NONTRONITE AT BINGHAM, UTAH

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Abstract

Nontronite has been found in abundance on the upper southwest levels of the Kennecott Copper Mine at Bingham, Utah. The rocks in this area were originally arkosic quartzites with dolomitic and/or argillaceous impurities. Contact action in these rocks has developed interstitial diopside, tremolite and pyrophyllite. Nontronite is present in localized areas as a weathering product of these minerals, where pyrite was present to supply sufficient iron for its development. Chemical analysis shows the mineral to have the formula:

$$(Al_{.77}Fe_{1.02}Mg_{.31})\ (Al_{.33}Si_{3.67})O_{10}(OH)_{2\times .36}.$$

Field evidences point to the conclusion that this nontronite formed in slightly acid solutions.

Introduction

During the progress of mapping the geology and hydrothermal alteration areas in the Bingham Copper Mine, nontronite was discovered in abundance in arkosic quartzite areas. The geological conditions at Bingham, Utah, are fairly well known through the writings of Boutwell (1905), Keith (1905), Butler (1920), Beeson (1917) and others. In brief, however, the geology may be stated as follows: a series of folded Pennsylvanian quartzites interbedded with several limestone lenses have been intruded by a comparatively small complex igneous mass called the Bingham stock. Contact action and hydrothermal alteration has materially changed the original character of all types of rock in the immediate area of the mine.

Occurrence of the Nontronite

The greenish nontronite is found in the altered quartzites generally at some distance from the intrusion, in areas where excavation in mining operations has not proceeded to great depth. These areas include the highest 10 levels in the south-west section of the mine, where the best specimens are obtained, and the upper 7 or 8 levels on the east side of Bingham Canyon. The nontronite seems to be present in two ways: (1) in patches associated with limonite chiefly in the vicinity of the uppermost levels, and (2) along cracks and joints, not particularly associated with limonite, in a somewhat larger area lower down in the quartzite, where it appears to have been transported as a dispersed phase in ground waters.

The original clastic sediments of the Bingham area were arkosic sandstones with orthoclase as the principal feldspar. Dolomitic and clay material apparently were the chief impurities. Since deposition the quartz and feldspar sand grains have been completely recrystallized, and contact action accompanying the intrusion has changed the interstitial material to tremolite (see Fig. 1*A*), pyrophyllite (see Fig. 1*B*) and diopside all of which are generally present in an interstitial position and are rarely observed to occur together. Thin sections of the nontronite-bearing rocks show that fine aggregates of nontronite are present along the edges and sometimes completely within these interstitial "contact" minerals (see Fig. 1*A* and 1*B*). Figure 1*C* shows a comparatively pure arkose

