QUARTZ AND FELDSPAR.

FELDSPAR AND QUARTZ DEPOSITS OF MAINE.

By Edson S. Bastin.

INTRODUCTION.

The commercially important feldspar and quartz deposits of Maine all belong to a single type of rocks known to the geologist as pegmatites. These rocks may be defined as coarse-grained crystal aggregates which as a rule have the composition of granite, their principal constituents being feldspar, quartz, and mica, usually with subordinate amounts of other minerals. The pegmatites of Maine were studied by the writer during part of the summer of 1906, the work being done in cooperation between the State Survey Commission and the United States Geological Survey.

GEOGRAPHIC DISTRIBUTION.

These deposits are confined largely to Sagadahoc, Cumberland, Androscoggin, and Oxford counties, in southwestern Maine, though occurring to some extent in association with all the large granite masses in other parts of the State. Excellent exposures occur in many open pits, from which feldspar, quartz, mica, or gem minerals have been mined, and in the cliffs along the seacoast, especially in the Boothbay Harbor region.

GEOLOGIC OCCURRENCE.

The pegmatites form masses that are plainly intrusive in the surrounding rocks. The latter are for the most part shaly sediments, probably of early Paleozoic age, which have been closely folded and altered to slates and schists. This alteration took place at the close of Ordovician time, during a period of dynamic or regional metamorphism which affected most of New England. In many of the more argillaceous layers the regional metamorphism has developed a fissility which is in some places highly inclined to the bedding planes and in others nearly parallel to them, depending on the character of

the folding. In the more quartzose layers, however, secondary fissility has been developed but weakly if at all, and such layers are in general numerous enough to define the trend of the original bedding and to render this the direction of easiest parting so far as the intrusion of considerable masses of igneous rock is concerned. Over large areas the rocks have been thrown into a series of closely compressed (isoclinal) folds standing in highly inclined positions, and in such areas the secondary fissility is as a rule nearly parallel to the bedding planes. The form of the pegmatite bodies, which in their intrusion followed in general the direction of least resistance, is therefore dependent largely on the position of the bedding planes in the surrounding sedimentary strata. Their form in regions of highly inclined strata is well shown along the shore near Boothbay Harbor, where most of the pegmatite masses are highly inclined and dikelike in form, though differing from the many dikes of diabase and of normal granite of the same region in not showing parallel walls, the typical form being a succession of lenticular masses produced by repeated pinchings and swellings of the dike. In regions where the sedimentary strata are but slightly inclined the pegmatite masses are flat-lying and sill-like rather than dikelike in form, though showing the same tendency toward lenticular form or toward repeated pinchings and swellings along the length of the sill. On account of their flat-lying character many pegmatite bodies of the latter type cover considerable areas and show a rather irregular surface outcrop. Other bodies are exposed only in cross section in a quarry cut or along the side of a valley. One of the best examples of the flat-lying pegmatite masses is exposed in the bed of Androscoggin River just above the road bridge between Lewiston and Auburn. The inclosing rocks here are gray to purplish slates that show distinct bedding and dip to the northeast at angles of about 30°, and several sill-like masses of pegmatite are intruded parallel to their bedding planes. The largest mass is lens-shaped, with a maximum thickness of 15 feet, and is exposed laterally for 300 feet, though probably extending much farther. The position of the falls here is undoubtedly dependent on the fact that this sill and the injected sediments adjacent to it offer more resistance to erosion than most of the schists. The pegmatite body that is worked for its gem minerals at Mount Mica, in Paris, Oxford County, is another example of the flat-lying, sill-like type. The sedimentary schists here dip 20° to 30° SW. and the pegmatite mass, apparently 20 feet or so in thickness, has a similar dip. Other pegmatite masses are unlike either of the types just described, but seem to be large, somewhat irregular stocks of uniform character throughout. One of the best examples of this type is Streaked Mountain, in the northwest corner of the town of Hebron, Oxford County, which is almost wholly pegmatite and seems to be a great dome of this rock.

ORIGIN AND AGE.

It is not possible here to enter into a detailed discussion of the origin of these pegmatites. There can be no doubt, however, that they represent simply one phase of the granitic intrusions so abundant in the southern and southeastern parts of the State. The evidence of this is found in their distribution with respect to the areas of true granite, in the presence of dikes and irregular intrusions of true granite in all the regions where pegmatite occurs, and in an actual gradation from pegmatite into fine-grained granite observed at many localities. The granites of the eastern part of Maine are known to be late Silurian or Devonian in age, and there is every reason to believe that the granites of southern Maine, with their associated pegmatites, are of similar age. They are certainly later than the period of dynamic metamorphism at the close of the Ordovician.

