MINERALS IN BATES LIMESTONE, LEWISTON, MAINE*

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INTRODUCTION

Location.—The city of Lewiston is located in the southwestern part of Maine, in Androscoggin County, on the left bank of the Androscoggin. The type locality of the Bates limestone is represented by the City quarry which is located in the southern part of Lewiston, in a low hill known locally as "West Rose Hill." This quarry is along the Brunswick division of the Maine Central Railroad, about one mile southeast of the Lewiston Lower Station. Another outcrop of the Bates limestone is to be found about one-half mile north of the City quarry, along the same railroad at Cedar Street. The Martin quarry, where the Bates limestone is worked, is about three-quarters of a mile south of the City quarry. In these three locations the Bates limestone shows the same general structural and mineralogical characteristics. Igneous intrusions of varying types occur in all three locations.

Local Geology.—The Bates limestone is exposed in the City quarry in a working face which is about 300 feet long and about 60 to 75 feet high. Numerous smaller abandoned pits are to be found on the northwestern slope of West Rose Hill. The Cedar Street location has as great a linear extent as the City quarry but is not as well exposed vertically. The Martin quarry is not as extensively developed as the City quarry. Pegmatites and basic dikes are very common in the City quarry, but the later intrusions are missing at both the Cedar Street and Martin quarry locations.

The Bates limestone has been metamorphosed but bedding planes are still visible. The thickness of the beds varies from a fraction of a foot to several feet. The general strike of the quarry rocks is northeast and the dip northwest. The dip increases rapidly in the immediate vicinity of West Rose Hill. Differences in mineral composition in the various beds are brought out beautifully by differences in weathering. At least five different mineralogical zones have been noted.

IGNEOUS INTRUSIONS IN THE LIMESTONE

Leucocratic Dikes.—Two large masses of pegmatites and numerous smaller pegmatitic and aplitic veinlets cut the limestone at the three localities indicated. The larger masses of pegmatites are made up of large

* Paper read before the *Mineralogical Society of America* at the New York meeting, December 28, 1935.

feldspar crystals, muscovite, some long, narrow, blade-like forms of biotite and large crystals of schorl. Some of the pegmatite zones show abundant graphite.[1]

Aplitic dikes may be seen in abandoned pits in West Rose Hill, in the City quarry proper, and at Cedar Street. In the City quarry minor faults in the aplite have been noted. Numerous small stringers of quartz were given off by these aplitic intrusions. In some of these quartz veins pyrrhotite and graphite have been found.

It should be kept in mind that the Lewiston area is only a few miles east of the famous Mount Apatite pegmatite region, and a few miles west of the Topsham pegmatite locality. An incomplete study of the sequence of formation of the pegmatites indicates that there were two, possibly three, periods of invasion by the acid dike rocks.

FIG. 1. A portion of the Lewiston City quarry showing trap dikes numbers 5 (left) and 6 (right). Height of quarry, 65 feet, distance between the dikes, 23 feet.

Melanocratic Dikes.—There are at least 16 basic dikes in the West Rose Hill area and seven of these are exposed in the present working face of the City quarry. Some of these basic dikes are two to four feet wide, the largest being 16 feet in width. Some of the dikes show hard, baked zones, and others a zone of loose or soft rock in contact with the limestone. Some of the baked zones are highly discolored. Most of the dikes show phenocrysts of feldspars and others have pyriboles and olivine phenocrysts. Some of the dikes, especially those in the abandoned pits, show typical vertical and transverse fractures with subsequent "step" development. The dikes have been numbered in order that the later discussions may be clearer. Those shown in the illustration are dikes Nos. 5 and 6. They are about 23 feet apart. Dike No. 5 is badly weathered along the contact,

[1] Fisher, Lloyd W., Graphite in Pegmatite: *Am. Mineral.*, vol. **19**, pp. 169–177, 1934.

but No. 6 shows a chilled zone. Studies made in 1930 showed a north-south fault in the upper part of dike No. 6 with displacement about equal to the thickness of the dike. This displacement is not now shown in the quarry face. Dike No. 8, about 100 feet south of dike No. 6, is faulted near the quarry floor.

