GEOLOGY OF THE ELK CREEK VERMICULITE DEPOSIT

MADISON AND BEAVERHEAD COUNTIES, MONTANA

RICHARD B. BERG

MONTANA BUREAU OF MINES AND GEOLOGY

OPEN-FILE REPORT 335

DECEMBER, 1995

GEOLOGY OF THE ELK CREEK VERMICULITE DEPOSIT

MADISON AND BEAVERHEAD COUNTIES, MONTANA

Richard B. Berg

INTRODUCTION

The Elk Creek vermiculite deposit is 14 miles (23 km) southeast of Dillon on the southern flank of the Ruby Range (Figure 1). Vermiculite occurs in sec. 36, T. 8 S., R. 7 W.; sec. 31, T. 8 S., R. 6 W.; secs. 1,2, and 11, T. 9 S., R. 7 W. and sec. 6, T. 9 S., R. 6 W. The east-west county line between Madison County to the north and Beaverhead County to the south crosses the northern part of this area of vermiculite occurrences. In 1990 a mill was constructed at this deposit and vermiculite was mined from cuts in the NE1/4 NW1/4 NE1/4 sec. 11, T. 9 S., R. 7 W. during 1990 and 1991.

Precambrian metamorphic rocks in the southern part of the Ruby Range have been mapped and described by Heinrich (1960) and Okuma (1971). The ultramafic rocks have been specifically described by Sinkler (1942) in her description of nickel occurrences here. Rabbitt (1948) described anthophyllite associated with the ultramafic rocks. Desmarais (1976 and 1981) presented detailed petrographic descriptions of the ultramafic rocks and made first mention of vermiculite formed by weathering of biotite schist associated with these ultramafic bodies. Field work for the outcrop map and interpretative geologic map (Figures 2 and 3) presented here was done in August 1995.

GEOLOGY

Precambrian Metamorphic Rocks

This area is underlain by Archean metamorphic rocks of the amphibolite facies of regional metamorphism. Quartzofeldspathic gneiss is the dominant rock type with lesser amphibolite, anthophyllite gneiss, quartzite and ultramafic rock. Metasomatic reaction between the ultramafic bodies and enclosing gneiss has in some instances produced an assemblage of rocks including biotite schist which has weathered to form vermiculite (Desmarais, 1976). Gneisses have been subjected to isoclinal folding and subsequent folding that produced open folds with northerly plunging fold axes. In much of the area shown in Figures 2 and 3 foliation strikes northeast and dips 30-60 degrees northwest.

Post-metamorphic diabase dikes trend northwest. One of these dikes was intruded along the northwest-trending Elk Creek fault (Figure 2). The Sweetwater fault, also a major northwest-trending fault, is a short distance northeast of the eastern boundary of the area shown in Figures 2 and 3.