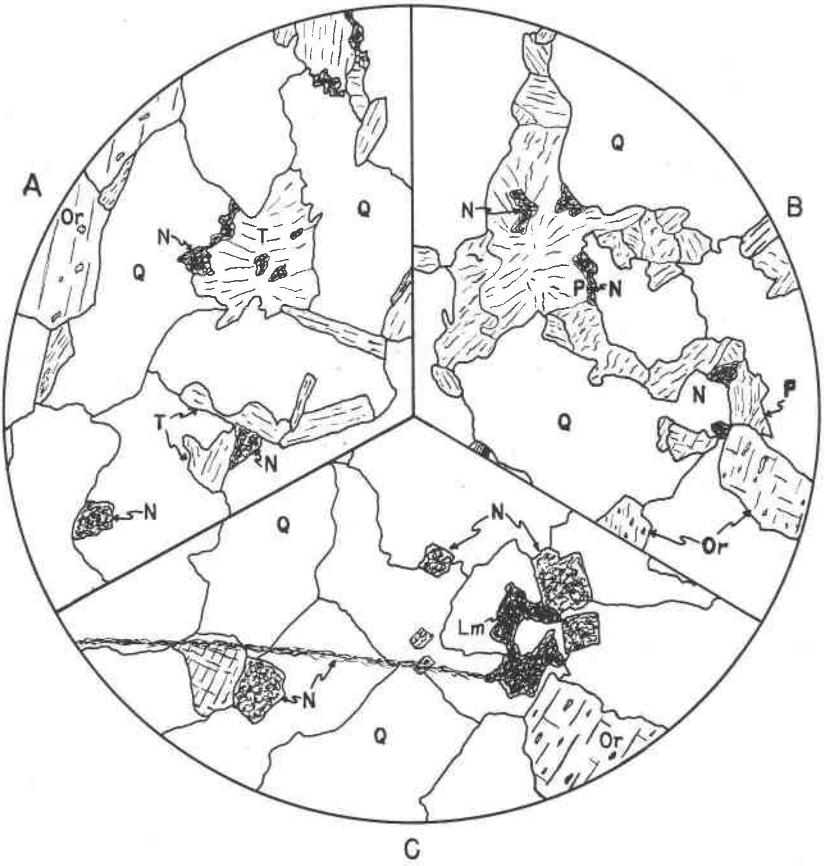

FIG. 1. Arkose, Bingham, Utah (×72). showing recrystallized quartz (Q) and ortho clase (Or) with nontronite (N) altering from interstitial tremolite (T) in *A*, and interstitial pyrophyllite (P) in *B*. In *C* nontronite is present in square patches presumably pseudomorphous after pyrite; while transported nontronite is seen in a veinlet cutting quartz and orthoclase and terminating against a bleb of limonite (Lm).

which contains nontronite in square or oblong patches and also in a veinlet which traverses quartz and orthoclase grains alike. The square patches are believed to represent former pyrite crystals thus furnishing evidence that nontronite may be pseudomorphous after pyrite. The veinlet is an example of the type of nontronite which has been transported.

In all instances where patches of nontronite are found, a limonite vein or veins are present in the immediate vicinity. Figure 2 shows an actual condition which is representative of this relationship. Here a 2 to 3 inch limonite vein containing a few remnant pyrite crystals, traverses white quartzite where tremolite is the interstitial mineral. The white quartzite is colored greenish by nontronite for a distance of 4 to 5 inches on either side of the limonite vein. Thin sections of the greenish rock show the condition described above (Fig. 1*A*), that nontronite is altering from the tremolite.

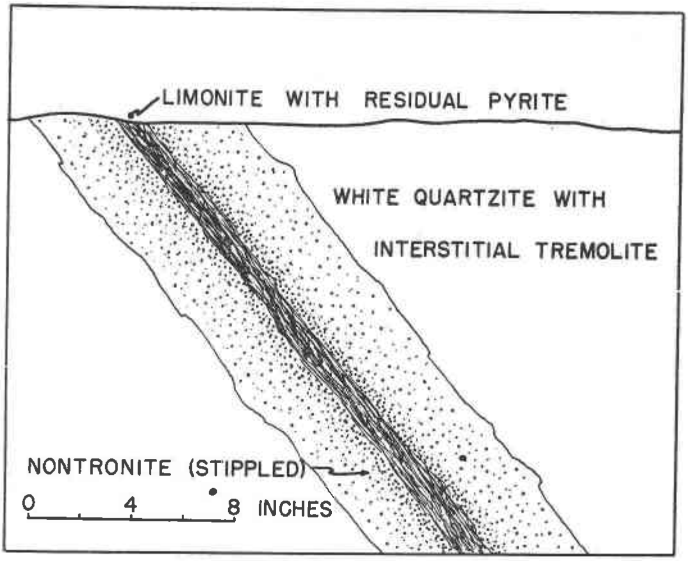

FIG. 2. Shows a section of a limonite vein in quartzite with nontronite equally developed on both sides.

MINERALOGY

Allen and Scheid (1946), and Ross and Hendricks (1945), have covered the literature on nontronite rather thoroughly and information relating to previous work need not be repeated here except simply to state that nontronite is now considered to be the high iron member of the montmorillonite-beidellite mineral group.

