica-alumina ratios in comparison of original limestones and the supposedly recrystallized phases. The ratio is not absolutely maintained, but the variation in the silica-alumination is slight as compared to the variations which are found in the parts of the contact zone in which materials have been clearly introduced. It would be remarkable if substances brought in at random from magmatic sources should approximate so closely the composition of residual impurities of limestone. A most striking case of this, which has been worked out quantitatively on a large scale, is the contact metamorphism of cherty iron carbonates by great masses of gabbro in the Lake Superior country. Here the iron-silica ratio of the altered phase corresponds almost exactly with that of the original carbonate rock, the change being merely an elimination of carbon dioxide. Analyses have been taken from many thousands of samples brought up in drill cores and in continuous sections across the formation.

2. Secondary silicates of contact zones have often been found to be localized along cherty beds or around fragments of chert in the carbonate. Again the Lake Superior region furnishes an illustration in that cores brought from a depth of many hundred feet, where there has been no chance of surface alteration, and at some distance from the intrusive, show the development of secondary iron silicates, principally grunerite, along contact of carbonate and siliceous layers, in a rock which is so dense there is little or no possibility for the introduction of these substances from without. The ratio of silica to iron has been almost exactly maintained. And yet these are clearly developed under influence of intrusives.

3. The similarity of secondary silicates in limestones and marbles far removed from igneous contacts to some of those developed at contacts is also suggestive evidence of recrystallization along contacts.

4. Elimination of carbon dioxide and lime is postulated under either hypothesis, "replacement" or "recrystallization." The natural consequence of elimination is recrystallization of the residual materials, whether or not these are supplemented by accessions from magmatic sources. There is no good *a priori* reason why accessions should always exactly balance elimination, especially when the physical conditions of intrusion are considered—and there is no satisfactory quantitative proof that they have. Under physical conditions which have been supposed to attend the earlier stages of intrusion of a magma it is easy to conceive of pore spaces caused by elimination to be closed as fast as formed, thereby reducing volume, and, in fact, it is usual to conceive of the pressure actually being a factor in the elimination. Under the replacement hypothesis we find it necessary to assume that whatever the pressure conditions were, whether those tending to close up openings or not, the materials taken out and those introduced were delicately balanced in

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