GENERAL CHARACTERS.

COMPOSITION.

The pegmatites in all parts of the State show great similarity in the principal minerals developed, although they exhibit notable differences in the minor constituents. In mineral composition they are essentially coarse granites, the principal light-colored constituents being potash feldspar, quartz, and muscovite, and the principal dark-colored constituents black mica (biotite) and black tourmaline. In pegmatites where black mica is abundant, black tourmaline is, as a rule, rare or absent, and vice versa. Accessory constituents that are almost invariably present are garnet, magnetite, and opaque green beryl. Accessory minerals that are present only in certain pegmatites number over 50 species; but perhaps the most important are lepidolite or lithium mica; blue, green, and pink tourmaline; transparent green or golden beryl, topaz, and amethystine quartz. In some places, as at Mount Mica, in Paris, Oxford County, certain of the gem minerals are present in considerable quantity and are of the finest quality, so that the pegmatite can be profitably exploited as a gem deposit.

COARSENESS AND TEXTURE.

The pegmatites show remarkable variation in coarseness, some, especially the narrower dikes and sills, being little coarser than coarse-grained granites, though differing from the latter in texture. In others single crystals of nearly pure feldspar may be 20 feet across, and single beryl crystals may reach the diameter of a hogshead. The major part of the pegmatites are nearer the lower limit of coarseness than the higher. Only the coarser bodies are commercially valuable for their feldspar, quartz, mica, or gem minerals, and these constitute

a relatively small percentage of the total mass of pegmatite material. In most of the pegmatites worked commercially the feldspar and quartz crystals do not average more than 4 or 5 feet in diameter.

The most striking characteristic of the texture of the pegmatites is its extreme irregularity. In a mass of typical granite there is considerable uniformity in size among grains of the same mineral species, but in the pegmatites there is no such regularity. A feldspar crystal, for example, is as likely to be two or three or even ten times as large as an adjacent crystal as to be of similar size. In most of the pegmatites there is also much graphic granite, consisting of an intimate intergrowth or interpenetration of single crystals of quartz and feldspar, the quartz forming, on certain faces of the feldspar crystals, a peculiar angular pattern somewhat resembling the cuneiform inscriptions of the ancients. Fine-grained phases pass into coarser graphic granite and this by decrease in quartz may pass into masses of pure feldspar, or by decrease in feldspar into masses of pure quartz. Much of the material mined as "spar" is coarse-grained graphic granite containing from 10 to 20 per cent of free quartz.

In the great majority of pegmatite bodies there is no regularity whatsoever in the distribution of the different minerals. The mica plates show, in many places, a tendency to group themselves along certain planes, but these seem to have no definite orientation with respect to the general outline of the mass, and this arrangement is by no means universal. A pegmatite which is of excellent commercial quality as regards its feldspar content may grade within a short distance and in a wholly irregular manner into rock which is worthless because of its large percentage of quartz or the abundance of biotite, black tourmaline, or garnet.

USES.

FELDSPAR.

Practically all of the feldspar mined in Maine is used in pottery manufacture, its main application being as a constituent of both body and glaze in true porcelain, white ware, and vitrified sanitary ware and of the "slip" (underglaze) and glaze in so-called "porcelain" sanitary ware and enameled brick. The amount of feldspar in the body of these wares generally falls between 15 and 35 per cent, though in some it is less and in some more. In glazes the percentage of feldspar is as a rule between 30 and 50. Small amounts of very pure spar, carefully hand picked, are occasionally shipped for use in the manufacture of artificial teeth. Feldspar mined in other Eastern States is also used principally for pottery purposes, though finding some application in glass making, in dentistry, and in the manufacture of certain polishes and scouring soaps that are less abrasive than those in which ground quartz is used. Much interest

has recently been aroused in the use of potash feldspar for fertilizing purposes. Potash is an important plant food which in fertilizers has usually been applied in the form of easily soluble potash salts imported from Germany. Recent experiments conducted by the Department of Agriculture have shown that certain plants are capable of readily decomposing feldspar that has been ground to the fineness usually demanded in the pottery industry (200 mesh and finer). The Department of Agriculture is now carrying on an exhaustive series of experiments to determine what plants are benefited by the use of feldspar and the exact character of the materials needed, and to avoid failures due to the misuse of these materials it is safer for fertilizer manufacturers and others to await the published report on these tests.

