C. 309

GEOLOGICAL SURVEY CIRCULAR 309

BERYLLIUM RESOURCES OF THE TIN-SPODUMENE BELT, NORTH CAROLINA

Prepared in cooperation with the North Carolina Department of Conservation and Development and the U. S. Atomic Energy Commission. The report is published with the permission of the Commission.

UNITED STATES DEPARTMENT OF THE INTERIOR
Douglas McKay, Secretary

GEOLOGICAL SURVEY
W. E. Wrather, Director

GEOLOGICAL SURVEY CIRCULAR 309

BERYLLIUM RESOURCES OF THE TIN-SPODUMENE BELT NORTH CAROLINA

By W. R. Griffitts

Prepared in cooperation with the North Carolina Department of Conservation and Development and the U. S. Atomic Energy Commission. The report is published with the permission of the Commission.

Washington, D. C., 1954

Free on application to the Geological Survey, Washington 25, D. C.

BERYLLIUM RESOURCES OF THE TIN-SPODUMENE BELT NORTH CAROLINA

By W. R. Griffitts

CONTENTS

ILLUSTRATIONS

TABLES

ABSTRACT

Pegmatite dikes in the tin-spodumene belt of North and South Carolina uniformly contain about 0.05 percent BeO. The most abundant minerals in the pegmatite contain from 0.0001 to 0.01 percent BeO. Beryl, having 12.0 to 12.3 percent BeO, is the only beryllium-rich mineral and contains more than 80 percent of the total beryllium in the rock. Beryl-bearing pegmatite crops out on hillsides near streams that flow through the pegmatite belt. Much of the pegmatite contains spodumene, feldspar, mica, cassiterite, and columbite, as well as beryl, but separating these minerals will require milling.

The minable spodumene ore in the Kings Mountain area, above a depth of 300 feet, contains about 40,000 tons of beryl, equivalent to 6,000 tons of BeO, if 80 percent of the BeO is assumed to be in beryl. Other pegmatite in that area contains an additional 238,000 tons of beryl, or 35,900 tons of BeO. On the basis of the same assumptions the spodumene ore above a depth of 300 feet in the Beaverdam Creek area contains 6,000 tons of beryl, or 800 tons of BeO, and all other pegmatite in that area contains an additional 13,000 tons of beryl, or 1,700 tons of BeO. The entire tin-spodumene belt contains 823,000 tons of beryl, equivalent to 122,800 tons of BeO.

Little beryllium was found in the Piedmont province outside of the tin-spodumene belt.

INTRODUCTION

The narrow belt of crystalline rocks containing many pegmatite dikes that aptly has been termed the "tin-spodumene belt" (Kesler, 1942) extends from Gaffney, S. C. to a point a few miles east of Lincolnton, N. C. (fig. 1) and is about 30 miles west of Charlotte. The belt is less than 2 miles in width and is about 25 miles in length. It is entirely in the Piedmont, the upland surface of which has an altitude of about 1,000 feet in the area of the pegmatite belt, and has been dissected

