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Spodumene deposits in the Leominster-Sterling Area, Massachusetts

by M. P. Billings and C. W. Wolfe

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Contents.

Prefatory Note

The mineral spodumene, a lithium-aluminum silicate having the composition $LiAl(SiO_3)_2$, is an important source of lithium, and is used in the chemical and ceramic industries. Its increased use since 1932 had so stimulated interest in sources of the mineral that a reexamination of certain known domestic deposits of lithium-bearing minerals was undertaken by the Geological Survey, under the "war minerals" program.

Like numerous non-metallic minerals, lithium minerals have an important but comparatively small market, and at the moment national demands appear to be satisfied by mining developments in North Carolina and South Dakota, so that new developments elsewhere would find themselves on a highly competitive basis. Nevertheless, greatly increased demands for various industrial minerals often develop rapidly and it is desirable to make an inventory of potential resources so that such demands could be met as promptly as possible.

Spodumene has long been known to occur at several places in Massachusetts. So far as available data show, the spodumene-bearing pegmatite veins that occur in the vicinity of Leominster seem to be the most promising. This area has not hitherto been closely examined as to its potential value for furnishing spodumene, although it has been recognized by some that considerable spodumene occurs there.

The commercial value of the Leominster-Sterling deposits can be determined only by considerable sampling and exploration. For such operations a basic geologic study is necessary in order that trenches for sampling and drill holes for exploration can be most advantageously placed. The object of this brief report is to provide such geologic data. Recoverable mineral contents of the different pegmatitic bodies should be determined by taking large samples from trenches cut at regular intervals across the exposures, and by experimental separation of the spodumene in a well equipped laboratory. The lengths of outcrops can be determined by stripping off the glacial overburden, but the vertical extent of the pegmatitic bodies can be ascertained closely by core drilling.

The object of this brief report is to place on public record the surface geologic data necessary for such exploratory operations when and if market conditions appear favorable. The probable economic value of the deposits cannot be stated until the deposits are adequately explored and sampled. The report is not to be construed as recommending such operations at this time; rather, it is presented as an item in the inventory of mineral deposits of the Commonwealth.

The work was done as part of a cooperative project between the Massachusetts Department of Public Works and the United States Department of the Interior, Geological Survey, and was incidental to the general program for preparing a detailed geologic map of The Commonwealth. During the present emergency period, it has been the policy to continue the general geologic mapping program only in areas where deposits of industrial mineral have been reported to exist. Besides contributing, therefore, to the object of the cooperative project, it also serves to supplement the important general review made by the Governor's special advisory committee on mineral resources of the State.

The report by Messrs. Billings and Wolfe, on the spodumene deposits of the Leominster-Sterling area, follows.

SPODUMENE DEPOSITS IN THE LEOMINSTER-STERLING AREA, MASSACHUSETTS

by

M. P. Billings and C. W. Wolfe.

Scope of Work

Spodumene-bearing pegmatites are exposed in the towns of Leominster and Sterling, along a north-south belt about 2½ miles long and a thousand feet wide. The northern end of this belt is 1½ miles southwest of Leominster post office. Most of the exposures are in the town of Leominster; three were found in the northern part of Sterling. The locations of the two areas studied for this investigation are shown on the key map, figure 1.

For mapping, the belt was conveniently divisible into two adjacent areas. The northern part lies within the Fitchburg quadrangle, and herein is called the Long Hill Area; the southern part lies within the Sterling quadrangle, and is called the Rocky Hill area. Because of the inaccuracy and small scale of the Fitchburg quadrangle topographic map, surveyed in 1887, it was necessary to prepare a large-scale plane-table map of the Long Hill area on which all rock exposures were mapped (figure 2). The Sterling quadrangle topographic map was surveyed in 1938, on a larger scale than the earlier (Worcester quadrangle) map, of which it corresponds to the northeastern quarter, and a photographic enlargement serves adequately as a base for plotting the exposures of the Rocky Hill area (figure 3).

The Long Hill and Rocky Hill areas as mapped are continuous, and corresponding points in each on the junction line are marked A, (figures 2 and 3), but these two maps do not agree in scale, because it would be undesirable either to reduce figure 2, or enlarge figure 3.

