

## A COMPARATIVE ANALYSIS OF TALC DEPOSITS IN THE RUBY RANGE, MONTANA

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Most geologists agree that continental growth occurred during the Archean, but much debate remains about the nature of the tectonic systems that facilitated the thickening of this crustal material (Windley, 1984). Many small remnants of Archean rocks, Archean terrains, occur scattered throughout the globe, primarily in the heart of mobile belts. These terrains contain clues about the Earth's early evolution and continental growth. The Archean basement of southwestern Montana, part of the northernmost Wyoming Province, is exposed in foreland block uplifts and contains a variety of metamorphic and structural styles that reflects the early continental growth of North America (Mogk and Henry, 1988). Late Archean basement rocks to the west of the Beartooth Mountains, including those rocks in the Ruby Range, southwest of Dillon, Montana, are dominated by high-grade quartzofeldspathic gneisses and supracrustal metasedimentary sequences, mainly schists, quartzites, and marbles (Mogk and Henry, 1988). A working model by Mogk and Henry (1988) calls for deposition of coarse clastic and platform-type sediments in a rift-bounded basin, followed by collapse of the basin, deep burial of sediments by means of tectonic thickening, isoclinal folding and nappe emplacement. In the Ruby Range this resulted in amphibolite- to granulite-grade metamorphism, with peak metamorphic conditions at 700°-750° C and 6-8 kbars (Dahl, 1979) at approximately 2.7 Ga (James and Hedge, 1980).

Talc deposits in the Ruby Range occur within dolomitic marble units of the Archean terrain. These talc deposits yield a high grade of relatively pure talc that is of economic interest. Ore reserves are estimated to be on the order of 10<sup>6</sup> tons (Anderson et al., 1990). Talcification of dolomitic marbles requires the metasomatic introduction of SiO<sub>2</sub>, Mg<sup>+2</sup>, and H<sub>2</sub>O, and the removal of large amounts of Ca<sup>+2</sup> and CO<sub>2</sub>. A Proterozoic retrograde regional thermal event overprinted granulite to amphibolite grade mineral assemblages with greenschist-grade assemblages. Previous workers (Olson, 1976; Berg, 1979; and Karasevich et al., 1981) have suggested that the talc formed by fluid movement along northwest trending faults active during this event. Based on Rb-Sr whole-rock analysis and K-Ar analysis of biotite this event has been dated at 1.6 Ga (Giletti, 1966). It has also been suggested that the emplacement of diabase dikes about 1.455 Ga, may have been accompanied by another metamorphic cycle of low intensity and that these dikes could have served as the source of heat and/or fluids for talc formation (James, 1990; and Anderson et al., 1990). The ultimate goal of this project is to determine the origin and subsequent evolution of the talc deposits that occur in the Ruby Range and other Precambrian terrains of southwestern Montana.

The purpose of my study is to characterize, on a regional scale, the petrographic and petrochemical nature of the Ruby Range talc deposits. Hence, seven known deposits were selected for study on the basis of geographic distribution, size, extent of outcrop, and accessibility. Of the seven localities, the Regal-Keystone Mine, is being studied in detail by Amy Larson and her work will serve as a basis for my regional comparisons.

In the summer of 1990, three weeks were spent collecting approximately 250 samples from the seven talc prospects (see Fig. 1 of Cheney and Brady, in this volume). An average of five samples from each deposit, 36 in all, were selected for thin-section study. These samples range, at each locality, from pure marble through talc plus carbonate rocks, to relatively pure talc rocks. Initial petrographic results are generally consistent with those of Anderson et al. (1990). Of particular significance is that the talc texturally postdates the carbonate, and the dominant mineral assemblage of talc bearing marbles is talc-dolomite-chlorite ± calcite with accessory graphite and pyrite.

As defined by Hoefs (1987), stable oxygen and carbon isotopic studies can constrain the nature of fluids and help determine peak metamorphic conditions. Isotopes may be used as a "tracers" in a rock's history; generally, certain types of rocks have a specific isotopic "signature". Because the dolomite should have a specific isotopic signature, any deviation from that signature will reflect the chemical influence of the talc forming fluids. Comparing isotopic data from deposit to deposit may provide conclusions about the overall nature of the infiltrating fluid and its effects on the country rock.

Three to four samples from each deposit, twenty-three in all, were selected for carbon and oxygen isotope analyses. These samples represent several textural types that include: 1) medium-grained "pure"

Since the passage of fluid through a rock unit can change the isotopic characteristic of the rock toward those of the fluid, oxygen and carbon stable isotope results reflect the state of equilibrium between the rock and the fluid (Hoefs, 1987). Thus, the wide range of  $\delta^{18}\text{O}$  values of marbles in this study indicate the pervasiveness of the fluid that passed through the Regal-Keystone Mine area. Rocks with higher  $\delta^{18}\text{O}$  values will have had less interaction with the fluid than those with lower  $\delta^{18}\text{O}$  values.  $\delta^{18}\text{O}$  values of 20‰ or greater are normal for metamorphosed carbonates unaffected by a fluid.