QUARTZ.

At present (1906) there is no market for the quartz mined in Maine, even when produced as an accessory in feldspar mining. At some of the mines it is thrown on the waste heaps; at others it is collected in piles in the hope of a future market. It formerly found a somewhat unsteady market for pottery and sandpaper purposes. The low value of the crude material, about $2 per ton at the mines, makes it impossible for Maine quartz to compete with quartz from Connecticut, New York, Pennsylvania, and Maryland quarries, which are nearer to the markets.

METHODS OF MANUFACTURE.

Feldspar is ground at two mills in Maine—one at Cathance station, near Brunswick, operated by the Trenton Flint and Spar Company, of Trenton, N. J.; the other at Littlefield station, near Auburn, operated by the Maine Feldspar Company. The method of grinding is similar at both of these mills and is the same as that generally used by feldspar and quartz grinders elsewhere in the United States. The lump material as it comes from the quarries is first crushed in a chaser mill, of which each factory usually has several. This consists of two burrstone wheels about 3 to 5 feet in diameter and 1 to 1½ feet thick attached to each other like the wheels of a wagon by a horizontal axle. This axle is attached at its center to a rotating vertical shaft which causes the wheels to travel over a burrstone bed, the feldspar being crushed between the two burrstone surfaces. The material as it comes from this mill is screened, the tailings being returned to the chaser mills for recrushing and the fines going to ball mills for their final grinding. The ball mills consist of steel cylinders revolving on a horizontal axis. They are usually lined either with wooden blocks or blocks made of highly siliceous brick and are charged with pebbles of Norway or French flint 2 to 3 inches in

diameter. A single load of feldspar is usually ground for four to six hours in these mills and in that time is reduced to a fineness of at least 200 mesh. The material is then ready for shipment either in bulk or in bags.

Quartz used for pottery purposes is ground in the same manner as feldspar, but none is now being produced in Maine.

COMMERCIAL AVAILABILITY OF DEPOSITS.

The answer to the question whether it will pay to work a given feldspar or quartz deposit is dependent on a number of different factors. Considered as a whole, the Maine deposits have the disadvantage, as compared with those of Connecticut, New York, Pennsylvania, and Maryland, of being far from the markets, a feature which renders the mining of quartz wholly unprofitable. The bulk of the material mined in Maine under the commercial name of "spar" is not pure feldspar, but an association of feldspar and free quartz, usually intergrown in the form of a coarse graphic granite. In the past a number of the quarries have produced much larger amounts of feldspar free from quartz than can now be mined. The requirements of the potter's trade demand that in general the percentage of free quartz associated with the feldspar in the ground product shall not exceed 15 or 20 per cent, and certain potters demand a spar which is nearly pure, containing probably less than 5 per cent of free quartz. In order to be profitably worked, in most feldspar mines in Maine, between one-fourth and one-half of the total material quarried must carry under 15 to 20 per cent of free quartz.

A factor of the utmost importance is the amount and distribution of the iron-bearing minerals—black mica, garnet, and black tourmaline. For pottery manufacture the spar must be practically free from these minerals, which if present in the ground spar produce brown discolorations in white ware on burning. To be workable commercially, these minerals must be so rare or so segregated in certain portions of the deposit that they can be separated from the feldspar without much more hand sorting and cobbling than is necessary anyway in the separation of the highly feldspathic material from that which is highly quartzose. A number of coarse-grained masses of pegmatite with feldspar of excellent quality are rendered worthless for pottery uses by the abundance of one or more of these iron-bearing minerals. The presence here and there of minute flakes of white mica (muscovite) can hardly be avoided even in the highest grades of commercial feldspar, and chemically this mineral is not injurious. It is, however, exceedingly difficult to pulverize the flakelike flexible plates of mica to a fineness equal to that attained by the feldspar, and it is therefore necessary in mining to separate the muscovite carefully from the spar.

Under present conditions in Maine it is usually essential to commercial success that the feldspar deposits be located not farther than 2 or at most 3 miles from the railroad, so that the cost of haulage from the mines to the cars will not exceed 75 cents or $1 per ton, the average price for most of the crude spar in Maine being about $3 f. o. b. at the mines. The feldspar mills are situated on the railroads as close as possible to the mines. Nearly all the ground and crude spar is shipped to Trenton, N. J., and East Liverpool, Ohio, where many of the largest potteries of the country are located. The average price of the ground spar f. o. b. mills is about $9 per short ton.

