
THE COPPER, LEAD, AND ZINC CONTENT OF METAMORPHIC ROCKS ON MT. MOOSILAUKE, NEW HAMPSHIRE¹

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ABSTRACT

Metamorphic rocks from Mt. Moosilauke in north-central New Hampshire were analyzed by X-ray fluorescence and atomic-absorption spectrophotometry for trace amounts of copper, lead, and zinc. Mean content was 89 ppm for copper, 44 ppm for lead, and 92 ppm for zinc. Values for the Devonian Littleton Formation, the dominant rock unit in the area, suggest that it is a metamorphosed shale slightly enriched in copper and lead.

INTRODUCTION

Concentrations of copper, lead, and zinc were measured in samples of metamorphic rocks from the west slope of the South Peak (1377 m elevation) of Mt. Moosilauke, located on the western edge of the White Mountain province in north-central New Hampshire (71° 51' W; 44° 01' N). Except for the work of Shaw (1954), which reported values for copper and lead in the highly metamorphosed Littleton Formation, this is the only study known to the authors of these trace-element levels in the metamorphic rocks of the Appalachians. Geological weathering of these rock units may be responsible for natural background concentrations of these elements in runoff waters.

METHODS

Twenty-seven bedrock specimens ranging in weight from two to four kilograms were collected during fall, 1971. The specimens are a sampling of the Lower Devonian Littleton Formation, the late Devonian (New Hampshire Magma Series) Bethlehem Gneiss, and the Upper Ordovician Ammonoosuc Volcanics, the three Paleozoic rock units present in the area (Billings, 1935). The ranges in elevation of the outcrops of these units are given in Table 1.

Field specimens were crushed, after the clearly weathered outer portion was removed from each specimen. Special care was taken to remove any organic

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matter adhering to the sample before crushing, because lichens and mosses tend to be rich in trace elements (Mitchell, 1964; Ruhling and Tyler, 1971). Each sample was run once through a jaw crusher and then was ground to 200-mesh size with a ceramic, electric mortar and pestle. The jaw crusher, composed of high-strength steel alloy, was a conceivable source of contamination, but each sample was run through only once and no systematic contamination in the samples was noted. Approximately 100 g of rock powder for each sample was stored in plastic vials.

TABLE 1

The copper, lead, and zinc contents of the individual rock specimens from the western slope of Mt. Moosilauke. Data are in parts per million and the elevational range of the outcrops of each formation is given in parentheses.

Formation	Rock Type	Cu	Pb	Zn
Littleton Formation (795-1377m)	Biotite schist	84	34	71
	" "	67	50	189
	Quartz-biotite schist	81	56	123
	" " "	42	40	57
	" " "	50	61	111
	Banded quartz-biotite schist	103	40	89
	" " " "	95	46	94
	" " " "	91	46	79
	Sillimanite schist	60	46	121
	" "	76	50	82
	Quartz-sillimanite schist	67	65	73
	" " "	151	50	84
	" " "	86	50	89
	" " "	75	35	70
Bethlehem Gneiss (587-795m)	Quartz-muscovite schist	105	30	46
	" "	120	40	80
	Quartz-biotite-sillimanite schist	49	40	64
	Quartz-biotite gneiss	115	50	88
	" " "	133	40	102
	" " "	82	35	96
	" " "	92	46	127
Ammonoosuc Volcanics (353-587m)	" " "	72	46	90
	" " "	103	46	84
	" " "	65	25	112
	Quartz-hornblende schist	201	46	94
	Quartz-biotite gneiss	125	40	41
	Epidote-rich band in quartz-hornblende schist	26	56	75

Copper and zinc were determined by replicate analysis by the Compton scattering-X-ray-fluorescence technique (Reynolds, 1963) on a GE-XRD-5 Spectrophotometer. To determine the background level of radiation from the X-ray tube, a blank with a mass-absorption coefficient close to those of the samples was prepared from reagent-grade calcium acetate. Unfortunately, there was considerable stray radiation from the tube, which caused some uncertainty in the accuracy of measurement. For zinc, analytical error was $\leq \pm 5\%$. Experimental determination of U.S. Geological Survey standard rock G-1 gave a value of 44 ppm for zinc, far below the average for our samples, but within five percent of the currently accepted value of 42 ppm (Taylor, 1969) and certainly within the experimental limits of 25 to 54 ppm reported by Fleischer (1969). Analytical error was $\leq \pm 30$ ppm for copper.