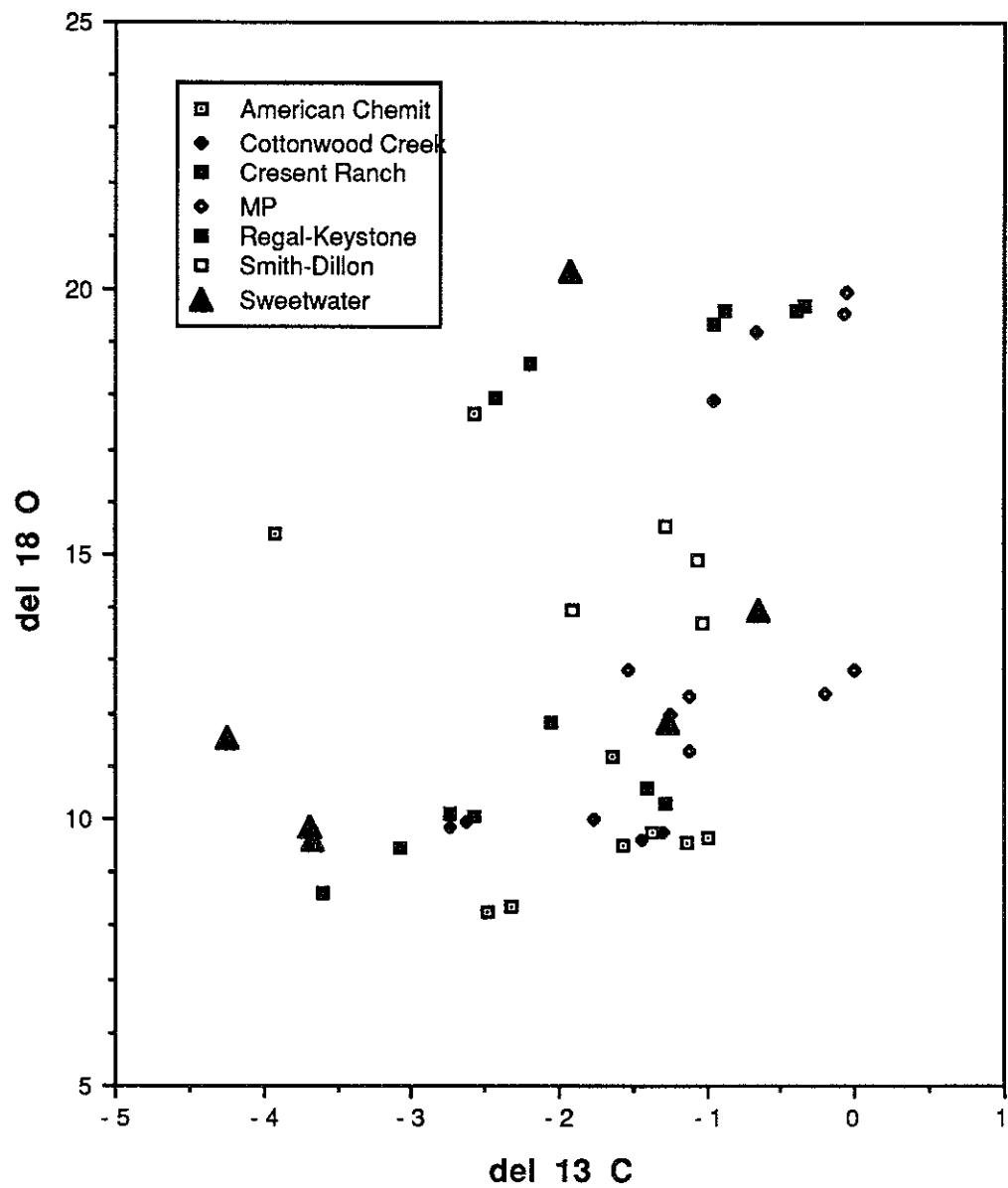
The marble samples in the lower pit of the mine and in the trenches showed  $\delta^{18}\text{O}$  below 20‰, indicating a high degree of interaction with a fluid. Marble samples in the north wall of the upper pit and many located in the nose have higher  $\delta^{18}\text{O}$  values, many near and above 20‰, suggesting low to no interaction with a fluid. Although small talc pods are present in the marble of the upper pit, its massiveness may have prevented pervasive fluid flow through the unit. The marbles in the trenches and lower pit, however, are thinly bedded, and the marble samples from the lower pit are units completely surrounded by the massive talc unit. Thus, the structure of the marble in these localities is more conducive to pervasive fluid flow, explaining its lower  $\delta^{18}\text{O}$  values. Hoefs (1987) explains that fluid flow can be channelized, due to rock structure and degree of permeability which would result in a heterogenetic isotope signature within the rock. Low  $\delta^{18}\text{O}$  values in the American Chemit Mine are also expected since fluid must have flowed through the mine area in order to form the talc deposit. The regional marbles were collected away from known talc deposits in order to have samples not associated with the talc formation. Thus, high  $\delta^{18}\text{O}$  results were expected. Only one regional sample, however, showed a high  $\delta^{18}\text{O}$  value (22.6‰) while the others showed  $\delta^{18}\text{O}$  results below 20‰. These low results may indicate that fluid flow, although channelized, is regional.