The geology was studied by M. P. Billings and C. W. Wolfe between July 8 and August 14, 1943. Complete outcrop maps of the two areas were made, and all exposures were examined in detail. Notable boulders of spodumene pegmatite, or concentrations of boulders, were also mapped.

Rock Formations

Similar formations are exposed in the two areas, so that a single set of symbols has been used for both maps. The formations mapped include (a) metamorphic rocks of sedimentary origin, (b) an intrusive mass of granitic rock, technically known as a granodiorite, (c) quartz veins, and (d) pegmatite veins.

Metamorphic rocks:- These include alternating beds of phyllite, schist, and quartzite, probably derived from shales and sandstones, but recrystallized and in part mineralogically reconstituted by heat, pressure, shearing stresses, and the permeation of solutions derived from intruding granitic material. According to Emerson 1/ these formations are of Carboniferous age; on his geologic map of

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1/ Emerson, B. K., Geology of Massachusetts and Rhode Island: U. S. Geol. Survey, Bull. 297, p. 59 at sec., 1917.

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the State, he designated these beds as belonging to the Worcester phyllite, the Boylston schist, and perhaps part of the Oakdale quartzite, but, as such distinctions are not necessary for the purpose of this paper, all these beds are included on the accompanying maps under the symbol m, for "metamorphic rocks." A brief lithologic description of the beds as they occur in this locality follows.

The phyllite beds are dark, foliated rocks, locally containing comparatively large crystals (porphyroblasts) of staurolite, garnet, and biotite. Toward the west, near the granodiorite, the phyllite beds are metamorphosed into schist which locally contains andalusite porphyroblasts 1/2 to 2 inches long; generally this mineral has been converted to a matted aggregate of staurolite, muscovite, and quartz. Sillimanite and black tourmaline have been observed in the schists in a few places near the granodiorite.

The quartzites are of two general types, gray and brown; they consist chiefly of quartz but also contain variable amounts of biotite, muscovite, and garnet. The brown quartzites, which are more massive than the gray, are confined to the southeastern part of the area.

Although bedding stratification may be observed locally in the metamorphic rocks, schistosity due to recrystallization and shearing is far more conspicuous.

Granodiorite:- A granitic igneous rock, known technically as "granodiorite", (labelled **g** on the accompanying maps), is exposed extensively in the western part of the spodumene area. This rock is medium-grained, dark-gray, and consists of feldspar, quartz, and biotite, the last constituting about 15 percent of the rock. It is commonly foliated, so that on exposed surfaces it appears to be banded. Locally, especially near contacts with the metamorphic rocks, a fine-grained facies of the granodiorite superficially resembles some of the quartzites. Emerson considered the granodiorite to be a border facies of the Fitchburg granite, but mineralogically and structurally it does not resemble typical Fitchburg granite.

Quartz veins:- Veins of quartz, generally as layers parallel to the foliation, are locally common in the metamorphic rocks. They range in thickness from a fraction of an inch to several inches. In the Sterling quadrangle a quartz vein on the west slope of Bee Hill is 425 feet long and averages 15 to 20 feet wide.

Pegmatites:- Veins of pegmatite cut both the metamorphic rocks and the granodiorite. They show a considerable range in size, and some are too small to be represented on the maps. For the most part they are comparatively short and no single pegmatite has been traced definitely for more than 250 feet, though it is probable that several of them may be considerably longer but have their extensions completely obscured by glacial overburden.

Many of the pegmatites follow approximately the north-south trend of the country rocks, others cut across this trend, and still others follow a zig-zag pattern both along and across the trend. In particular, pegmatite #1, about 1,000 feet north-northwest of the Boutelle farmhouse, shows a very irregular trend.

In general, the pegmatite bodies show considerable variation in width as well as trend, and their exposures may be described as roughly lenticular; the contacts are also commonly irregular in detail, though they are more regular where they follow the foliation of the enclosing beds.