Some of the basic dikes show chilled zones against the limestone but others show a very sharp contact. Many of the chilled zones are yellowish brown in color but others are purplish black. One of the largest dikes shows a displacement equivalent to the width of the dike. There are numerous smaller offsets in both basic and acidic dikes. There is also one multiple dike. It is suggested that these dikes represent several closely related invasions of the same basic magma in fractures in the Bates limestone.[2]

Summary of the Geologic Sequence.—The Bates limestone cannot be traced for any great distance along the line of strike because of heavy glacial cover and the past building activities in the immediate vicinity. The limestone appears, however, to represent a lens in a larger series of rocks. A knowledge based on field studies indicates the following probable sequence of formations and events in the environs of Lewiston.

Post Silurian..................	Trap dikes (youngest in the region)
	Pegmatites, aplites and granites
Cambro-Ordovician?............	Tacoma Series
	Sabattus garnet schist
	Minwah limy gneiss
	Hill Ridge biotite schist
	Stetson Brook limestone
	Thorncrag limy gneiss
	Bates limestone
	Androscoggin gneiss and schist
Pre-Cambrian..................	Ortho-gneisses.

Pegmatites and basic dikes cut all the metamorphosed sediments in the immediate region. The pegmatites appear to be post-Cambrian to Carboniferous in age. The trap dikes are the youngest rocks of the region and are possibly post-Paleozoic.

Description of Thin Sections

Limestones near Pegmatites.—Slides made from specimens taken about nine inches apart in a limestone bed, four inches above the contact with the graphite-bearing pegmatite, show a number of interesting features. Calcite plates are numerous in some of the slides and are subordinate to brown mica in others. Twinning lamellae in the calcite are not bent or

[2] A paper on the trap dikes of the Lewiston City quarry is being prepared by Wendell Crawshaw.

curved. Scapolite grains are fairly common and are, in general, almost completely surrounded by calcite. Graphite is quite abundant in some of the slides. In one of the slides graphite flakes are arranged in a streak suggesting a conduit for the producing materials. There are scattered feldspar grains, most of them being close to the calcium end of the plagioclase series. Tremolite and actinolite have been partially replaced by chlorite. These prismatic minerals show frayed ends against the adjacent minerals. Diopside is more common than either actinolite or tremolite, and is fairly fresh. Clinozoisite is less abundant than the amphiboles and pyroxenes, but more abundant than feldspar and scapolite.

The biotite plates in the slides, from specimens near the pegmatite, show a number of interesting features. In one slide there is a very definite foliation of the plates and in others the foliation is either weak or lacking. Where foliation is strong other prismatic minerals, such as diopside and actinolite, have been developed at approximately 45 degrees to the long axis of the mica. Zircon is the chief accessory mineral. Apatite, in small, bluish grains is sparingly found.

In some of the slides, taken from specimens obtained from the City and Martin quarries, amphiboles and pyroxenes appear to be segregated into zones, although the individual minerals are not oriented in any definite direction. In specimens where such apparent zoning is noted, graphite and pyrrhotite are fairly common. Both these accessory minerals are developed in thin veinlets or along the cleavages of earlier minerals. Calcite plates are fairly rare in these specimens of zoned pyriboles.

A highly silicified limestone is represented by slides taken north of dike No. 5 in the City quarry. In slides of this type of limestone quartz occurs in two forms; as zones of granulated quartz in which very few adjacent grains extinguish at the same time, and as elongated, fractured and strained quartz. In one of the slides there are four zones of crushed and three zones of elongated quartz. Chlorite is moderately abundant at the contact between two of the zones. Zircon is enclosed in some of the chlorite suggesting the formation of this latter mineral from biotite. One nearly perfect euhedral grain of vesuvianite occurs with the elongated quartz. The crushed zones show some feldspar belonging to the albite-oligoclase end of the plagioclase series. There is no calcite in the four slides of this type of limestone.

