BRACHIOPODS FROM MICA SCHIST, MT. CLOUGH, NEW HAMPSHIRE.

MARLAND P. BILLINGS AND ARTHUR B. CLEAVES.

ABSTRACT.

Fossils from crystalline schists are rare, but two brachiopods have been found in high-grade (katazonal) metamorphic rocks on Mt. Clough, New Hampshire. One of the specimens has been identified as *Spirifer sp. ind.* These brachiopods constitute one line of evidence, along with other data, to demonstrate that some of the high-grade metamorphic rocks of western New Hampshire are of Devonian age. Since fossils are also found in metamorphic rocks (mesozonal) at Bernardston, Massachusetts, it is pointed out that further search of the crystalline schists of New England for fossils may prove fruitful.

Fossils from crystalline schists are rare. The writers were very much surprised, therefore, when, in the course of studying the geology of the Moosilauke quadrangle of New Hampshire, they discovered two specimens of brachiopods in mica schists belonging to the katazone or "high-grade" zone of the Grubenmann-Niggli classification (5)[1] of metamorphic rocks.[2] The fossil locality is 1.6 miles N. 66° W. from the summit of Mt. Moosilauke, at an elevation of 2650 feet on the more northerly of two "slides" on the east slope of Mt. Clough. In a previous paper the writers have described Silurian and Devonian fossils from epizonal rocks in the Littleton area (2), about 16 to 18 miles north of the locality discussed here.

One specimen, Brachiopod, *gen. et. sp. ind.* (Fig. 1) was discovered in July, 1933, by Mr. Billings, accompanied by Messrs. Jarvis B. Hadley, Charles B. Moke, and William F. Jenks. It was found in a metamorphosed concretion, consisting of quartz, clinozoisite, diopside, amphibole, garnet, and titanite. The other specimen, *Spirifer, sp. ind.* (Fig. 2) was discovered by Mr. Cleaves in June, 1934, accompanied by Mr. Billings. It was found about 20 feet west of the first specimen.

[1] Numbers in parentheses refer to list of references at end of paper.

[2] In many metamorphic areas there is a progressive change in the mineral composition of the rocks even though the original sediments may have had precisely the same composition. A well-known example is shale, which passes through the slate and phyllite stages to become mica schist. Grubenmann and Niggli have found it convenient to establish three zones—the epizone, or low-grade zone, the mesozone, or middle-grade zone, and the katazone, or high-grade zone. In general the epizone is characterized by chlorite, sericite, albite, and non-aluminous hornblende, the mesozone by biotite, garnet, staurolite and aluminous hornblende, and the katazone by sillimanite instead of staurolite. Although these zones were originally believed to be depth zones, they are no longer so regarded, and in the opinion of the present writers are largely a function of temperature.

in a garnetiferous mica schist, consisting chiefly of quartz, biotite, andesine-labradorite, and garnet. The petrography of these rocks is described in greater detail below.

The writers wish to express their gratitude to Dr. F. M. Carpenter for photographing the specimens and to Professor P. E. Raymond for reading the manuscript.

DESCRIPTION OF FOSSILS.

As might be expected both specimens are poorly preserved, yet in neither instance is there any doubt that the specimen is a brachiopod. In one case both the genus and species is in doubt, although it may be a small Spirifer; the second specimen, however, is unquestionably a Spirifer.

Fig. 1. Brachiopod, *gen. et sp. ind.*, from metamorphosed concretion, Mt. Clough, New Hampshire. x 3.

Brachiopod, gen. et sp. ind.

Figure 1.

This specimen is but a fragment of the original shell. Nine costae are present, although there were originally a larger number, possibly twelve to fourteen. The interspaces are

about the same width as the costae and both are angular. Strongly impressed, slightly angular lines of growth cross both costae and interspaces and so far as can be observed are more strongly concentrated toward the beak. The width of the fragment is 15 mm., the length 5 mm.

Locality: Elevation of 2650 feet, northern slide on the east slope of Mt. Clough, Moosilauke quadrangle, New Hampshire.

Museum Comp. Zoology, No. 8710.