METHODS OF MINING.

The feldspar and quartz of Maine are all mined from open pits. Unlike the deposits of Maryland and southern Pennsylvania, there is little or no associated kaolin formed by the decomposition of the feldspar. This is due to the fact that the Pennsylvania-Maryland region is unglaciated, whereas in Maine the ice planed off nearly all the products of rock decay. It is necessary, therefore, to sink drill holes and blast out most of the material with powder or dynamite. It is then broken up with sledges to lumps under 6 or 8 inches in size, and at the same time the quartzose and iron-bearing portions are sorted from the feldspar. The rock is hauled by teams to the mills.

DESCRIPTION OF PRINCIPAL LOCALITIES.

GEORGETOWN, SAGADAHOC COUNTY.

The Georgetown quarry is about 1½ miles northeast of Bay Point Landing, near the mouth of Kennebec River, and is readily reached by team from Five Islands, 4½ miles to the northeast, on Penobscot River. It is operated by the Golding Sons' Company, of Trenton, N. J. The spar is hauled about one-fourth of a mile by teams, then loaded onto scows and carried up Kennebec River 10 miles to Bath, where it is loaded onto cars for shipment to Trenton, N. J., and East Liverpool, Ohio. In the past some shipments have been made by sea. The quarry covers an area of about 3 acres and at its south end has a maximum depth of approximately 50 feet, though most of the quarry is much shallower. The pegmatite is inclosed by metamorphic sedimentary schists trending somewhat east of north. These are highly inclined and are somewhat injected by granitic materials, so that locally they become gneisses. The pegmatite mass is plainly intrusive in these shists, and its greatest length is parallel to their trend; it thus forms in reality a short dike. The present quarry openings cover almost the whole area of outcrop of this mass, and future work must consist largely in deepening the present pit. There seems every reason to expect that the rock will continue of good quality and of about

the same dimensions to a considerable depth. A number of other dikes of pegmatite of similar size and shape occur in this vicinity and some of them have been worked to a slight extent. None of these, so far as seen, showed any large amount of feldspar of the grade required for pottery purposes.

The rock now quarried is mainly a coarse graphic intergrowth of feldspar and quartz, and it is estimated that about 50 per cent of the total material excavated is of commercial grade. The quarry has been worked intermittently for over thirty years, and in the past has produced larger amounts of perfectly pure spar than at present. It is said that a single blast would sometimes loosen 100 tons of almost pure feldspar. Black mica is almost wholly absent. Black tourmaline is somewhat abundant, but is so aggregated in certain parts of the deposit that it can be easily separated in mining. Some deep flesh-colored garnet is also present. Muscovite (white mica) is only locally abundant. The feldspar is cream colored and is largely of the potash variety, as shown by the following analysis made by the Pittsburg testing laboratory:

Analysis of feldspar from Georgetown, Me.

SiO_2	65.23
Al_2O_3	20.09
Fe_2O_3	.71
K_2O	11.60
Na_2O	2.00
Loss on ignition	.36
	99.99

TOPSHAM, SAGADAHOC COUNTY.

Two quarries in Topsham are operated by the Trenton Flint and Spar Company, of Trenton, N. J. The larger quarry is about $1\frac{3}{4}$ miles northwest of Cathance station and the smaller about half a mile southwest of the larger. The spar is hauled by teams from these mines to the mill, which is located on Cathance River near Cathance station. During wet seasons the water power of the river is utilized, but the mill is also equipped with steam. The grinding machinery consists of three chasers and four ball mills, each capable of grinding a ton of spar in four to five hours. The capacity of the mill is about 16 tons a day. The quarry, which is the largest one in Maine, covers an area of several acres and is about 50 feet in maximum depth. In its southern portion the rock is very similar to that at the Georgetown quarry, being largely a graphic intergrowth of feldspar and quartz in greatly varying proportions. At the north end of the quarry the pegmatite is much coarser and graphic texture is practically absent. At one place a continuous bed of white quartz 10 feet high and 50 feet long is exposed, and adjacent to it is a mass of pure feldspar 15 feet across. The principal iron-bearing mineral at

this quarry is black mica (biotite) in lath-shaped crystals up to 3 or 4 feet in length. Most of it can be separated readily from the feldspar. Garnets are not abundant. Muscovite or white mica is uniformly of the A variety and nowhere of commercial grade. It is concentrated principally along certain planes and is not difficult to separate from the highly feldspathic rock. The surrounding rocks at this quarry are metamorphic schists, probably of sedimentary origin, which dip at steep angles and strike slightly east of north. Next to the pegmatite mass they have been much injected and also show signs of softening. The form and extent of the pegmatite body can not be accurately determined because of a scarcity of outcrops.