Contact Types.—Two sets of slides representing contact action of the basic dikes on the limestone were also studied. The contact of trap dike No. 6 with the limestone shows the development of much biotite. The plates and flakes are well oriented. Foliation is approximately at right angles to the contact. The oriented biotite shows a fairly wide zone in the slide, but gives way rather abruptly to a zone in which zoisite, feldspar and quartz are the chief minerals, in the order named. This zone is succeeded by one composed chiefly of calcite plates in which there are metacrysts of diopside, a few slender needles of actinolite, replaced by chlorite, and some graphite. Ten feet north of the contact with dike No. 6 calcite is more abundant, chlorite is more scattered throughout the slide, and biotite plates are not oriented. Amphiboles and pyroxenes are next in importance to calcite. The boundaries of the minerals in this zone are more rounded than at the contact. In both cases, near the dike and at a distance from it, graphite shows no apparent preference for a host mineral. Accessory minerals are vesuvianite, zircon, and titanite.

An entirely different contact condition is noted on the south side of dike No. 5. A fairly large area of strongly pleochroic tourmaline comes in contact with the dike. Vesuvianite is very abundant near the contact and the contact zone is more highly altered than that of dike No. 6. The biotite plates of dike No. 5 are more thoroughly chloritized than at dike No. 6.

General Conclusions

The mineral associations noted in the different zones in the limestone suggest that the Bates limestone was originally an impure magnesium carbonate formation. Various types of metamorphism have transformed some of the original differences into different relative proportions of the minerals in the same bed, and into different mineral assemblages in adjacent beds. The development of calcium and magnesium silicates, as diopside, chlorite and zoisite in fairly large amounts, and tremolite, green hornblende and actinolite, in smaller amounts, suggest a rearrangement of original chemical constituents of the limstone. Scapolite, vesuvianite and tourmaline, the latter only occasionally, indicate additions from the intruding magmas. The abundance of quartz veins near some of the trap dikes suggests introduced material. Occurrences of graphite in the pegmatite, and of graphite and calcite, in some of the basic dikes, indicate a slight amount of assimilation by those dikes.

The general lack of parallelism of the prominent prismatic minerals suggest that dynamic metamorphism was not an important factor in the area. In a few of the slides examined plates and blades of biotite show parallel arrangement. This might be due to pressure or to the preservation of biotite in streaks or lenses originally rich in that mineral in the sediments. The zonal arrangement of some of the minerals, as diopside, zoisite and biotite, noted especially in hand specimens, might have been inherited from the original sediments. Granulation of quartz is noted in only a few of the slides and all of these represent specimens taken from near pegmatitic or aplitic intrusions. The bending of mica plates and the development of calcite twinning planes are not common. It thus appears that dynamic metamorphism is not the controlling factor in the formation of minerals now occurring in the Bates limestone.

There are no pronounced metamorphic aureoles around either the acid or basic intrusives, but the presence of vesuvianite, scapolite and tourmaline, as noted above, suggest introduced materials. No well developed garnet zones are found associated with the basic dikes. This fact together with the observation that most of the trap dikes show chilled borders, indicate a rather low temperature for the invading basic material.

The close proximity of the large pegmatite dikes of Mt. Apatite, six miles west of the City quarry, the Topsham pegmatite, about twelve miles east, and the Woodbury granite, four miles to the south, suggest the presence of a large granitic batholith underlying the Lewiston area. The presence of certain minerals foreign to the limestone is accounted for by assuming the introduction of materials by solutions and gases from this underlying batholith.

A medium to low grade of metamorphism is suggested by the suite of minerals encountered, and by the development of a crude, crystalloblastic texture of some of the minerals that form at moderate temperatures. In some of the slides two generations of biotite follow different planes of foliation which are at angles to the plane of foliation followed by the amphiboles and pyroxenes. Two-fold metamorphism is suggested by these features.

It is believed that the initial change in the minerals of the limestone was caused by the heat, gases and possibly solutions given off by the underlying granitic batholith. This contact metamorphism was then followed, on a smaller scale, by the intrusive action of the pegmatites, aplites and associated quartz veins. The basic dikes are the youngest rocks in the region and their injection apparently caused very little change in the limestone.