THE AMERICAN MINERALOGIST, VOL. 43, JANUARY–FEBRUARY 1958

A CHLORINE-RICH BIOTITE FROM LEMHI COUNTY, IDAHO

DONALD E. LEE, *Stanford University, California.*

ABSTRACT

A metamorphic biotite from Lemhi County, Idaho, has a chlorine content of 1.11 per cent and a fluorine content of 0.23 per cent. The biotite occurs in schist, associated with garnet, muscovite and quartz, smaller amounts of tourmaline and zircon, and a few rare grains of sphene. A complete analysis is given for the biotite, the mineralogy of the schist is described, and the features of its field occurrence are outlined.

GEOLOGIC OCCURRENCE

A reconnaissance survey of the area was made in August, 1955. Biotite-garnet schist crops out for a distance of several hundred feet at about 45°07′ N, 114°18′ W, in Lemhi County, about 23 miles west of Salmon City, Idaho. The exposure is on a steep face along the north side of Big Deer Creek, about two miles east of its junction with Indian Creek.

The biotite-garnet schist occurs as irreglar pods, as much as six feet across, along the entire exposed length of a narrow shear zone that strikes northeast and dips about 30° NW. The shear zone is developed in a folded quartz-biotite schist of pre-Cambrian age. Acidic dikes, striking north-south, cut the quartz-biotite schist within 200 yards east of the shear zone; beyond the northern end of the shear zone the strike of these dikes swings toward the northwest. Granite has intruded the quartz-biotite schist within 500 yards of the shear zone both to the north and to the east, forming an arcuate contact concave toward the southwest. The acidic dikes were not observed to cut the granite.

Basic dikes also are exposed in the area, and the biotite-garnet schist may be a metamorphosed basic dike. Whether the rock is a metamorphosed dike or a rock developed in place out of sheared material, metasomatism has certainly played a role in its formation. The chlorine and fluorine contents of the biotite and the presence of tourmaline (boron) in the biotite-garnet schist are evidence of metasomatism; moreover the quartz-biotite schist "country rock" bordering the shear zone is locally impregnated with sulphides. Erythrite (cobalt bloom) and secondary copper minerals are present here and there immediately adjacent to the pods of biotite-garnet schist, and the shear zone along which this schist occurs probably has exerted a structural control on the sulphide mineralization. (Cobalt and copper have been known in this area since 1901. See for example Umpleby, 1913, pp. 71, 72 and 160.)

MINERALOGY

Biotite

This mineral makes up about 60 per cent of the rock. In thin section some garnet grains are seen to be partly rimmed by a thin coating of chlorite, formed mostly at the expense of biotite and suggesting incipient retrograde metamorphism. Also, a few biotite grains contain inclusions of zircon, some of which are surrounded by dark (not pleochroic) halos. But on the whole the biotite is remarkably fresh and free of inclusions, and the preparation of a clean fraction for analysis was acually a simple matter, certainly an unusual circumstance in the case of metamorphic biotite.

The following physical properties were determined on the material analyzed: Specific gravity $3.21 \pm .01$; $\alpha = 1.605 \pm .003$, $\beta = \gamma = 1.668 \pm .003$; $\gamma - \alpha = .063$; $2V = 0°$, or practically $0°$, and pleochroism pronounced, with X = light olive green, and Y = Z = very dark olive green. The chemical analysis is given in Table 1.

The composition of this metamorphic biotite combines some of the

TABLE 1. BIOTITE, LEMHI COUNTY, IDAHO
Analyst: Eileen H. Oslund

	Weight per cent	Metal Atoms/12 Oxygens		
SiO_2	33.09	2.69		4.00 (Si + Al 1.31)
Al_2O_3	17.65	1.69	1.31 / .38	
TiO_2	1.30	.08		
Fe_2O_3	2.42	.15		
FeO	29.22	1.98		2.93 (Al .38 through MgO)
MnO	.04	.003		
MgO	2.83	.34		
CaO	.10	.01		
Na_2O	.13	.02		
Rb_2O	.10	.005		.98 (CaO through BaO)
K_2O	9.04	.94		
BaO	.09	.003		
H_2O^+	2.92	1.58		
F	.23	.06		1.79 (H_2O^+, F, Cl)
Cl	1.11	.15		
H_2O^-	.04			
Total	101.31			
Less O≡F & Cl	.34			
	99.97			