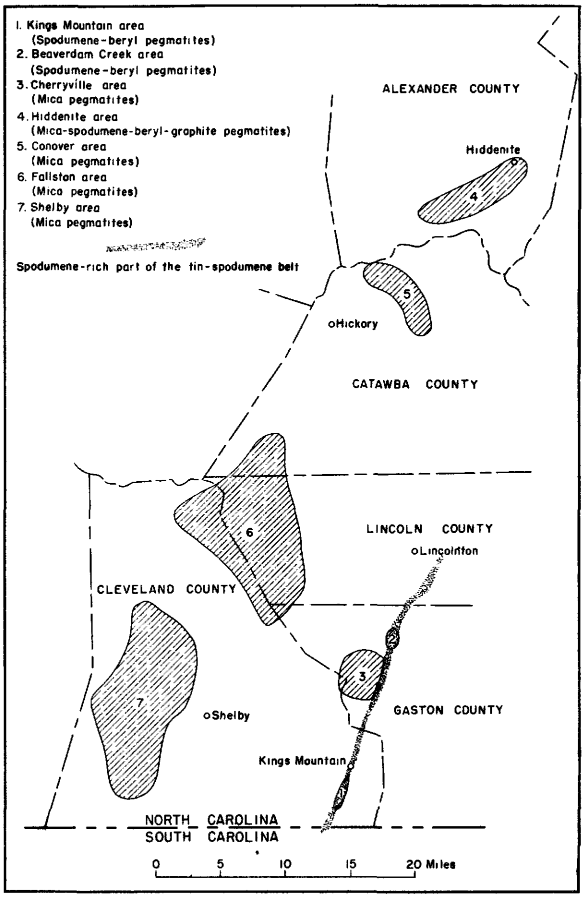


Figure 1.—Index map of pegmatite areas of the Piedmont province in North Carolina.

to form gently-rolling hills with a local relief of about 150 feet. A few hills rise several hundred feet above the surrounding country.

Inasmuch as this part of the Piedmont is heavily populated there is a network of good paved and dirt roads that provide ready access to most of the pegmatite deposits. Rail service is available at Kings Mountain, Lincolnton, Grover, Bessemer City, and at a few small mill towns along the pegmatite belt.

The discovery of beryllium in mill tailings near Kings Mountain was made as a result of the wartime mill products investigations of the Geological Survey. The presence of beryllium was verified by L. R. Page, who took samples of them in 1948, and a more extensive program of sampling the concentrates, tailings, and pegmatite was then started under his general direction. W. R. Griffitts began this sampling in January 1949, with the assistance of Robert E. Burns, and continued it alone through the summer of 1949. The work was done by the U. S. Geological Survey in cooperation with the Division of Raw Materials of the U. S. Atomic Energy Commission and the North Carolina Department of Conservation and Development.

GEOLOGY

General features

The tin-spodumene belt is underlain by muscovite schist, biotite schist, hornblende schist and gneiss, and quartz monzonite (Keith and Sterrett, 1951), and is a short distance east of a large body of Cherryville quartz monzonite (Griffitts and Overstreet, 1952, fig. 1). The foliation of the metamorphic rocks trends northeast, roughly parallel to the trend of the belt.

Pegmatite geology

Distribution and attitude

The tin-spodumene belt includes three main types of pegmatite: spodumene-microcline-albite-quartz pegmatite, microcline-albite-quartz pegmatite, and perthite-oligoclase-quartz-muscovite pegmatite. The first two, characterized by non-perthitic microcline and albite, have a rather uniform content of beryl. The albite-bearing pegmatite dikes are composite, consisting of aplite as well as pegmatite. Although the separation is imperfect, the spodumene-bearing pegmatites are commonest in the middle part of the belt. Excluding the oligoclase- and muscovite-bearing pegmatites, the belt is 35 miles long and not over 2 miles wide. The part of the belt that encloses albite-microcline pegmatites rich in beryl, and includes both spodumene-bearing and spodumene-free pegmatites, is outlined on plate 1.

Pegmatite dikes are not evenly distributed through the belt. They are abundant and closely spaced in the Kings Mountain area at the narrowest part of the belt and are abundant but more widely spaced in the Beaverdam Creek area and to the north (Kesler, 1942, pls. 39, 40).

South of Kings Mountain the pegmatite dikes strike from north to north-northeast; north of that town the strike is less constant, but it is most commonly northwest, northeast, or east-northeast. The dips are generally steeper than 45 degrees. Several dikes southwest of Kings Mountain plunge northward at angles of from 10 to 30 degrees. The dikes farther north may also plunge gently but neither the direction nor the angle has been determined.

Size and shape

The pegmatite dikes range from a few feet to 3,200 feet in length and from 6 inches to 400 feet in width. Drilling by the Foote Mineral Co. has shown a pegmatite dike to extend at least to a 900-foot depth (Anonymous, 1952). At the Ka-Mi-Tin mine, which is at the north end of the belt, a spodumene- and cassiterite-bearing pegmatite dike was proved by diamond drilling to extend at least to a depth of 140 feet, according to D. B. Sterrett (field notes, 1912).