The method of high-temperature fusion was used to prepare a liquid solution of rock specimens for lead analysis. One-tenth gram of rock powder was added

to 0.5 g lithium tetraborate in a graphite crucible and fluxed 10 to 15 minutes at 900 to 1000°C. At this point the molten bead was poured into 25 ml of 6% reagent-grade HNO₃ in glass-distilled water treated with Chelex 100 resin (Biorad Laboratories) to remove heavy metals by chelation. The bead was quickly covered to prevent steam losses and stirred to aid in solution. Volatilization losses of lead during fluxing are possible, but Ruch *et al.* (1972) report that such losses are slight. Lead concentration was determined by four to five replicate analyses on a Perkin-Elmer Model 303 atomic absorption spectrophotometer. Low-level lead contamination was linked to lead content in the lithium tetraborate used. Assuming a uniform distribution of lead in this reagent, a blank value which amounted to 50% of our mean concentration was subtracted to correct for this contamination. All glass and teflonware used in these procedures were washed with concentrated nitric acid (ACS) and thoroughly rinsed with glass-distilled water treated with Chelex 100. Experimental determination of lead in the U.S. Geological Survey standard rock GSP-1 yielded a value of 70 ppm, slightly higher than the mean value of 52.5 ppm given by Flanagan (1969).

RESULTS AND DISCUSSION

For copper and lead, the range of concentrations (Table 1) and the mean concentrations (Table 2) for our Mt. Moosilauke specimens are considerably

TABLE 2

Mean content = standard error for copper, lead, and zinc in Mt. Moosilauke rocks and those from studies in the literature. Number of samples analyzed is given in parentheses if known. Data are in parts per million.

	Cu	Pb	Zn
Present Study			
Littleton Formation (17)	82±6.7	46±2.3	90±8.0
Bethlehem Gneiss (7)	95±9.1	41±3.3	100±5.8
Ammonoosuc Volcanics (3)	117±50.7	47±4.7	70±15.5
Shaw (1954)			
Littleton Formation (30)	12.5	27.3	n.d.
Krauskopf (1955)			
shale	30-150	20	50-300
Turekian and Wedepohl (1961)			
shale	45	20	95
igneous	55	13	70
Taylor (1969)			
basalt	100	5	100
granite	10	20	40

higher than are those of Shaw (1954). We believe that neither possible contamination nor analytical errors can wholly explain our higher values. Krauskopf (1955) and Turekian and Wedepohl (1961) cite a value of 50 ppm copper and 20 ppm lead for an average shale (Table 2), with a considerable range of values. We believe that our results indicate slight copper and lead enrichment and normal zinc values for the Littleton Formation in the area sampled.

The Devonian Littleton Formation, the dominant rock unit in the area, is a product of varying shallow marine depositional environments during the Acadian orogeny, which took place about 385 million years ago (Eardley, 1962). Turekian (1969) has described the biological and sorption processes important in the precipitation of trace-elements in shallow marine environments. Sulphide precipitation under strongly reducing conditions and sorption on clay and iron-hydroxide particles in mildly alkaline waters are important mechanisms for trace-metal

fixation in shales. While the Littleton Formation does contain sulphide-rich bands elsewhere in the state (John B. Lyons, personal communication, 1972), the principal metamorphic minerals in the collection area, muscovite, sillimanite, quartz, and biotite, suggest that the Littleton Formation was originally a relatively pure clay, probably slightly enriched in iron. The trace-element data from this study suggest that the unit is a metamorphosed shale, the slight copper and lead enrichment probably being a result of processes also responsible for the occurrence of iron in the original sediment.

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