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Geodynamic interpretation of stable isotope data of the Swiss Central Alps

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Stable isotope data

A detailed discussion of stable isotope data from minerals of rocks from the Swiss Central Alps has been presented elsewhere (HOERNES & FRIEDRICHSEN 1980). It is the main goal of this paper to summarize the results in the light of the geodynamic polyphase evolution of this part of the Alps.

Oxygen- and hydrogen isotopic composition of minerals in Premesozoic rocks show only limited variation indicating extensive homogenization with a fluid phase of magmatic composition. Metapelites within the Premesozoic series, as a result of this homogenization, are now isotopically identical to metaigneous rocks (granites) of the same series. Sediments which have been metamorphosed only during the Alpine events (i.e. rocks of Carboniferous to Jurassic age), on the other hand, show a large variation of their $^{18}O/^{16}O$-ratios and D/H ratios. With the exception of the Carboniferous rocks all $\delta^{18}O$ values of the minerals are heavier (= enriched in ^{18}O) and the δD values of waterbearing phases are lighter (= depleted in D) in comparison to the Premesozoic rocks. The oxygen isotopic composition of the whole rocks do not show extensive homogenization. We have to conclude that during Alpine metamorphism fluids were transported only on a small scale (cm to dm).

In general oxygen isotope equilibria between different minerals from Mesozoic rocks are attained in low grade to medium grade areas. Mesozoic rocks from high grade areas are characterized by O-isotope disequilibria. In Premesozoic series, on the other hand, oxygen isotope equilibria are more frequently verified, but the equilibrium temperatures, which can be calculated from the mineral fractionations in many cases are 100-150 °C below the maximum termperatures of Alpine metamorphism. It has been concluded that the fractionations reflect the temperatures at the time of recrystallization which is thought to be ± contemporaneous with the deformation of these rocks during Alpine orogeny. Only a limited number of samples yielded temperatures which are concordant with petrologic estimations of the maximum temperatures during Alpine metamorphism.

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Geodynamic interpretation

Large parts of the Penninic nappes existed already as high grade rocks before the Alpine orogeny. This has been stressed in numerous petrologic and geochronologic papers. But the minerals coexisting today are thought to be products of Alpine metamorphism, because of the discordant course of mineral zone boundaries and isograds. (For a compilation of the literature see FREY et al. 1974; HOERNES & FRIEDRICHSEN 1980.)

The large differences in the isotopic composition between Premesozoic and Mesozoic rocks show that no interaction of the fluid phase happened between the two series during Alpine Metamorphism. The large scale homogenization in the Premesozoic rocks therefore must be connected with a Prealpine event (Herzynian or older). This seems to be a general feature in the Alps because the same relationship has been found in the Tauern area of the Eastern Alps (HOERNES & FRIEDRICHSEN 1974) and in the Ötztal-Stubai Alps (HOERNES & FRIEDRICHSEN 1978). The conservation of the Prealpine D/H and $^{18}O/^{16}O$ ratios in Premesozoic rocks indicate a very limited supply of fluids to the gneiss-cores of the Penninic nappes during Alpine metamorphism.

However, concordant fractionations in Premesozoic and Mesozoic rocks of the northern part indicate small scale Alpine reequilibration during the recrystallization of the Prealpine minerals. The recrystallization has been related to the deformation of the rocks. The penetrative deformation during Alpine orogeny is believed to be the only mechanism which favours the contemporaneous recrystallization of already existing mineral phases. This again is necessary to attain oxygen isotope equilibria between all phases of the rocks (HOERNES & FRIEDRICHSEN 1978). According to TRÜMPY (1960) the last penetrative deformation which represents the main phases of Alpine rock deformation took place in early to mid-Oligocene times. As WENK (1943) pointed out, this event represents the beginning of the "Lepontine-phase" of Alpine metamorphism. A detailed cooling model based on various radiogenic methods has been worked out for this area (WAGNER et al. 1977). These data permit the reconstruction of the temperature-time relationship after the peak of Alpine metamorphism.

The stable isotope data give information on *earlier* stages of the Alpine history. The Premesozoic rocks of the Penninic nappes recrystallized at temperatures of about 500 °C at the beginning of the "Lepontine-phase" of Alpine metamorphism. During prograde metamorphism to the maximum temperatures of the Alpine event the oxygen isotope ratios of most mineral phases did not reequilibrate. Cation exchange equilibria however rather display the maximum temperature event (a.o. WENK 1970; THOMPSON 1976).

Taking into account the results of stable isotope investigations of DESMONS & O'NEIL (1978) from the Western Alps and the results of age determinations in the same area of HUNZIKER (1974) we may extend the model of the temperature/time evolution even to the "Eoalpine phase" of Alpine metamorphism. A large step back in time to the Herzynian (?) event shows that a homogenization of major parts of the continental crust took place at very high temperatures due to interaction with fluid phases of magmatic composition.

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