distinctive features of igneous biotites of several different parageneses (Heinrich, 1946, and Nockolds, 1947). For example, the high FeO content is what one might expect to find in biotite from granitic pegmatites or from alkalic igneous rocks, while the extremely low MnO is more typical of biotite associated with pyroxene and/or olivine.

But it is the chlorine content of this biotite that is most noteworthy. The highest chlorine content previously reported for the mineral is 0.24 per cent, in siderophyllite from Brooks Mountain, Alaska (Gower, 1957, p. 154). Other chlorine contents reported for the mineral are: 0.20 per cent, in biotite from a quartz monzonite at Butte, Montana (Weed, 1899, pp. 742–743); 0.18 per cent, in biotite from a quartz monzonite at Rockville, Minnesota and 0.11 per cent, in biotite from St. Lawrence County, New York (Kuroda and Sandell, 1953, pp. 889, 891). Kuroda and Sandell (1953, p. 889) state: "Determinations of chlorine in biotite are scarce, but the data available indicate that as much as 0.2 per cent is not uncommon." Correns (1956, p. 192) also points out the lack of information on chlorine in biotites.

The high chlorine content has no apparent effect on the optical propertities of the Idaho biotite. Hall (1941) has related the color of biotites to their contents of FeO, MgO, and TiO_2. The color of the Idaho biotite is in accord with Hall's findings. Heinrich (1946, p. 347) has graphed the relationship between index of refraction (γ) and chemical composition in the biotite-phlogopite series. Values for the Idaho biotite cross at a point almost exactly on his curve.

Garnet

Garnet, present almost exclusively as discrete euhedral grains 1–3 mm. across, makes up about 30 per cent of the rock. In impressive contrast to the biotite, the garnet is dirty with tiny inclusions. These are tourmaline, zircon, possibly rutile, and grains of unidentified material.

In grains of 0.07 mm. size the garnet has a pale mauve or lilac color in reflected light. In transmitted light these are pale pink to colorless, but grains of 0.15 mm. size exhibit a definite reddish hue. In addition, the following properties were determined: Specific gravity maximum $4.24 \pm .01$, minimum 4.20 ± 0.1, average 4.22; index of refraction maximum $1.818 \pm .003$, minimum $1.814 \pm .003$, average 1.816; and unit cell size 11.550 Å $\pm .003$. The MnO content was determined by C. O. Ingamells of the University of Minnesota Rock Analysis Laboratory, to be 1.64 per cent, which is equivalent to a spessartite content of 3.8 molecular per cent.

Fleischer (1937), in a statistical study of 57 garnet analyses, confirmed Ford's (1915) thesis that there is a direct relationship between chemical composition and physical properties in the garnet group. The specific gravity, index of refraction and unit cells size values determined for this mineral suggest that other end member garnets (along with spessartite) are present in molecular per cents about as follow: almandine, 81–83; pyrope, 8–10, and grossularite and andradite, 5.

Tourmaline

Tourmaline is estimated to make up less than .05 per cent of the rock. It occurs as unzoned euhedral to subhedral grains, generally with biotite, but in some instances included in garnet. In both cases the *c* axis of the tourmaline tends to parallel the general schistosity of the rock. The tourmaline crystals associated with biotite are fairly uniform in size, with an average length of about 0.06–0.07 mm.; the grains included in garnet are somewhat smaller.

The following physical properties were determined: Specific gravity = $3.18 \pm .02$; uniaxial, with $o = 1.665$, $e = 1.635$; both $\pm .003$; $o - e = .030$, and pleochroism intense, from dark bluish green or black (*o*) to pale reddish violet (*e*). Therefore the mineral must contain a high molecular per cent of the iron tourmaline, schorlite, which one would expect in view of the compositions of the associated minerals.