The smaller quarry one-half mile southwest of the large one was opened in 1906 and covers only about an acre, with an average depth of about 10 feet. In general the materials are similar to those of the large quarry. Some masses of pure feldspar are 10 feet across. Outcrops are very few in the immediate vicinity of this quarry and the form of the pegmatite body can not be determined. In both of these quarries the feldspar is mainly cream colored and of the potash varieties microcline and orthoclase. Crystals of white feldspar showing twinning striations on certain of their faces are albite, a soda feldspar, but they are not abundant.

Another quarry within a few rods of the small quarry just described is worked by the Maine Feldspar Company, of Auburn, Me. The output is very small and the character of the rock is entirely similar to that at the adjacent quarries. Feldspar has been quarried in the past at several other points in this vicinity, notably at Mount Ararat, near Topsham village.

AUBURN AND POLAND, ANDROSCOGGIN COUNTY.

The third important feldspar locality is Mount Apatite, in the town of Auburn, about 6 miles west of the city of Auburn. The quarry here is worked by the Maine Feldspar Company, the crude spar being hauled by team about 2 miles to the mill at Littlefield station, on the Grand Trunk Railway. This mill is equipped with one chaser larger than that used in most spar mills, each burrstone weighing 3½ tons. The ball mill also is longer than those commonly used and grinds 3 tons every four and one-half hours, the capacity of the mill being about 15 tons in twenty-four hours.

The rock mined at Mount Apatite is taken from a number of pits 75 to 150 feet long, about 50 feet wide, and 10 to 20 feet deep. These form part of a single mass of pegmatite covering most of the summit of the hill and intrusive into schists of probable sedimentary origin. Exposures are not continuous enough to trace the exact outlines of the mass, but its greatest extension seems to be in a north-northeast and south-southwest direction, parallel to the trend of the surrounding

schists. As at the other feldspar localities much of the commercial material quarried is a coarse graphic intergrowth of quartz and feldspar, though there are also very considerable amounts of pure feldspar. The latter is mostly cream colored, with here and there bluish-gray streaks and blotches. It is a potash feldspar, though small amounts of soda and lime-soda feldspar are associated with it. Both black mica and black tourmaline are present, but they are abundant only in places and are readily separable from the commercial spar. A considerable amount of quartz, white to dark gray in color, occurs and is saved, though at present finding no market. At the time of the writer's visit (August, 1906) about 300 tons of quartz were piled up at the quarries. There seem to be large amounts of excellent spar available at Mount Apatite for some time to come.

A smaller quarry, operated by A. R. Berry, is situated in the town of Poland, about 1 mile south of Mount Apatite. Irregular excavations here cover an area of about 2 acres and have a maximum depth of 18 to 20 feet. The spar is all sold to the Maine Feldspar Company and hauled about 3 miles to their mill at Littlefield. The character and mode of occurrence of the feldspar and quartz are similar to those at Mount Apatite. At both these localities lithium mica is occasionally found and tourmalines and beryls of fine gem quality also occur. They are not abundant enough, however, to pay for working these deposits for gems alone.

HEBRON, OXFORD COUNTY.

A small feldspar and mica mine has been opened during the last year (1906) about 1½ miles north of Hebron village, near the Buckfield road. This mine is located on the farm of Alton Hibbs and is being operated by J. A. Gerry, of Mechanic Falls, Me. The pegmatite is exposed for a distance of 300 to 350 feet along the southwest side of a small creek valley, the average width of outcrop being about 30 feet. Schists bound the pegmatite mass on its southwest side, their trend varying from N. 30° W. to N. 50° W. and averaging about N. 45° W. Their average dip is 45° NE. The northeast border of the mass is wholly obscured by glacial drift, which fills the bottom of the valley. The strippings and small excavations already made show numerous bodies of pure feldspar 2 to 3 feet across and much graphic granite containing only a small percentage of quartz. It is estimated that 60 per cent of the material mined is of commercial grade. No predictions can be made as to the continuance of this rock beyond the limited area of present exposure or in depth. It is probable, however, that its greatest extent is in a northwest-southeast direction, parallel to the trend of the neighboring schists. The feldspar is of the potash variety and is cream-gray to blue-gray in color. Black mica is scanty

in amount, but black tourmaline is moderately abundant. Its separation, however, does not entail great labor. Muscovite (white mica) is very abundant and of commercial quality in a zone about 4 feet wide next to the southwest wall of the pegmatite mass, but in the remainder of the rock it occurs only in scattered plates, mostly not more than 2 to 3 inches across. At the time of the writer's visit (September, 1906) no spar had been marketed. The material must be hauled about 3 miles to Hebron station, on the Portland and Rumford Falls Railway.

