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CONTACT METAMORPHISM AND FLUID FLOW IN THE EASTERN MONZONI THERMAL AUREOLE

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Introduction

The Monzoni intrusive complex in the western central Dolomites intruded previously unmetamorphosed Permo-Triassic sediments during Mid Triassic time. The country rocks comprise a stratigraphic sequence of Upper Permian to Mid Triassic limestones alternating with dolomitic, marly, and siliciclastic members. We use petrologic and stable isotope evidence from four distinct lithologies of the country rock sequence to identify the factors that controlled fluid evolution during contact metamorphism. The selected lithologies are a siliciclastic interval of the Campil Member of the Werfen Formation with subordinate marly layers, a pure dolomite oolite and a marl-limestone interbedded sequence of the Cencenighe Member in the uppermost Werfen Formation and the nodular limestone-chert sequence of the Mid Triassic Buchenstein Formation.

Contact metamorphism

In the dolomite oolite contact metamorphism lead to the formation of tremolite in the outer contact aureole. Forsterite formation at a distance of 300 m from the intrusive contact occurred by the reaction: 1 tremolite + 11 dolomite ⇒ 8 forsterite + 13 calcite + 1 H_2O + 1 CO_2. Calcite - dolomite thermometry (INDERST, 1987) yields 450°C and thus indicates $X_{CO2} > 0.1$ for these rocks. At about 250 m fom the contact dolomite disappears supposedly due to its prograde breakdown to calcite + periclase or calcite + brucite.

In the marly layers of the Cencenighe and Campil Members and in the Buchenstein Beds the first low-temperature metamorphic minerals are clinozoisite and tremolite at 850 m from the intrusive contact. The first appearance of garnet by the reaction - 2 clinozoisite + 5 calcite + 3 quartz ⇒ 3 garnet + 1 H_2O + 5 CO_2 - is very well defined at 650 m from the contact. This limits the fluid composition to $X_{CO2} < 0.04$ at temperatures ≤ 400°C. The typical high temperature paragenesis in the marly layers consists of garnet - diopside - wollastonite - calcite. In pure limestone layers the only effect of contact metamorphism is a significant grain coarsening. In limestone layers with silicate phase impurities grain coarsening is hampered and calcite remains fine grained up to the intrusive contact.

Stable isotope systematics

The oxygen isotope compositions of the carbonates within the contact aureole are generally shifted towards lower values with respect to the unmetamorphosed equivalents. The extent of the oxygen isotope shifts is largely controlled by lithology. Pure carbonates, both calcitic and dolomitic, show only a moderate ^{18}O depletion from $\delta^{18}O$ (SMOW) = 26 ‰ in the unmetamorphosed to about 22 ‰ in the contact metamorphic samples. Impure carbonates and marly layers of the Werfen Formation show significant oxygen isotope depletion from $\delta^{18}O$ = 25 ‰ down to as low as 14 ‰. The concomitant $\delta^{13}C$ shift is from $\delta^{13}C$ (PDB) =+3 ‰ in the unmetamorpheosed samples to about -2 ‰ in the contact metamorphosed equivalents. The extent of $\delta^{13}C$ shifts correlates with metamorphic temperature and with the extent of decarbonation reactions, indicating isotopic fractionation by Rayleigh distillation. Lithologic control on ^{13}C depletion through decarbonation is observed on a cm-scale in layered limestone-marl samples.

In the Buchenstein Beds $\delta^{13}C$ shifts are insignificant, whereas $\delta^{18}O$ (SMOW) is shifted over more than 15 ‰ from values of about 27 ‰ in the unmetamorphosed reference samples down to less than 12 ‰ within the contact aureole. This is in line with the observation of the small extent of decarbonation reaction in the Buchenstein Beds.

Discussion

Both the petrologic and the stable isotope systematics indicate that pure carbonaceous lithologies did not interact with significant amounts of external fluid. In the case of non reactive rock types such as pure calcite marbles this may be interpreted as evidence for the maintainance of low porosities and low permeabilities during contact metamorphism. Low fluid to rock ratios are, however, also characterstitic for reactive rocks such as the dolomite oolite from the Cencenighe Member which would be prone to the production of reaction enhanced permeability (ABART, 1998). In this case the massive internal fluid production in the course of the decarbonation associated with the prograde breakdown of dolomite repelled external fluid even if permeability was available.

In contrast, lithologies with abundant silicate phase impurities were permeable to external, isotopically light fluid and fluid composition was externally controlled. In this case internal volatile production appears to have been insuffiicient to prevent the intruduction of external fluid. The role of the silicate phase impurities in the carbonate matrix was to supress grain boundary migration and grain coarsening which appears to have maintained relatively high permeability during contact metamorphism. The aureole scale permaebility structure during metamorphism was rather hetereogeneous and it appears to have been largely lithologically controlled.

References

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