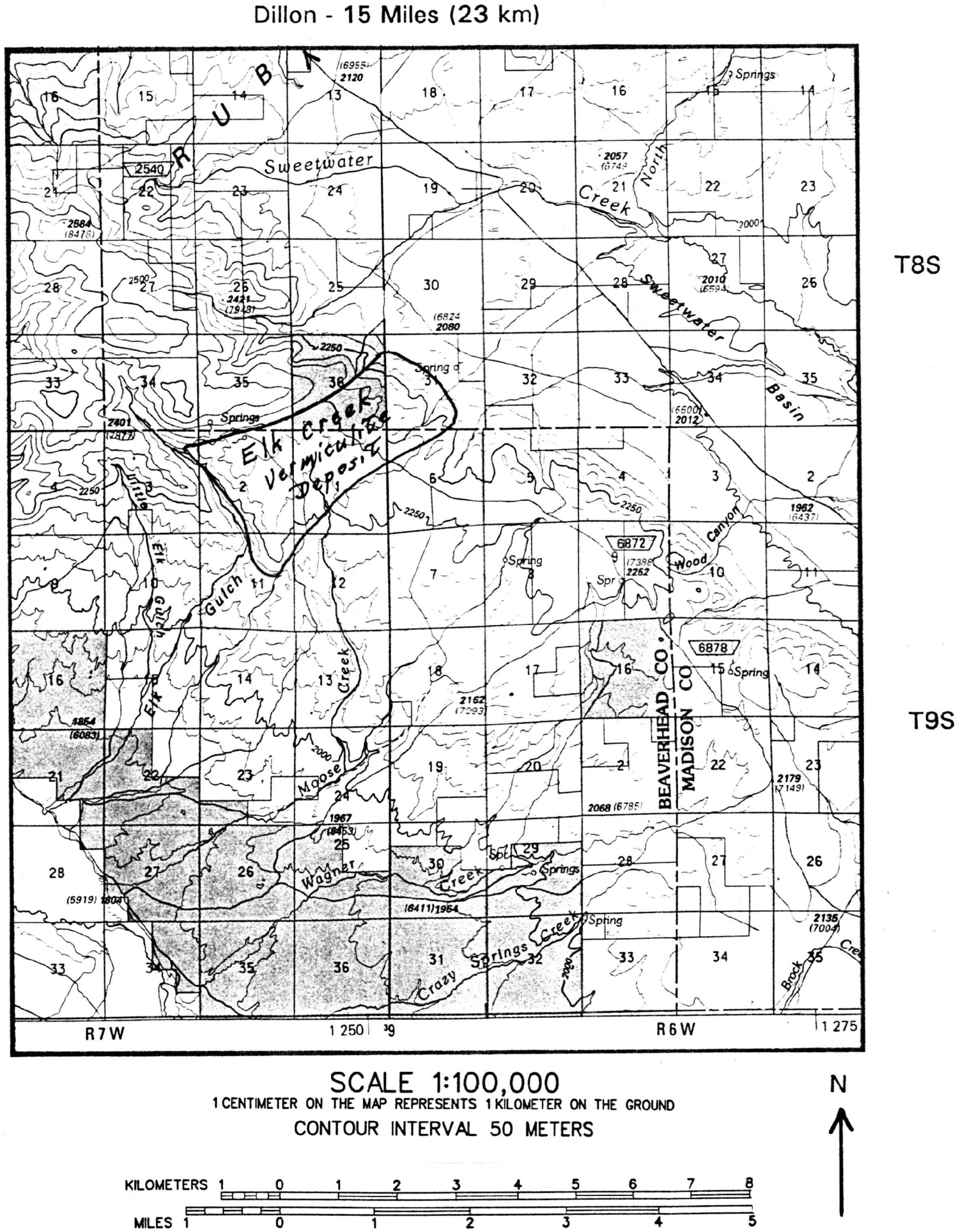

Figure 1. Index map showing location of the Elk Creek vermiculite deposit.

Quartzofeldspathic gneiss - The dominant rock type in this area, as well as throughout the Ruby Range, is quartzofeldspathic gneiss. Outcrops of quartzofeldspathic gneiss range from low outcrops that project only a few inches above the soil and are largely hidden by sagebrush, to cliffs such as those on the south side of a timbered ridge in the N1/2 sec. 2, T. 9 S., R. 7 W. Because of limited exposures and discontinuous lithologic layers in this area of multiply folded gneisses, individual lithologic types in the quartzofeldspathic gneiss were not mapped except for the distinctive leucocratic garnetiferous gneiss.

Leucocratic garnetiferous gneiss - This weakly foliated gneiss weathers to form massive, angular blocks 1-2 meters across that are recognizable from a distance because they are white as compared to the other quartzofeldspathic gneiss which weathers light brown to reddish brown to gray and forms irregular and rounded exposures. The leucogneiss consists of quartz and feldspar with red garnet porphyroblasts that range from several millimeters to 1 cm in diameter and are sparsely scattered throughout the gneiss in a concentration of several percent. This gneiss forms layers up to 30 ft (10 m) thick that can be traced on basis of outcrop and distinctive float. Best exposures are in the W 1/2 sec. 1 and the E 1/2 sec. 2, T. 9 S. R. 7 W.