OTHER QUARRIES.

Numerous other quarries in Maine which have in the past produced feldspar and quartz were visited by the writer and will be described in the final report.

PRODUCTION.

The total production of crude feldspar in Maine for 1905 was 2,312 long tons, valued at $6,405. The production of ground spar was 9,317 short tons, valued at $83,850.

FELDSPAR AND QUARTZ DEPOSITS OF SOUTHEASTERN NEW YORK

By Edson S. Bastin.

INTRODUCTION.

The feldspar and quartz deposits near Bedford village, in Westchester County, N. Y., were visited by the writer in January, 1907. These deposits have been described briefly in the reports of the New York State Museum[a] and from that description a part of the material for this report has been obtained.

The quarries here described are located near Bedford village and 2 miles to the south in the town of North Castle. They can be reached by a 6 to 8 mile drive from Mount Kisco, a station on the Harlem division of the New York Central Railroad, 38 miles north of New York City.

GEOLOGIC RELATIONS.

The feldspar and quartz of these quarries occur as constituents of a class of rocks known to the geologist as pegmatites. In their mineral composition these rocks are closely allied to granites, the principal constituents in both being feldspar, quartz, and mica. The grain of the pegmatites, however, is as a rule exceedingly coarse and the texture very irregular, as brought out in another part of this bulletin (pp. 385–386) in the description of the pegmatites of Maine.

The rocks of the region are a mica schist (the Hudson schist) and scattered masses of crystalline limestone (the Stockbridge dolomite). Both of these rocks have been shown to be of sedimentary origin, though extensively altered by metamorphic action. They now lie in a series of closely compressed folds, whose general trend in the region here described is northeast and southwest. The Hudson schist has been shown to be of Ordovician age; the Stockbridge dolomite is in part Ordovician and in part Cambrian.

In the vicinity of the feldspar and quartz quarries and along much of the road between Bedford village and Mount Kisco the Hudson

[a] Bull. N. Y. State Museum No. 102, 1905, p. 69.

schist has been injected by granite, pegmatite, and basic igneous rocks, so as to show locally a gneissic texture. Here and there, as along the road from Bedford village to the Hobby quarry, in North Castle, small masses of normal granite occur. There can be little doubt that the pegmatites, which are of commercial importance in this region, are simply one phase of the granitic intrusion and injection of the Hudson schist, and that, like the granites, they are Silurian or later in age.

KINKLE QUARRY.

This quarry is situated on the east and northeast slopes of a small hill about three-fourths of a mile southeast of Bedford village. The excavations consist of four open pits, three closely adjacent ones on the upper part of the hill slope and one at a lower level. All the pits are elongate in a northeast-southwest direction, which probably represents the trend of the pegmatite dikes. The lower pit exposes the downward and northeastward continuation of the same pegmatite mass that is revealed in the southernmost of the upper-level pits.

The northernmost of the upper-level pits is about 50 feet wide, 100 feet long, and 35 feet in maximum depth. The two southern pits on this level are larger, being 100 to 150 feet wide, about 300 feet long, and about 50 feet in maximum depth. Most of the rock exposed in the central pit of the upper group is quartz, which is mainly white but here and there assumes a very beautiful rose tint. Some black tourmaline occurs in single crystals or radiating crystal aggregates in the quartz, and there has been some coating of fracture planes in the quartz with thin layers of black tourmaline. These thin coatings, in few places over one thirty-second of an inch in thickness, have plainly developed subsequent to the solidification and fracturing of the quartz and may be explained either as secondary depositions by surface waters percolating along the fractures or as a deposition by hot aqueous or gaseous solutions penetrating along the cracks in the pegmatite mass in the very latest stages of its solidification. Quartz with this black-tourmaline coating is unfit for commercial use and is discarded. The quartz seems to be associated with the feldspar in a wholly irregular manner. It forms most of the northwestern and southwestern walls of this quarry but in the southeastern wall is abundant only at the base, the upper parts of the wall being feldspathic. The feldspathic constituents of the pegmatite are best exposed in the other three pits, where they constitute a large proportion of the whole rock. The feldspar is of two principal varieties, one pink or flesh-colored and the other white. When examined under the microscope, the pink variety shows the optical properties of the feldspar microcline. The analyses of the pink spar (see Nos. 1 and 2 of the following table) show small amounts of soda and lime, but no soda or lime-soda feldspars were observed associated with the microcline in