Diamond drilling shows that the pegmatites do not change in character with depth and that some pegmatite dikes not exposed at the surface are present at depth. Kesler (1942, p. 268, 269) assumed a downward extension of 100 feet in determining the spodumene resources of the Kings Mountain and Beaverdam Creek areas. This now seems to be a very conservative estimate and a depth of 300 feet is used in estimating resources in this report. Actually, it is probable that beryl- and spodumene-bearing pegmatite is as abundant and widespread at a depth of a mile or more as at the surface, but individual dikes naturally are not expected to persist to that depth.

Many of the pegmatite dikes are tabular and others have straight tabular members between sharp bends. Some dikes that have been explored finger out at their ends and apparently below their keels as well. A few are very irregular, with tabular or wedge-like offshoots from a moderately large central part.

Lithology and internal structure

The overall composition of each main type of pegmatite is moderately uniform throughout the belt, but the textures vary greatly. South of Kings Mountain much of the pegmatite is fissile or gneissic. The larger spodumene and microcline grains form eyes that are wrapped in moderately to very strongly layered albite-quartz pegmatite that may contain smaller grains of spodumene and microcline. The cleavage surfaces of the large grains commonly are bent and the crystals themselves are broken and the pieces surrounded by the albite-quartz matrix. Most of these dikes are composite, containing aplite as well as pegmatite. The aplite occurs as layers that may be several feet thick. It has less spodumene and microcline than the pegmatite but otherwise it is similar in composition.

In the pegmatite dikes south of Kings Mountain, zones are absent or restricted to a few small masses of rock near the contacts where movements in the crystallizing magma did not interfere with normal crystallization. The zones are neither large enough nor common enough to be of much importance in planning either exploration or development.

Pegmatite bodies north of Kings Mountain commonly are not conspicuously zoned. The contrast in composition between zones is small and the division must be based primarily upon the size or orientation of the mineral grains and, in some places, on arbitrarily fixed limits of mineral proportions. The grains in the outer part of the dikes are commonly normal to the contacts. Microcline is slightly more abundant in the inner parts of some pegmatite dikes. Some border zones are spodumene free, some are spodumene bearing; otherwise, spodumene seems to be present throughout the spodumene-bearing dikes. Because of the narrowness of most dikes in the northern part of the tin-spodumene belt and the small variation in mineral proportions, zones cannot be selectively explored or mined. Many of the dikes in the northern part of the belt are composite, with thin dikes of spodumene-bearing pegmatite cutting larger dikes of spodumene-free pegmatite or of aplite dikes cutting either spodumene-bearing or spodumene-free pegmatite. Uncommonly, aplite dikes are cut by spodumene-free pegmatite.

In table 1 the textures are described as massive, cleavable, gneissic, sugary, or comb. The massive rocks show no prominant segregation or parallelism of the constituent mineral particles. The cleavable rocks are generally fine grained or have a fine-grained matrix. In these rocks the minerals are not segregated into distinct layers but, because of a strong parallelism among the grains, the cleavage of the rock is well developed. In gneissic rocks the minerals are segregated into layers of different composition; cleavage may be well developed. Sugary texture is common in fine-grained rocks or aplites that show neither strong parallelism of mineral grains nor conspicuous segregation of minerals into layers. Comb structure, found commonly only in the pegmatites north of Kings Mountain, consists of elongate mineral grains, generally spodumene, oriented normal to the contacts of the pegmatite dike.

Mineralogy

The pegmatites of the tin-spodumene belt are composed very largely of albite, microcline, spodumene, and quartz (table 1). Other minerals only locally make up as much as 5 percent of the rock. The common accessory minerals are muscovite, apatite, beryl, cassiterite, and garnet. Many other minerals have been found in the pegmatites (Kesler, 1942, p. 255), but of these only columbite is likely to be of value. The oligoclase-perthite-quartz-muscovite pegmatites along the western side but within the tin-spodumene belt and the sheet-mica bearing pegmatites that are west of the tin-spodumene belt contain fewer minerals, much more muscovite and biotite, and are more clearly zoned.