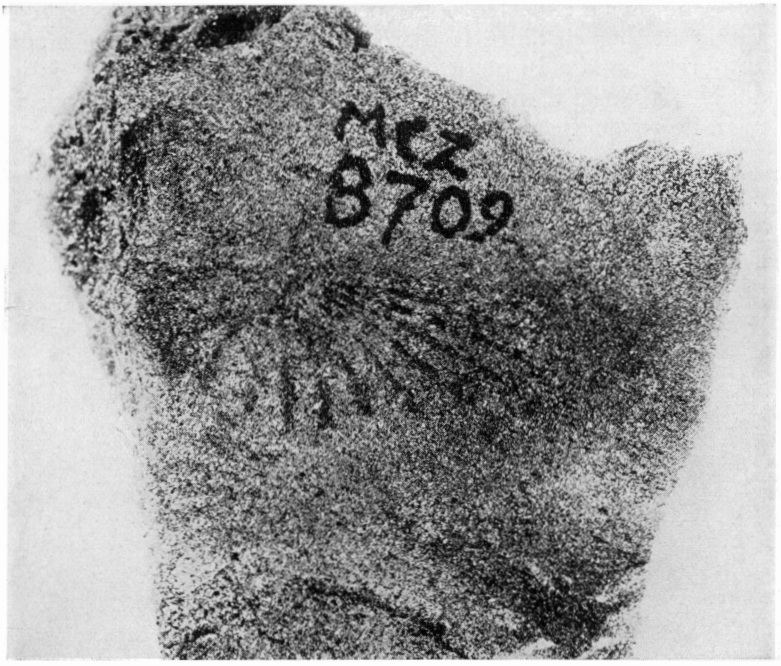

Fig. 2. *Spirifer, sp. ind.*, from biotite-garnet schist, Mt. Clough, New Hampshire. x 2.

Spirifer, sp. ind.

Figure 2.

A flattened and slightly twisted specimen with one inch of its width showing. It is about 27 mm. long. There were at least 14 costae present of which 11 are preserved. They are about half as wide as the interspaces. All surface ornamentation is obscured.

This specimen resembles *Spirifer murchisoni* which occurs

commonly in the strata 20 miles to the northwest with which these beds have been correlated.

Locality: Elevation of 2670 feet, northern slide, on the east slope of Mt. Clough, Moosilauke quadrangle, New Hampshire.

Museum Comp. Zoology, No. 8709.

PETROGRAPHY.

Since fossils in mica schists are rather rare, it seems worthwhile to record in some detail the petrography of the rocks in which these occur and the strata with which they are associated.

Brachiopod, gen. et sp. ind. (Fig. 1). This fossil occurs in the central part of a concretion in strata which are essentially vertical. Half of the concretion has been destroyed by erosion, but one may safely infer that it originally had the shape of a triaxial ellipsoid. The major axis, oriented parallel to the strike of the rocks, is about 12″, the minor axis, perpendicular to the schistosity, is about 7″, and the intermediate axis, essentially vertical, is inferred to have been about 9″ long, although only 4″ are now preserved.

The central part of the concretion is a pink to buff-colored, dense, siliceous rock shaped like a triaxial ellipsoid. Microscopic study shows that the texture is granoblastic and that most of the grains are about 0.1 mm. across. The minerals, and their percentages by volume are: quartz (55%), clinozosite (25%), diopside (12%), actinolite (5%), and titanite (3%). The diopside, in irregular crystals somewhat larger than the rest, is from 0.2 to 0.3 mm. across. The actinolite is in tablets of similar size. The quartz is in round grains about 0.1 mm. across, with the clinozoisite as irregular interstitial grains. The fossil occurs about half an inch inside of the outer boundary of this portion of the concretion.

Surrounding this central ellipsoid is an outer portion a little more than an inch (3 centimeters) thick. In general it is black, or black and white, due to the presence of hornblende, and is composed of many shells, some of them only a fraction of a millimeter thick. The individual minerals range from 0.1 to 0.3 mm. across, and the percentages may greatly vary in the different shells. The average mineral composition is as follows: hornblende (34%), garnet (12%), quartz (31%), titanite (2%), clinozoisite (15%), bytownite (6%) and pyrite (tr).

The concretion is embedded in a fine-grained black mica

schist, with a distinct schistosity. Microscopic study shows that the minerals are from 0.1 to 0.2 mm. across, and the minerals, with percentages given in volume, are as follows: quartz (60%), biotite (22%), andesine (10%), and garnet (8%).

Brachiopod, Spirifer, sp. ind. The rock in which this fossil occurs is a fine-grained buff-colored mica schist, in which, however, the schistosity is not very pronounced. Microscopic study shows that the individual minerals range from 0.05 to 0.2 mm. and are quartz (65%), biotite (13%), andesine-labradorite (12%), garnet (8%), magnetite (1%), chlorite (altered from biotite, 1%), and zircon (tr.).