the specimens examined. It is probable that part of the soda is chemically united with the potash in the microcline and that the feldspar is in reality a soda microcline. Analysis 4 of the table represents a pink microcline from the feldspar quarries at Bedford, Ontario, and is inserted for purposes of comparison.

Analyses of microcline feldspars.

	1.	2.	3.	4.
Silica (SiO_2)	65.95	65.85	65.33	65.40
Alumina (Al_2O_3)	18.00	19.32	20.96	18.80
Iron oxide (Fe_2O_3)	.12	.24	.71	Trace.
Lime (CaO)	1.05	.56	None.	None.
Magnesia (MgO)	Trace.	.08	None.	None.
Potash (K_2O)	12.13	14.10	10.65	13.90
Soda (Na_2O)	2.11		1.37	1.95
Loss on ignition				.60
	99.36	100.15	99.02	100.65

1. Pink microcline feldspar from quarry of Kinkle's Sons, Bedford, N. Y. Analysis by John C. Wiarda & Co.
2. Pink microcline feldspar from quarry of Kinkle's Sons, Bedford, N. Y. Bull. New York State Museum No. 93, 1905, p. 926.
3. Buff-colored microcline feldspar from quarry of Albert Hobby, North Castle, N. Y.
4. Pink microcline feldspar from quarry of Richardson & Sons, Bedford, Ontario. Analysis by Heinrich Ries, Cornell University.

The pink feldspar is in part pure and in part intergrown with quartz. This intergrowth consists of single crystals of quartz and feldspar penetrating each other in such a manner that on certain cleavage faces of the feldspar the quartz forms a peculiar pattern somewhat resembling the cuneiform inscriptions of the ancients. From this fancied resemblance to ancient writings the rock has been called graphic granite. There is every gradation from pure feldspar through coarse-grained graphic granite into fine graphic granite. The pink feldspar, pure or in intergrowth with quartz, generally occurs in somewhat irregular but sharply bounded areas within the general pegmatite mass. In the southernmost of the upper quarries these constitute about one-half of the whole pegmatite mass. A few of the smaller pink feldspar areas have perfectly straight boundaries which parallel the cleavage directions within the crystal. One sharply-outlined mass of pink feldspar 3 feet long by $1\frac{1}{2}$ feet wide was bordered on all sides by white quartz. The larger masses are as a rule inclosed partly by pure quartz and partly by irregularly associated white quartz and white feldspar, in varying proportions, with a little pink feldspar, biotite, black tourmaline, beryl, etc. The white feldspar is shown by microscopic examination to be largely albite and constitutes the second important feldspar variety characteristic of this quarry. The parts of the pegmatite characterized by its presence are in a few places graphic granite, but for the most part show a very irregular texture and varying proportions of feldspar and quartz from point to point.

The mica of these quarries is mainly muscovite, which is commonly

associated not with the quartz but with the feldspathic portions of the deposit or may lie between feldspathic areas and areas of pure quartz. In places the mica "books" lie with their sides parallel to the quartz-feldspar contacts, but more generally they stand at right angles to these contacts. Few of them exceed 4 to 5 inches in diameter and almost all show the A structure and much "ruling." No plate mica was seen and the total amount of muscovite is hardly sufficient to make it worth while to save it for scrap mica. Being mainly confined to rather definite bands in the pegmatite, most of it can be readily separated from the highly feldspathic portions. It is not injurious chemically either in pottery or glass manufacture, but the thin elastic plates are difficult to grind to the requisite fineness.

Biotite (black mica) occurs in long, thin, lath-shaped crystals some of which reach a length of several feet though most are much smaller. Black tourmaline is associated mainly with the quartz, but is here and there present in the feldspathic parts of the pegmatite. Magnetite and garnet are present in few places, but no gem varieties of tourmaline or of beryl have been found. Columbite is present here and there in small crystals, as are some other rare minerals.