The average grain size of the pegmatites is moderately small. The largest spodumene crystal found was 38 inches long and the largest microcline grain 25 inches. Most crystals of both minerals are smaller than 1 foot. The albite is in grains about 0.1 of an inch across. Quartz grains, 0.1 of an inch or smaller in diameter, are clustered in aggregates that are as much as 6 inches wide.

The beryl in the pegmatites is white to pale green or pale blue; white beryl predominates. The beryl grains range in diameter from 0.001 inch to as much as 2 inches; most are very small, few measuring more than 0.1 of an inch. Most large grains either have no crystal faces or are stubby crystals about as long as they are wide. The fine-grained white beryl is very hard to recognize in the pegmatite as its color and luster are not very different from those of the associated quartz and feldspar. The omega refractive index of the beryl ranges from 1.587 to 1.589, which indicates that the beryl contains from 12.0 to 12.3 percent BeO.

Distribution of beryllium

The BeO of the samples shows no variation that is closely related to the distance of the sample from the walls, crest, or keel of the dike. Dike 25 (pls. 2, 3), exposed in the opencut south of Kings Mountain, was sampled at its north end near its crest and a bulk sample of its middle and lower parts was obtained from the stock pile of millfeed. Near the crest of the dike (sample localities NW, NE, E.) the pegmatite averages 0.036 percent BeO whereas in the lower part (sample MH-1, table 1) it contains 0.053 percent. Dike 21 (pl. 3) was sampled near its south end (sample locality KM2) and about 600 feet farther north (sample locality KM3) and the BeO assays were 0.059 and 0.054 percent,

Table 1.--BeO and mineral content of samples from the tin-spodumene belt, North Carolina[1]

[Symbols: C, cleavable; G, gneissic; M, massive; K, comb; S, sugary]