Zircon

This mineral probably comprises less than 0.1 per cent of the rock, but the small portion recovered during fractionation work is worthy of special note. In reflected light the mineral has an ash-gray color. Under the microscope most grains are 0.05–0.15 mm. long, and although zircon is noted for its resistance to attack and alteration, these grains have suffered severe corrosion and pitting; crystal faces have been completely obliterated. Perhaps these zircons were originally detrital in the quartz-biotite schist "country rock," only to be mixed with the basic dike during the time of shearing. Thus incorporated into the original materials of the biotite-garnet schist, they would be exposed for a time to the rigors of a pneumatolytic environment.

Other Minerals

Muscovite, intergrown with the biotite, probably amounts to more than five per cent of the rock. Quartz is only about a third as abundant as muscovite. A few rare grains of fresh-looking sphene were encountered during the fractionation process, but this mineral is not apparent in thin section. Minor quantities of an unidentified yellow secondary mineral are forming along fractures in the garnets.

Conclusions

As mentioned above, Kuroda and Sandell (1953, p. 889) and Correns (1956, p. 192) have pointed up the need for further determinations of chlorine in micas. To this one might add that the presence of chlorine is especially to be suspected when careful analysis of a mica gives a low total for the oxides and fluorine, and calculations show the deficiency to be in the (OH) group.

Acknowledgments

The chemical analysis of the biotite presented here was made possible by the Shell Oil Company through the Shell Grant for Fundamental Research.

It is a pleasure to acknowledge the help received during this study from Dr. Samuel S. Goldich and Mrs. Eileen H. Oslund of the University of Minnesota Rock Analysis Laboratory. The chlorine content of the biotite described was detected and determined by Dr. Goldich and Mrs. Oslund solely on their own initiative, when the oxide and fluorine determinations requested gave a low total, and their calculations showed the deficiency to be in the (OH) group. Thus the discovery of the most remarkable feature of the biotite described in this paper is largely a result of their research.

Bibliography

1. Correns, Carl W. (1956), The geochemistry of the halogens: in *Physics and Chemistry of the Earth*, Edited by Ahrens, L. H., Rankama, Kalervo and Runcorn, S. K., McGraw-Hill, pp. 181–233.
2. Fleischer, M. (1937), The relation between chemical and physical properties in the garnet group: *Am. Min.*, **22,** pp. 751–759.
3. Ford, W. E. (1915), A study of the relations existing between the chemical, optical and other physical properties of the members of the garnet group: *Am. Jour. Sci.*, Ser. 4, **40,** pp. 33–49.
4. Gower, John Arthur (1957), X-ray measurement of the iron-magnesium ratio in biotites: *Am. Jour. Sci.*, **255,** No. 2, pp. 142–156.
5. Hall, A. Jean (1941), The relation between color and chemical composition in the biotites: *Am. Min.*, **26,** pp. 29–33.
6. Heinrich, E. Wm. (1946), Studies in the mica group; the biotite-phlogopite series: *Am. Jour. Sci.*, **244,** No. 12, pp. 836–848.
7. Kuroda, P. K. and Sandell, E. B. (1953), Chlorine in igneous rocks: *Bull. Geol. Soc. Am.*, **64,** pp. 879–896.
8. Nockolds, S. R. (1947), The relation between chemical composition and paragenesis in the biotite micas of igneous rocks: *Am. Jour. Sci.*, **245,** No. 7, pp. 401–420.
9. Umpleby, Joseph B. (1913), Geology and ore deposits of Lemhi County, Idaho: *USGS. Bull.* **528,** 182 pp., esp. pp. 71, 72, 160.
10. Weed, Walter Harvey (1899), Granite rocks of Butte, Montana, and vicinity: *Jour. Geol.*, **7,** No. 8, pp. 737–750, esp. pp. 742–743.

Manuscript received May 17, 1957.