Biotite-quartz-feldspar gneiss and hornblende-biotite-quartz-feldspar gneiss - These gneisses include a variety of compositions, some hornblende bearing and grading into amphibolite (>50 percent hornblende). Foliation results from alternating biotite and/or hornblende rich layers with quartzofeldspathic layers. Biotite is generally randomly oriented. Okuma (1971) and other geologists have referred to these gneisses as the Dillon Granite Gneiss.

Migmatitic garnetiferous quartzofeldspathic gneiss - This distinctive variety of gneiss is well exposed on the south side of the timbered ridge in the N 1/2, sec. 2, T. 9 S., R. 7 W. and in scattered exposures south of this ridge. It is characterized by biotitic layers up to several centimeters thick intermingled with discontinuous quartzofeldspathic layers that contain red garnet porphyroblasts up to 3 cm. in diameter. Small isoclinal folds are recognizable in many outcrops.

Amphibolite - Amphibolite tends to form more outcrops than the quartzofeldspathic gneiss, although many of these outcrops are small and hidden among the sagebrush. Most amphibolite is characterized by very dark green to black hornblende and scattered garnet porphyroblasts. Some amphibolite consists of faintly foliated layers with small feldspar grains interspersed with very dark green to black hornblende producing a "salt and pepper" texture interlayered with quartz-feldspar layers up to a few centimeters thick. Increase in the abundance of these quartz-feldspar layers causes more pronounced foliation.

Anthophyllite gneiss - Anthophyllite gneiss is recognized by the medium-brown anthophyllite prisms and locally abundant lilac garnet porphyroblasts. It is most abundant in the NW1/4 sec. 2, T. 9 S., R. 7 W.

Quartzite - Quartzite is exposed in the NE1/4, NE1/4 sec. 1, T. 9 S., R. 7 W. where exposed width of this layer is about 10 ft (3 m). Quartzite lacks recognizable foliation and is very coarse grained with individual quartz grains up to 1 cm. in maximum dimension. It forms angular outcrops with prominent joints. Garnet, although probably in a concentration of less than one percent, is conspicuous because of the contrast between red garnet and white quartz. Pale rose quartz, scattered concentrations of sillimanite and feldspathic layers were observed in the quartzite.

Ultramafic Bodies - Ultramafic bodies range in size from the largest body exposed on the northeast side of Elk Creek that is 4000 ft (1200m) long to small bodies only a few tens of feet across. The bodies form prominent brown-weathering outcrops characterized by a knobby surface caused by orthopyroxene megacrysts up to several centimeters across. Desmarais (1976, p. 25) described the ultramafic rock as consisting of hypersthene megacrysts, amphibole (actinolite/tremolite, anthophyllite/cummingtonite), spinel and olivine.

In the NW1/4, SW1/4, NW1/4, sec. 1, T. 9 S., R. 7 W., a small body of ultramafic rock is surrounded by quartzofeldspathic gneiss. In all instances where quartzofeldspathic gneiss or amphibolite is exposed close to the contact with ultramafic rock, a concordant relationship is indicated. Ultramafic bodies are generally foliated within a few feet of the contact with the enclosing gneiss. This foliation is parallel to the contact with the enclosing gneiss. It is inferred that many of the small exposures of ultramafic rock in the S1/2 sec. 36, T. 8 S., R. 7 W. and N1/2 sec. 1, T. 9 S., R. 7 W. are isolated bodies surrounded by quartzofeldspathic gneiss. Usually granules of quartz and feldspar can be found in the soil near these exposures of ultramafic rock.