Locality	Sample	Weight (pounds)	Length (feet)[2]	Position	Minerals[3] Spodumene Percent	Spodumene Grain size (inches)	Microcline Percent	Microcline Grain size (inches)	Albite Percent	Albite Grain size (inches)	Quartz Percent	Quartz Grain size (inches)	Muscovite Percent	Muscovite Grain size (inches)	Texture	BeO (percent)[4]
1. Kings Mountain area[5] (See pl. 3)																
KM- 1	A	4.4	10	West wall---------	10	0.5	0	----	45	0.1	35	0.1	10	0.5	C-G	0.056
KM- 1	B	5.4	4	East of A---------	5	.05	0(?)	----	60	.05	30	.05	5	.07	C	.12
KM- 1	C	4.2	7	East of B---------	---	---	---	----	65	.1-.4	30	.1	5	.3	G	.12
KM- 1	D	7.6	13	East of C---------	10	1	15	1	50	.3	25	.3-.5	0	---	G	.034
KM- 2	A	7.9	13	West wall---------	25	5	10	.5	45	.3	20	.3	0	---	---	.085
KM- 2	B	7.6	10	East of A---------	25	6	10	6	45	.5	20	.4	0	---	---	.079
KM- 2	C	7.9	13	East of B---------	---	---	---	---	---	---	---	---	---	---	---	.064
KM- 2	D	7.6	14	East of C---------	30	4	35	4	18	.3	10	.5	7	.5	M	.050
KM- 2	E	7.8	12	East of D---------	30	4	35	4	18	.3	10	.5	7	.5	M	.052
KM- 2	F	7.3	4	East of E---------	10	.1	10	.1	60	.1	20	.1	0	---	G	.062
KM- 2	G	9.4	16	East of F---------	20	5	18	5	37	.3	20	.5	5	.5	G[6]	.034
KM- 2	H	9.4	20	East of G---------	20	4	60	6	60[7]	.1	20	---	---	---	(8)	.060
KM- 3	A	7.0	8	East wall---------	25	1	20	1	25	.3	25	1	5	.5	M	.067
KM- 3	B	7.2	7	West of A---------	20	5	20	4	20	.3	25	.5	15	.5	M	.043
KM- 3	C	7.3	9	West of B---------	25	4	15	4	15	.3	40	1.5	5	.3	G	.046
KM- 3	D	5.1	7	West of C---------	10	3	40	3	30	.1	10	.1	10	.2	G	.071
KM- 3	E	15.6	12	West of D---------	30	4	40	3	10	.2	20	.5	0	---	C	.051
KM- 3	F	7.9	11	West of E---------	10	3	30	3	38	.2	20	.5	2	.3	G	.052
KM- 4	A	3.3	1	East wall---------	20	.1	15	.1	35	.05	25	.1	---	---	C[9]	.057
KM- 4	B	15.0	12	West of A---------	35	5	20	4	30	.2	15	.5	0	---	M	.032
KM- 4	C	17.2	20	West of B---------	20	1	10	1	54	.1	15	.1	1	.2	G	.077
KM- 4	D	7.8	7	West of C---------	35	8	35	5	20	.3	10	.1	0	---	M	.016
KM- 5	A	33.7	30	Entire width------	---	.1	---	.1	---	.1	---	.1	---	---	G	.089
KM- 6	A	8.6	10	---do-------------	15	4	10	3	25	.2	50	2	---	---	G	.036
KM- 7	A	19.4	20	East wall---------	30	3	10	4	38	.1	20	4	2	.1	M	.027
KM- 7	B-1	9.7	10	West of A---------	---	---	25	4	50	.1	25	.1	---	---	G	.052
KM- 7	B-2	10.8	13	West of B-1-------	---	---	---	---	---	---	---	---	---	---	G	.033
KM- 7	B-3	11.0	14	West of B-2-------	---	.1	---	.1	---	.1	---	.1	---	.1	C	.031
KM- 7	B-4	18.3	18	West of B-3-------	5	1	35	5	40	.1	17	.1	3	.1	G	.066
KM- 7	C	12.0	23	West of B-4-------	7	1	25	3	36	.2	30	1	2	.05	G	.064
KM- 7	D	8.6	17	West of C---------	20	1	20	4	35	.1	22	.1	3	.1	G	.046
KM- 7	E	9.8	19	West of D---------	10	1	25	4	41	.1	22	2	2	.1	G	.058
KM- 7	B-5	10.3	5	West of E---------	---	---	---	---	---	---	---	---	---	---	---	.042
KM- 8	A	31.8	80	Entire width------	20	4	20	5	40	.1	15	1	5	.3	M-G	.035
KM- 9	A	7.6	12	East wall---------	20	2	25	3	35	.1	15	2	5	.5	G	.069
KM- 9	B	8.8	18	West of A---------	25	1	20	2	29	.2	25	.5	1	.05	G	.072
KM- 9	C	8.1	27	West of B---------	20	1	30	2	30	.5	17	1	3	.3	M	.027
KM- 9	D	7.7	17	West wall---------	15	5	30	5	30	.2	20	5	5	.3	---	.036
KM-10	A	17.4	---	Entire width------	0	---	35	4	40	.5	25	3	0	---	M	.0049