Three grades of feldspathic material are obtained from these quarries. "No. 1" is selected from the purer portions of the pink-feldspar masses and will probably run considerably less than 5 per cent in free quartz. Nos. 1 and 2 of the table are said to be analyses of the nearly pure pink spar and may be assumed to represent rather closely the composition of the "No. 1" spar, which is placed on the market. All of this grade is shipped in bulk. The "No. 2" feldspar produced at this quarry includes the coarser graphic intergrowths of pink feldspar (microcline) and quartz and also includes pegmatitic material rich in the white soda feldspar, albite. This grade is therefore higher in free quartz and in soda than the "No. 1." Both the "No. 1" and "No. 2" grades are used in the manufacture of pottery and must be entirely free from black mica, black tourmaline, garnet, and other iron-bearing minerals. The "No. 2" spar is not shipped in the crude state, but is ground at the quarries. A "No. 3" grade, made up mainly of the albite-quartz mixture with some of the finer grained pink graphic granite, is also ground at Bedford for use in glass manufacture. It is somewhat higher in quartz and soda than the "No. 2," and muscovite, biotite, and black tourmaline are not so carefully eliminated as in the "No. 1" and "No. 2" grades, these constituents not being so injurious in glass as in pottery manufacture. Microscopic examination of the "No. 3" spar shows the presence of free quartz, microcline (potash feldspar), and albite (soda feldspar).

The quartz from this quarry is all shipped in the crude state to the Bridgeport Wood Finishing Company at New Milford, Conn., where it is ground and used in the manufacture of a wood filler.

The grinding mill of Kinkle's Sons is located at the quarries and is similar in equipment to most feldspar mills elsewhere,[a] except that the spar as it comes from the chasers goes to a vibration separator, only the tailings being sent to the ball mills. For pottery spar this separator is provided with a 140-mesh screen, but in the preparation of spar for glass manufacture only a 60-mesh screen is required.

In one sample of the "No. 3" spar measured under the microscope no particles over 0.01 inch (0.25 mm.) in diameter were seen. Most of the material was under 0.002 inch in diameter and the finest particles were under 0.0001 inch.

The ground spar is usually shipped in bags. All of the material from this quarry and mill is hauled by team 5 miles to Bedford station, on the New York Central Railroad. The average price for the crude "No. 1" spar is about $5, for the ground "No. 3" spar about $6.50, and for crude quartz about $3 per ton, f. o. b. cars at Bedford station. The "No. 1" and "No. 2" grades for pottery use are shipped mainly to Trenton, N. J., and East Liverpool, Ohio, though small amounts have been shipped as far as Portland, Oreg.

HOBBY QUARRIES.

A small quarry owned by Albert Hobby, of Bedford, N. Y., and operated by Max Büresch, has recently been opened in the town of North Castle, near the west side of Mianus River, about 1½ miles southeast of the Kinkle quarry. The quarry is situated on a steep eastern hill slope and is about 100 feet wide, 150 feet long, and 40 feet in maximum depth. No exposures of the surrounding rocks were observed near the quarry. The pegmatite shows masses of pure feldspar 8 to 10 feet across associated with masses of pure quartz, some of which are 15 feet across. The quartz is in part white and in part a beautiful rose tint. There is almost no intergrowth of quartz and feldspar. The feldspar is buff colored and is shown by microscopic examination to be microcline (potash feldspar, probably containing a little soda). Its analysis is No. 3 of the table. Small and very thin plates of muscovite occur along some of the cleavage planes in the feldspar, but they are not abundant enough to affect the quality of the spar materially. Muscovite in larger plates is mainly segregated in somewhat irregular bands in association with black tourmaline in prismatic crystals that reach 1½ inches in diameter.

This quarry differs from the Kinkle quarry in the fact that the feldspar is practically all buff-colored microcline, and in the more complete separation of quartz and feldspar, graphic granite being apparently wholly absent. The present exposures cover only a small area, and it is impossible to predict the extent or uniformity of

[a] For description of grinding process see p. 387 of this bulletin.

the deposit. Mianus River is capable of furnishing ample water power for operating a grinding mill, and the materials could be carried by gravity down the hill slope to the mill. The material is hauled by teams 8 miles to Bedford station. Little material has as yet been marketed. It is unfortunate that this property is located so far from transportation lines.

A small quarry owned by Mr. Hobby and situated about one-half mile east of the Kinkle quarry is not now being operated and was not visited by the writer.