Desmarais (1976) recognized a zonation in rock type along some of the contacts of the ultramafic rocks with the enclosing gneiss. The sequence, where fully developed, is ultramafic-anthophyllite schist-hornblende schist - biotite schist-quartzofeldspathic gneiss. Some of the hornblende schist contains an amphibole with a striking blue schiller effect. The amphibolite layers found within the quartzofeldspathic gneiss sequence can be distinguished from the hornblende schist because the amphibolite contains either scattered plagioclase porphyroblasts producing a salt and pepper texture or prominent quartz-feldspar layers, whereas the hornblende schist consists essentially of black hornblende. Likewise anthophyllite gneiss can be distinguished from reaction zone anthophyllite schist because anthophyllite gneiss contains quartz, feldspar and often garnet in addition to anthophyllite, whereas the anthophyllite schist consists mainly of anthophyllite.

Desmarais (1976) interpreted this sequence of anthophyllite schist-hornblende schist - biotite schist as having formed by metasomatic reaction of the ultramafic rock with the enclosing gneiss during regional metamorphism. Not all zones are developed uniformly along these contacts. Desmarais attributed the presence of particular reaction assemblages to the original chemical composition of the country rock. Where quartzofeldspathic gneiss is in contact with the ultramafic rock, formation of biotite schist is favored because of the availability of potassium in the gneiss, necessary for the formation of biotite. He noted that biotite schist was not developed along amphibolite-ultramafic contacts. This was also my observation. For instance on the southwest side of the large ultramafic body that forms a prominent hill in the SW1/4 sec. 36, T. 8 S., R. 8 W., amphibolite is exposed in contact with the ultramafic rock without the formation of reaction zones.

Because vermiculite that formed by weathering of the biotite schist is associated with the ultramafic bodies, an understanding of the geometry of these bodies is important to evaluating the vermiculite resources of this deposit. On the basis of reconnaissance mapping Heinrich (1960) interpreted isolated exposures of ultramafic to be of one intrusion cut by the Elk Creek fault on the southwest and by the Sweetwater fault on the northeast. Desmarais (1976) suggested that the ultramafic bodies formed by the tectonic emplacement of partly serpentinized ultramafic rock either before or during folding of the surrounding gneisses. He concluded that the mineralogy of these bodies is compatible with the amphibolite facies metamorphism that affected the surrounding gneisses. My interpretation is in agreement with that of Desmarais - namely that the isolated exposures of ultramafic rock are in most instances individual concordant bodies indicating that emplacement of this rock preceded Precambrian folding. Whether the ultramafic rock was emplaced magmatically as a melt or tectonically as a serpentinite is unclear from field relationships. Whichever their mode of emplacement, it appears probable that the ultramafic bodies were tectonically disrupted during folding of the gneisses to form numerous isolated bodies.

Locally the ultramafic rock has been serpentinized to produce a rock that is pale, dusty green in outcrop and lacks the prominent orthopyroxene megacrysts. Chrysotile veinlets a few millimeters thick surrounded by massive serpentine are conspicuous in some of the serpentinized ultramafic rock. Microveinlets and disseminated grains of magnetite are abundant in the serpentinized ultramafic rock. Serpentinization is most abundant and pervasive near the Elk Creek fault (Figure 3).

Four samples of ultramafic rock were analyzed for Au, Pt and Pd by Chemex Labs Ltd. using atomic fluorescence spectrometry. The sample descriptions are as follows:

EC-411 Sample of blasted rock at exposure where annabergite is found along fractures - NW1/4 SE1/4 NW1/4 sec. 1, T. 9 S., R. 7 W.

EC-466 Chip sample of outcrop on west side of mill - SE1/4 SW1/4 SE1/4 sec. 2, T. 9 S., R. 7 W.

EC-467 Composite sample of three exposures near the NE corner of sec. 1, T. 9 S., R. 7 W.

EC-468 Composite sample from outcrops in the SW 1/4 SE1/4 sec. 36, T. 8 S., R. 7 W.

Sample	Au (ppb)	Pt (ppb)	Pd (ppb)
EC-411	8	5	<2
EC-466	<2	5	<2
EC-467	<2	5	<2
EC-468	<2	5	<2

Detection limits: 2 ppb Au, 3 ppb Pt, 2 ppb Pd.