Chemical Analysis.—Special care was necessary in selecting specimens of nontronite for analysis. Some material was obtained from a particularly rich area near the top southwest part of the mine which contained only a very little quartz and orthoclase as an impurity. This material was quite wet when first collected but dried immediately when it was exposed to the air at room temperature. This dried sample was ground to 200 mesh and then centrifuged to obtain as pure a sample as possible. The chemical analyses given in Table 1 were made by Mr. Harold R. Bradford at the University of Utah. With these figures a formula was calculated, according to the Ross and Hendricks method as $(Al_{.77}Fe_{1.02}Mg_{.31})$ $(Al_{.33}Si_{3.67})$ O_{10} $(OH)_2$ $(NaK(Ca/2))_{.36}$. This formula proves to be similar to the type nontronite of Ross and Hendricks in that $Al_{.33}$ substitutes in the tetrahedral coordination, but differs in that Fe^{+++} is lower. It is probable that some K was present in the analyzed sample as orthoclase, and thus perhaps should not be used in calculating the base exchange factor. Omitting K the value of the base exchange factor, (Na(Ca/2)), is .35.

TABLE 1. CHEMICAL ANALYSIS AND FORMULA OF NONTRONITE FROM BINGHAM, UTAH

H. E. Bradford, *Analyst*

SiO_2	48.56
Al_2O_3	12.46
Fe_2O_3	17.91
MgO	2.77
CaO	2.15
K_2O	.15
Na_2O	.06
H_2O (−)	8.83
H_2O (+)	5.66
	98.55

Formula calculated according to the method of Ross and Hendricks.

$(Al_{.77}Fe_{1.02}Mg_{.31})(Al_{.33}Si_{3.67})O_{10}(OH)_2\times_{.36}$

X-Ray—A powder *x*-ray pattern was taken of the Bingham material and compared with a check pattern made from authentic nontronite from Colfax, Washington, and the two patterns were found to be practically identical.

Optics—The index of refraction of the Bingham nontronite was found to be $\alpha=1.560$ and $\gamma=1.593$ with $\gamma-\alpha=0.033$. These measurements were not made on especially prepared samples and hence do not correspond to

Ross and Hendricks (1945, p. 55) measurements on nontronite of similar composition from Spokane, Washington.

Differential thermal analysis—Curves were obtained on Bingham nontronite using conventional apparatus. A check was made with Colfax, Washington nontronite, considered to be authentic, to make sure that our apparatus was giving standard results and this curve compared favorably with those published by Kerr, Hamilton, and Kulp (1949).

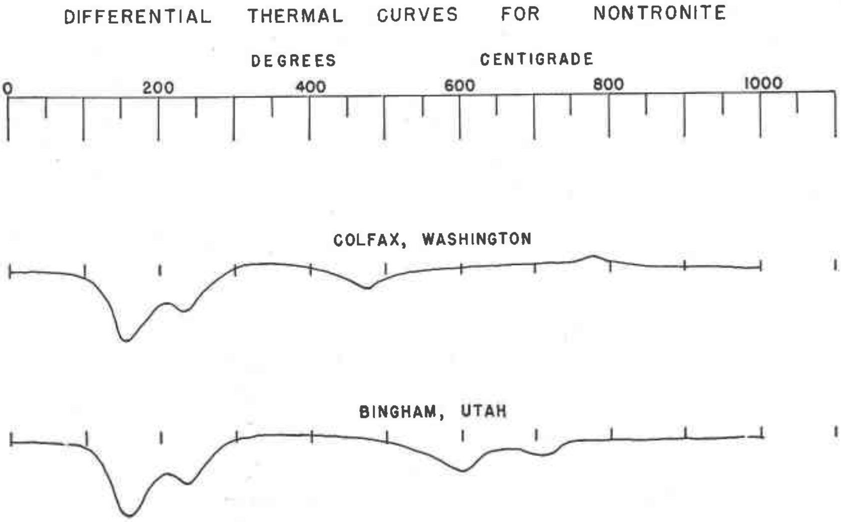

FIG. 3. Thermal curves of nontronite.