As mapped, the pegmatite veins appear to be most abundant near the contact between the granodiorite mass and the metamorphic rocks, but this may be only an apparent localization; for rock exposures are much more numerous on the broad ridges (Long Hill and Rocky Hill) than elsewhere, and the crests of these topographic features appear to have been formed on the more resistant granitic rock; on the other hand, the formation boundary, as shown on figures 1 and 2, is well up on the east sides of these ridges, and on Long Hill it is not far from the crestline, a condition that suggests a possibly greater invasion of granitic (pegmatitic) material in the contact zone than elsewhere in the area of the metamorphic rocks.

Boulders (glacial erratics), which have probably not travelled far from their parent ledges, are exceedingly abundant in the Rocky Hill area (figure 2).

As to mineral composition the pegmatites may be classified in two groups--those with spodumene and those without. All the pegmatites are composed largely of quartz and feldspar. Muscovite, as flakes averaging 1/8 inch in diameter but with a maximum diameter of approximately 1 inch, averages 1 percent (rarely as much as 2 percent) of the rock; blue tourmaline crystals, up to ½ inch in diameter and 3 inches long, have been seen in several exposures; black tourmaline occurs in the non-spodumene pegmatites. Along the margins of many of the pegmatites a contact facies, averaging 8 inches thick, consists chiefly of fine-grained quartz and muscovite.

The spodumene pegmatite deposits are discussed in further detail beyond.

Structure:- All of the country rocks are characterized by a foliation that strikes north (generally from N. 10°E. to N. 10°W.) and dips 60 degrees west (generally from 40°W. to 80°W.). The bedding in the metamorphic rocks is usually parallel to the thin foliation or schistosity. Small folds are common; although shown occasionally by the bedding, they are displayed far more conspicuously by the quartz veins. The axial planes of these small folds dip 60°W., and the axes plunge 60°W.--that is, directly down the dip of the axial planes.

The Spodumene Pegmatites

Exposures of spodumene-bearing pegmatites are most abundant in the northern two-thirds of the Long Hill area (see figures 2 and 3). Elsewhere they are rare. Attention is directed (figure 3) to the exceptional abundance of boulders in the Rocky Hill area, which were doubtless derived from ledges of the north. Only the larger boulders have been indicated on the maps, but their distribution, quantity, and large size of some of them (up to 4 feet in diameter) are noteworthy because collectively they may contain a considerable tonnage of spodumene.

The spodumene pegmatite bodies as measured in the field average 66 feet in length, 12 feet in width and about 830 square feet in area. One of the largest, (No. 7 in figure 2) is 160 feet long and 40 feet wide, and is exposed over an area of about 5,000 square feet. Pegmatite No. 16, although not continuously exposed, appears to be 270 feet long and 15 feet wide, but, because gaps in the exposure total 65 feet, the length given in the table, page 8, is 205 feet.

Mineralogy:- Besides spodumene in exceptional abundance, the spodumene pegmatites contain minor amounts of green to blue tourmaline, and local mineralogists have reported also a little amblygonite, pollucite, and purpurite.

The spodumene crystals occur as rectangular plates in which the ratio of length to breadth to thickness is about 10:4:1. The average crystal is one to two inches long; the largest crystals observed in outcrops are 6 inches long, but in glacial boulders crystals 12 to 24 inches long are common, and in one boulder a crystal 60 inches long was found. The larger crystals of spodumene tend to be buff colored, but the smaller crystals are white and have a silky lustre. Many of the crystals an inch long or less are colorless and glassy.

As based on field estimates, the average spodumene content of all the spodumene pegmatites is 10.4 percent, although small pockets a foot or two across may contain as much as 40 percent. Feldspar is generally present as crystals 1½ inches to 2 inches in maximum length and only rarely exceeds 6 inches in length. It averages 64 percent of the pegmatite. Quartz is characteristically milky, averages ¼ inch in diameter, and rarely is as much as an inch in diameter. It averages about 25 percent of the spodumene pegmatites.

Economic considerations:- The following table may be used as a basis to estimate the tonnage of spodumene available.