The other rocks in the Littleton formation, exposed on the same slide, are various types of mica schist, some of which contain sillimanite and staurolite. Sillimanite is most abundant on the lower few hundred feet of the slide, and is present as crystals from 1 to 2½ centimeters long. Staurolite is also present, but only as aggregates of microscopic crystals a fraction of a millimeter long. Each aggregate is clearly pseudomorphic after a sillimanite crystal and was developed during a retrogressive phase of the metamorphism. Pegmatite dikes, from a few inches to a few feet wide, are found both above and below the fossil locality, and 120 feet above the latter is the east border of a large mass of the Bethlehem granodiorite gneiss.

SIGNIFICANCE.

These fossils, although poorly preserved, are very significant. They demonstrate conclusively that the mica schists in which they occur cannot be pre-Cambrian. Taken by themselves, they indicate that the age of the strata in which they are found must lie within the range of the genus *Spirifer*, that is, from middle Silurian to Jurassic. Silurian, however, may be rather definitely eliminated, for the strata of this age in western New Hampshire consist of quartz conglomerate, quartzite, marble, calcite-biotite schist and related rocks. Triassic and Jurassic are impossible, for the Mesozoic sediments of New England occur as gently dipping, non-metamorphosed continental rocks. Carboniferous may be eliminated, for the known Carboniferous of New England consists of non-marine, plant-bearing strata. A Devonian age, however, is very probable. The Devonian of New Hampshire and northern Maine is marine, and brachiopods are the most common fossils. More-

over, the original lithology of the rocks must have been precisely like that of the Littleton formation and Moose River standstone. Finally, of the greatest importance is the fact that before these fossils were discovered the mica schists in which they occur were correlated with the Littleton formation, of Oriskany (Lower Devonian) age, on lithologic, stratigraphic, and structural grounds. The fossils are thoroughly consistent with this interpretation.

COMPARISON WITH BERNARDSTON LOCALITY.

At Bernardston, Massachusetts, fossils have been found in highly metamorphosed sediments belonging to the mesozone. They were first described by Edward Hitchcock (4) in 1833, but the most complete description of the locality is that by B. K. Emerson (3, pp. 253-299). The only identifiable fossils come from one locality, about seventh-eighths of a mile N. 10° W. of the village of Bernardston. Some of the fossils are found in a highly recrystallized marble, and others in a quartz-mica schist about 25 feet stratigraphically higher. The mica schists in the adjacent outcrops contain such minerals as biotite and garnet, indicative of mesozonal metamorphism. Staurolite occurs in the schist both to the east and west.

The fossils are brachiopods, corals, and crinoids. In 1895 John M. Clark (3, p. 259) concluded that the enclosing strata were upper Devonian, and this correlation has been accepted ever since. As early as 1883, however, Whitfield (6) had suggested that the limestones in the Bernardston formation might be middle Silurian. Lithologically the limestones and associated quartzites are very similar to the Fitch formation of New Hampshire, and the writers suggest that the age of the Bernardston rocks might well be restudied.

Although a greater assemblage of forms is found at Bernardston, the Mt. Clough locality is in some ways more surprising, for the enclosing rocks belong to the katazone and are injected by pegmatite dikes.

Although there are numerous fossil localities in New England besides the Bernardston and Mt. Clough occurrences, as far as the writers are aware they are all in low-grade metamorphic rocks, rocks which in the Grubermann-Niggli classification would be classified either as unmetamorphosed sediments or epizonal metamorphic rocks.

Such occurrences as those at Bernardston and Mt. Clough

indicate, therefore, that the search for fossils in the highly metamorphosed schists of New England is not futile. Although the identification of species will probably always be impossible, and the recognition of genera difficult, such discoveries in the future may shed great light on the Paleozoic history of New England.

REFERENCES.

1. Billings, Marland: Geology of the Littleton and Moosilauke quadrangles, New Hampshire, State Planning and Development Commission, New Hampshire, 1935.
2. ——— and Cleaves, Arthur B.: Paleontology of the Littleton area, New Hampshire; this Journal, vol. 28, pp. 412-438, 1934.
3. Emerson, Benjamin K.: Geology of Old Hampshire County, Massachusetts; Mon. 29, U. S. Geol. Survey, 1898.
4. Hitchcock, Edward: Report on the geology, mineralogy, botany, and zoology of Massachusetts, 1833.
5. Grubenmann, U., and Niggli, P.: Die Gesteinsmetamorphose, 1924.
6. Whitfield, R. P.: Observations on the fossils of the metamorphic rocks of Bernardston, Massachusetts; this Journal, vol. 25, pp. 368-369, 1883.

HARVARD UNIVERSITY,
CAMBRIDGE, MASS.