Insignificant change in carbon isotope values suggest that carbon, unlike oxygen, is not a large constituent of the fluid involved with talc metasomatism. Thus, variations of  $\delta^{13}\text{C}$  values may reflect differences in the organic content originally in the rock prior to metamorphism. Further analysis of carbon stable isotope values in graphite in regional and American Chemit marbles will be compared with the carbon stable isotope values of the carbonate in these same rocks in order to interpret the geothermometry of the retrograde event.

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Figure 1. Comparison of stable isotopic ratios from seven talc deposits.



dolomitic marbles 2) course-grained calcite crystals in contact with talc or contained in a talc matrix 3) calcitic marbles with an abundance of silicate minerals and 4) fine-grained carbonate with significant amounts of fine grained talc. As shown by Figure 1, the initial results reflect  $\delta^{18}\text{O}$  values for these carbonates that are significantly lower than expected for Precambrian marine carbonates. The  $\delta^{18}\text{O}$  value of marine carbonates of recent age vary from +28 to +30 ppt (parts per thousand) relative to SMOW (Faure, 1986). However, there is evidence that the  $\delta^{18}\text{O}$  decreases in rocks of increasing geologic age, to a level of about 20 ppt 3.4 Ga ago (Faure, 1986). Only six samples yielded a  $\delta^{18}\text{O}$  of 17.5 or higher. The remaining carbonates have a  $\delta^{18}\text{O}$  value that average 11.0 ppt. These  $\delta^{18}\text{O}$  values reflect a trend where most of the carbonate rocks have a lower  $\delta^{18}\text{O}$  than one might predict for Archean marbles; this is consistent with the reequilibration of oxygen isotopes in the carbonate minerals due to contact with a talc forming fluid. The fluid must have had a "lighter" isotopic signature than the carbonates, a lower  $\delta^{18}\text{O}$  value which reset the oxygen isotopic value of the carbonate rocks. This is consistent with the suggestion by Anderson et al. (1990) that the fluid was most probably sea water.

The  $\delta^{13}\text{C}$  values of these carbonates are more constrained; they have a much smaller variance than the oxygen data. There appears to be no correlation between the anomalously high  $\delta^{18}\text{O}$  values and their associated  $\delta^{13}\text{C}$  values. Marbles tend to have a  $\delta^{13}\text{C}$  value of -5 to +5 ppt (Duke et al., 1990). The  $\delta^{13}\text{C}$  data collected from the samples falls within that range, having an average  $\delta^{13}\text{C}$  of -1.7 ppt. Unlike the oxygen isotopic data, the  $\delta^{13}\text{C}$  of the samples suggests that carbon isotopes were not significantly affected by the fluids.

Finally, the similar isotopic signature seen from deposit to deposit appears to reflect the infiltration of a relatively homogenous fluid, such as sea water, as suggested by Anderson et al. (1990).

Anderson et al. (1990) suggest that the talc formed at relatively shallow crustal conditions of 2 kbars (~6km) and 400°C. They also suggest that a water/rock ratio > 600 was needed to convert high-grade marble to talc in a constant volume process and that fluids were sufficiently dilute so that  $\text{X}_{\text{CO}_2}$  was very nearly zero. Additional analysis of the isotopic data should help to test these hypotheses by providing some constraints on both the fluid composition and provide a rock/fluid ratio.

Work continues with more detailed petrography via the Scanning Electron Microscope (SEM) to further characterize textures and compositions that might yield clues as to the nature of the talcification process and fluid composition. An additional twenty thin-sections are being made for petrographic study from those samples used for oxygen and carbon isotope work and approximately eighteen more samples will be analyzed for stable isotopes in order to continue the preliminary results interpreted here.

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