VERMICULITE

In the Elk Creek area, weathering of biotite in the quartzofeldspathic gneiss has produced vermiculite. However, the biotite flakes in the gneiss are only several millimeters across and biotite in this gneiss is in low concentration. Although biotite schist was not found in the gneiss sequence, it simply may not be exposed because of ease of weathering (to vermiculite) as compared to quartzofeldspathic gneiss or amphibolite. The biotite schist developed at the contact of the ultramafic bodies with the enclosing gneiss consists mainly of biotite and is coarse grained, in one instance with biotite flakes up to 6 cm long (Figure 4). Weathering of this biotite schist has produced concentrations of vermiculite which, if of sufficient size, are mineable. Because biotite schist is only developed where the ultramafic bodies are in contact with quartzofeldspathic gneisses, this contact offers the best possibility for the development of vermiculite ore bodies. Although biotite schist (now vermiculite) occurs around at least some of the smaller ultramafic bodies, because of the small size of these bodies, these occurrences of vermiculite offer poorer possibilities for formation of minable vermiculite bodies than along the contact of larger ultramafic bodies. On the basis of the examination of ant hills and soil for vermiculite, it appears that development of biotite schist (and subsequent weathering to vermiculite) is not consistent along the contacts between

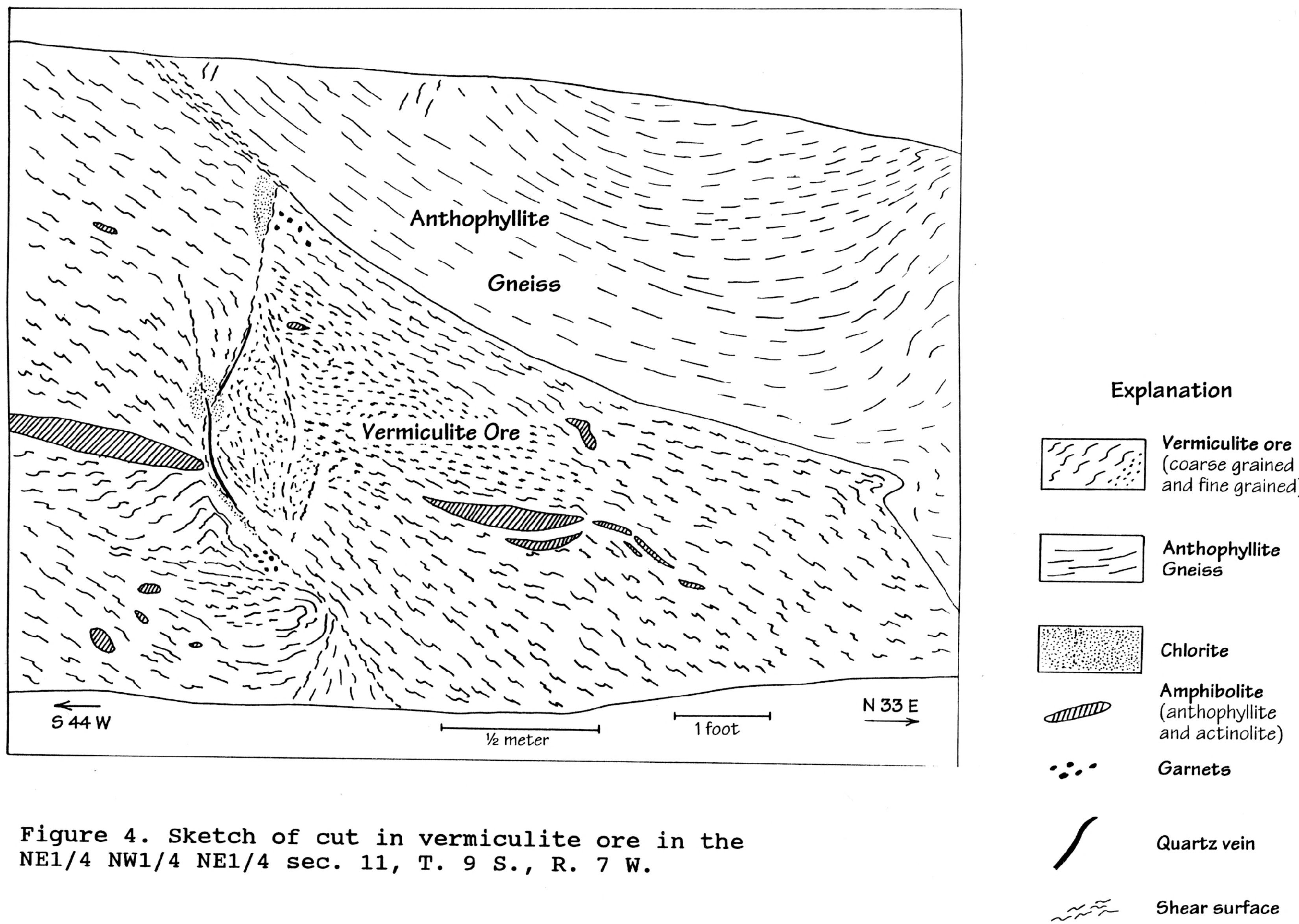

Figure 4. Sketch of cut in vermiculite ore in the NE1/4 NW1/4 NE1/4 sec. 11, T. 9 S., R. 7 W.

ultramafic rocks and quartzofeldspathic gneiss.

The Elk Creek deposit may have some similarities to vermiculite deposits in West Australia that are associated with Precambrian mafic and ultramafic rocks (Lipple, 1990). The North Carolina vermiculite deposits are also related to ultramafic bodies (Kulp and Brobst, 1954), where weathering of phlogopite next to pegmatites in dunite bodies has formed vermiculite.