2. Kings Mountain area, Solvay Process Co. opencut[10]
(See pls. 2, 3)

NW	1	5.2	1.2	East wall---------	0	---	0	---	75	0.2	25	0.2	0	---	M	0.045
NW	2	---	1.4	West of 1---------	0	---	50	2	15	---	35	---	0	---	M	.061
NW	3	---	3.9	West of 2---------	0	---	0	---	80	---	20	---	0	---	G	.036
NW	4	---	5.3	West of 3---------	15	3	20	2	35	.1	30	.1	0	---	G	.033
NW	5	---	11.7	West of 4---------	15	4	5	4	60	---	20	---	0	---	G	.019
NW	6	---	18.0	West of 5---------	15	4	5	4	60	---	20	---	0	---	---	.013
NW	7	---	6.0	West of 6---------	10	---	15	---	50	---	25	---	0	---	---	.038
NE	1	---	.5	East Wall---------	0	---	0(?)	---	---	.1	(?)	.1	---	---	M	.044
NE	2	---	1.7	West of 1---------	25	10	30	4	0	---	45	.1	0	---	M	.034
NE	3	---	3.1	West of 2---------	10	2	5	1	---	.1	---	.1	---	---	G	.062
NE	4	---	.5	West of 3---------	0	---	---	---	---	.1	---	.1	---	.1	---	.055
NE	5	---	1.9	West of 4---------	30	3	15	13	---	---	---	---	---	---	G	.050
NE	6	---	3.5	West of 5---------	30	2	10	2	0	---	60	.1	0	---	G	.030
NE	7	---	5.0	West of 6---------	15	4	10	4	---	.1	---	.1	---	---	---	.055
NE	8	---	10.0	West of 7---------	10	3	10	2	60	---	20	---	0	---	G	.025
NE	8	---	---	Part of 8---------	---	3	---	3	---	---	---	---	---	---	G	.051
NE	10	---	1	West wall---------	0	---	---	.1	75	.1	25	.1	---	.1	M	.033
NE	11	---	---	West wall rock----	---	---	---	---	---	---	---	---	---	---	---	.017
NE	12	---	---	East wall rock----	---	---	---	---	---	---	---	---	---	---	---	.004
E	1	---	.7	East wall---------	0	---	0	---	70	.1	30	.1	0	---	---	.036
E	2	---	1.3	West of 1---------	0	---	0	---	68	.2	30	.1	2	.2	---	.055
E	3	---	2.1	West of 2---------	20	3	15	3	0	---	65	.5	0	---	---	.043
E	4	---	4.2	West of 3---------	---	---	---	---	---	---	---	---	---	---	---	.067
E	5	---	1.5	West of 4---------	40	4	5	3	35	---	20	---	0	---	---	.042
E	6	---	2.5	West of 5---------	---	---	---	---	---	---	---	---	---	---	---	.017

3. Kings Mountain area, products of Solvay Process Co. mill[10]

---	MH-1	73	---	------------------	---	---	---	---	---	---	---	---	---	---	(11)	0.053
---	C-1	11	---	------------------	---	---	---	---	---	---	----	---	---	---	(12)	.074
---	C-2	5	---	------------------	---	---	---	---	---	---	---	---	---	---	(13)	.015
---	C-3	7	---	------------------	---	---	---	---	---	---	---	---	---	---	(14)	.058

4. Beaverdam Creek area[5]
(See fig. 3)

BC- 1	A	8.6	20	Entire width------	15	3.0	5	4	53	0.2	25	1	2	0.5	M	0.053
BC- 2	A	7.6	20	----do------------	20	4	10	2	42	.2	25	2	3	.3	M	.036
BC- 3	A	7.6	40	----do------------	30	8	15	3	35	.2	20	1	---	---	K	.045
BC- 4	A	5.9	15	----do------------	10	2	15	6	55	.2	20	1	---	---	M	.022
BC- 5	A	6.0	13	----do------------	25	4	30	5	19	.2	25	3	1	.5	M	.035
BC- 6	A	6.5	10	----do------------	10	3	25	6	35	.2	25	6	5	.5	M	.061
BC- 7	A	8.7	16	West side---------	15	2	30	3	22	.2	30	---	3	.5	M	.053
BC- 7	B	8.3	22	East side---------	15	2	35	4	23	.2	25	---	2	.5	M	.034
BC- 8	A	10.1	13	----do------------	0	---	59	1	10	.1	30	1	1	.1	M	.041
BC- 8	B	7.9	8	West side---------	0	---	59	---	10	---	30	---	1	---	M	.042
BC- 9	A	9.3	25	East side---------	0	---	30	3	38	---	30	---	2	.4	M	.043
BC- 9	B	8.3	20	West side---------	0	---	35	5	33	---	30	---	2	.3	M	.063
BC-10	A	8.0	15	Entire width------	15	3	20	6	39	.1	25	1	1	.5	M	.045

See footnotes at end of table.