SPODUMENE PEGMATITES OF THE LEOMINSTER-STERLING AREA, MASSACHUSETTS

No.	Length (Feet)	Max. Width (Feet)	Depth (Feet)	Area Sq. Ft.	Volume Cu. Ft.	Pegmatite Tons	Spodumene Av.%	Spodumene Max.%	Tons
1	110	15	10	1000	10000	750	8	20	60
2	25	10	10	200	2000	150	4	7	6
3	70	20	10	1000	10000	750	10	15	75
4	22	5	10	100	1000	75	5	7	4
5	13	4	10	50	500	37.5	8	10	3
6	70	20	10	1000	10000	750	10	12	75
7	160	40	10	5000	50000	3750	12	20	450
8	110	15	10	1500	15000	1125	8	12	90
9	15	5	10	50	500	37.5	5	10	2
10	70	20	10	1000	10000	750	10	16	75
11	250	20	10	4000	40000	3000	12	15	360
12	150	12	10	1600	16000	1200	8	15	96
13	100	7	10	600	6000	450	6	7	27
14	19	3.5	10	57	570	42.8	7	7	3
15	35	5	10	175	1750	131	10	12	13
16	208	12	10	2200	22000	1650	9	14	149
17	30	5	10	100	1000	75	12	15	9
18	60	15	10	800	8000	600	14	20	84
19	80	10	10	600	6000	450	5	12	22
20	100	5	10	450	4500	338	8	20	27
21	27	7	10	180	1800	135	10	12	13
22	40	12	10	450	4500	338	14	18	47
23	20	3	10	50	500	37.5	0	1	0
24	70	15	10	800	8000	600	8	18	48
25	20	12	10	200	2000	150	10	16	15
26	8	5	10	35	350	26	5	5	1
27	22	12	10	250	2500	137.5	12	18	23
28	22	8	10	175	1750	131	15	25	20
29	55	27	10	1375	13750	1031	14	30	144
30	11	5	10	50	500	37.5	10	--	4
Av.	66.4	11.8	10	833	8349	626	10.4		64.8
Totals						18,785.3	10.4		1945

Nos. 1-27 (inclusive) are in the Long Hill area (Figure 2).
Nos. 28-30 (inclusive) are in the Rocky Hill area (Figure 3).
Numbers in the first column refer either to a single continuous exposure of pegmatite or to a group of adjacent exposures; thus No. 7 refers to a single large exposure, and no. 2 refers to two adjacent exposures. Length, as given in the second column refers to the total length of all the pegmatite exposures grouped under a single number.
No. 29 may be a large boulder.

The area of the exposures can be determined with considerable precision. The percentage of spodumene given is probably reasonably close. The depth to which mining can extend is a variable, depending upon several factors, and for purposes of calculation, a depth of 10 feet has been used. For every 10 feet of mining, about 2,000 tons of spodumene is estimated. If mining goes to a depth of 50 feet, 10,000 tons of spodumene would be available on this basis. These figures are considered to be very conservative, as they are based on areas of actual exposure. Reasonable extrapolation of known exposures would double the amount of spodumene, making it 4,000 tons for every ten feet depth of mining, or 20,000 tons if mined to a depth of 50 feet. The depths to which the pegmatite may extend and contain spodumene, however, is not known and needs to be determined by drilling.

Exploration by mining, trenching, drilling, and other methods would undoubtedly uncover more spodumene pegmatites. This is particularly true of the southern half of the Long Hill area. Exposures here are not numerous, but the glacial boulders suggest that somewhere in the area there are pegmatites with large spodumene crystals.

Exploration might also uncover large bodies in the southcentral part of the Rocky Hill area, between the Heywood Reservoir and Hapgood Road (fig. 2). One definite outcrop of spodumene pegmatite is known in this area, but boulders of spodumene pegmatite are abundant. Similarly, west of Hapwood Road, exposures are rare, but here, also, boulders are abundant.

The pegmatites are readily accessible. Good roads skirt the eastern part of the Long Hill area (fig. 1) and a good dirt road passes through the middle of the Rocky Hill area (fig. 2). Farm and woods roads, with grades that are not too steep, are not far from the pegmatites.

Exploration to the north and south of the area mapped would be a long, tedious task, and reconnaissance suggests it would be unprofitable. The first step would be geologic mapping. From observations made in the Leominster-Sterling area it is apparent that the spodumene pegmatites are concentrated within a few hundred feet of the contact between the metamorphic rocks and the granodiorite facies of the Fitchburg granite.