Several samples were run on the Bingham material and in each case the results were the same. The curves from the two different localities are compared in Fig. 3. The first endothermic peak at 160° to 170° C. shows the initial expulsion of interlayer water and the second endothermic peak at 230° to 240° C. is the result of the breakdown of the hydrated, interlayer calcium hydroxide molecules. For the Bingham material the next endothermic peak at 600° C. represents the breakdown of the hydroxyl groups in the lattice. This peak takes place at a higher temperature than the Colfax material due to the fact that it contains less iron and more aluminum. The hydroxyl ions are presumed to be bonded more strongly to the aluminum ions and it therefore requires a higher temperature to effect this break. Following at 700° to 720° C. is a small but broad endothermic peak the cause of which is not known. The endothermic peak at 720° C. on the Bingham material appears to mask the expected exothermic peak at 780° C. seen on the Colfax material where it is thought that the rearrangement of the nontronite lattice to form a new lattice of spinel type occurs (Grim and Bradley, 1940). The 720° C. peak is broad and flat with greatest slope on the high temperature side which indicates that perhaps exothermic effects are becoming predominant over endothermic effects as the temperature increases.

ORIGIN OF THE NONTRONITE

In considering the origin of the nontronite at Bingham it is found that events apparently began with formation of ferrous and sulfate ions from pyrite by percolating ground waters containing dissolved oxygen. The solutions were then acid and they began to migrate and mingle with fresh accessions of ground water as well as the constituents of the country rock. During this mingling the pH of the solutions increased by dilution, some ferrous iron was oxidized to ferric iron by additional oxygen, and the solubility product of ferric hydroxide was continuously approached but not exceeded. At this time nontronite was formed by reaction of these solutions with tremolite, pyrophyllite, diopside, and orthoclase (Fig. 1*A* and 1*B*). Complete pseudomorphous replacement of pyrite by nontronite also apparently took place at this time as is shown in Fig. 1*C*.

Subsequently, with increasing pH of the solutions by dilution, the solubility product of ferric hyroxide was exceeded and ferric hydroxide gel was precipitated and subsequently converted to limonite. This sequence of events is thought to be correct since limonite is observed to cut both transported nontronite and nontronite in situ in field and microscopic examples. See Figs. 1*C* and 2.

Since nontronite is found forming from minerals which were developed by hydrothermal alteration, and further, since nontronite is associated with zones and veins of limonite resulting from the destruction of pyrite by weathering processes, it is concluded that nontronite is exclusively a product of weathering at Bingham, and further this nontronite was formed in a slightly acid environment.

This view is different from the one proposed by Allen and Scheid (1946) for the formation of the nontronites of the Columbia River region. They concluded that those nontronites were formed in alkaline solutions in areas of poor drainage.

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REFERENCES

1. ALLEN, V. T., AND SCHEID, V. E. (1946), Nontronite in the Columbia River region: *Am. Mineral.*, **31,** 294–312.
2. BEESON, J. J. (1947), The disseminated copper ores at Bingham, Utah: *AIME trans.*, **54,** 356–401.
3. BOUTWELL, J. M., AND KEITH, ARTHUR (1905), Economic geology of the Bingham mining district, Utah: *USGS, Prof. paper* **38.**
4. BUTLER, B. S. (1920), Ore deposits of Utah: *USGS, Prof. paper* **111.**
5. GRIM, R. E., AND BRADLEY, W. F. (1940), Investigation of the effect of heat on the clay minerals illite and montmorillonite: *Jour. Am. Ceramics Soc.*, **23,** 247.
6. KERR, P. F., KULP, J. LAWRENCE, AND HAMILTON, P. K., Differential thermal analysis of reference clay mineral specimens. *American Petroleum Institute Project* **1949.** Preliminary report No. 3. May, 1949.
7. ROSS, C. S., AND HENDRICKS, S. B. (1945). Minerals of the montmorillonite group: *USGS, Prof. paper* **205-B.**