Table 1.—BeO and mineral content of samples from the tin-spodumene belt, North Carolina[1]—Continued

[Symbols: C, cleavable; G, gneissic; M. massive; K, comb; S, sugary]

Locality	Sample	Weight (pounds)	Length (feet)[2]	Position	Minerals[3]										Texture	BeO (percent)[4]
					Spodumene		Microcline		Albite		Quartz		Muscovite			
					Percent	Grain size (inches)	Percent	Grain size (inches)	Percent	Grain size (inches)	Percent	Grain size (inches)	Percent	Grain size (inches)		
5. Other areas[15] (See pl. 1)																
1	A	5.0	5(?)	------------------	0	---	---	0.1	---	0.1	---	0.1	---	0.1	C	0.092
2	A	10.0	---	------------------	25	---	20	---	30	---	25	---	0	---	M	.071
3	A	---	6	Entire width------	0	---	10	4.0	60	.2	25	1	5	.2	M	.12
4	A	7.1	5(?)	----do------------	0	---	20	---	50	.2	25	---	5	.1	M	.058
5	A	12.2	8	----do------------	0	---	15	1.0	42	.1	33	.3	10	.2	M	.054
6	A	15.0	6	----do------------	25	4	20	6.0	35	.2	13	1	7	.3	M	.047
7	A	9.2	(16)	Scattered---------	0	---	20	.1	50	.5	25	1	5	.5	M	.0005
7	B	7.0	500(?)	Near middle(?)----	0	---	0	---	---	---	100	.1	0	---	S	.014
8	A	7.0	5	Entire width------	0	---	0	---	0	---	75	---	25	.2	M	.056

[1] Composition (nearest 1 percent) and grain size were estimated visually.
[2] Measured normal to dike.
[3] Other minerals: KM-4 (A), apatite, 5 percent; KM-4 (B), cassiterite (?); KM-4 (D), cassiterite(?); KM-10 (A), biotite; NE-5, tourmaline; NE (10), apatite.
[4] By spectrographic assay.
[5] Analyses by Saratoga Laboratories, Inc.
[6] 75 percent.
[7] Matrix.
[8] Aplite matrix (25 percent coarse grains).
[9] Poor.
[10] Analyses by National Spectroscopic Laboratories, Inc.
[11] Mill feed.
[12] Spodumene concentrate.
[13] Muscovite concentrate.
[14] Feldspar concentrate.
[15] Analyses by Strock Laboratories, Inc.
[16] Thin pods.

respectively. The uniformity of BeO content in the samples of the entire area given on table 1 suggests that there is little variation within the dikes.

The BeO of the pegmatite does not vary greatly with varying proportions of the essential minerals—spodumene, microcline, and albite. The general relation between BeO and the proportions of these minerals, recalculated to total 100 percent, is plotted on triangular coordinates in figure 2. In most of the samples containing more than 0.06 percent BeO, the albite comprises from 35 to 65 percent of the three minerals; microcline and spodumene are present in a ratio of about 40 to 60.

Although beryl has been recognized in only a few pegmatites in the tin-spodumene belt, it is probably the mineral in which most of the beryllium is contained. Some albite samples contain as much as 0.01 percent BeO, but the material assayed was fine grained and might well have contained small grains of beryl. However, plagioclase generally contains much less BeO as shown by the lack of a very close correlation between the plagioclase and BeO contents of the pegmatites. Semiquantitative spectrographic analysis shows that plagioclase from four other pegmatites in the belt contain from 0.000X to 0.00X percent BeO. Similar analyses of microcline from these four pegmatites indicated up to 0.000X percent BeO. Quartz interstitial