The ammonium cation exchange capacity (CEC) and exchangeable cations of two vermiculite samples were determined by Steven W. Boese, Applied Analysis, Laramie, Wyoming.

Sample	EC 399	EC 412
Exchangeable Cations (meq/g)		
Na	0.00, 0.00	0.00, 0.00
K	0.01, 0.01	0.01, 0.01
Ca	0.45, 0.45	0.25, 0.25
Mg	0.27, 0.27	0.09, 0.09
Ammonium CEC (meq/g)	1.09, 0.93	0.92, 0.90

Sample EC 399 is from the area of fine-grained vermiculite shown in Figure 4 of cut in vermiculite ore. Sample 412 is from a stockpile of vermiculite in the middle of three cuts at this mine.

REFERENCES CITED

Desmarais, N.R., 1976, Structural and petrologic study of Precambrian ultramafic rocks, Ruby Range, southwestern Montana (M.S. thesis): University of Montana, Missoula, 88 p.

Desmarais, N.R., 1981, Metamorphosed Precambrian ultramafic rocks in the Ruby Range, Montana: Precambrian Research, v. 16, p. 67-101.

Heinrich, E. Wm., 1960, Geology of the Ruby Mountains *in* Pre-Beltian geology of the Cherry Creek and Ruby Mountains areas, southwestern Montana: Montana Bureau of Mines and Geology Memoir 38, p. 15-40.

Kulp, J.L, and Brobst, D.A., 1954, Notes on the dunite and the geochemistry of vermiculite at the Day Book dunite deposit, Yancey County, North Carolina: Economic Geology, v. 49, p.211-220.

Lipple, S.L., 1990, Talc, *in* Geology and Mineral Resources of Western Australia: Western Australia Geological Survey , Memoir 3, p. 678-679.

Okuma, A.F., 1971, Structure of the southwestern Ruby Range near Dillon, Montana (Ph.D. dissertation): Pennsylvania State University, College Park, 122 p.

Rabbitt, J.C., 1948, A new study of the anthophyllite series: American Mineralogist, v. 33, p. 263-323.

Sinkler, H., 1942, Geology and ore deposits of the Dillon nickel prospect, southwestern Montana: Economic Geology, v. 37, p.136-152.