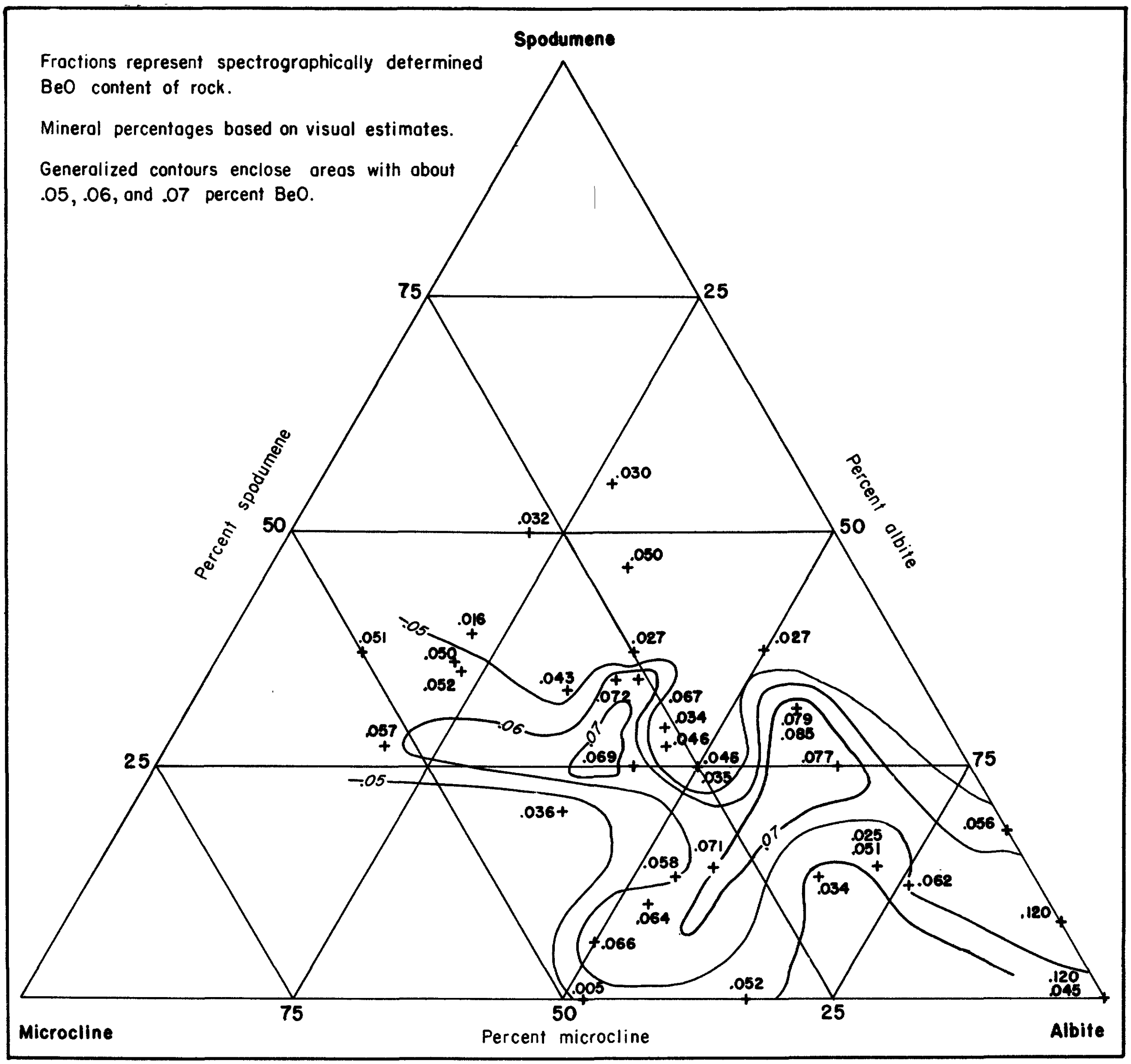


Figure 2.—Relation of BeO content to mineral composition of pegmatite.

to feldspar and spodumene contained less than 0.0001 percent BeO, the minimum detectable by the semiquantitative spectrographic methods used in the Geological Survey laboratories.

The spodumene concentrate produced in the mill of the Solvay Process Co. contains as much as 0.074 percent BeO (sample C-1, table 1), because beryl is concentrated with the spodumene The beryllium is not in the spodumene itself, but results from admixtures of beryl in the concentrate. Kesler (unpublished notes, 1945) reported a spodumene concentrate that contained 1.2 percent of beryl as determined by grain counts. A hand-picked spodumene concentrate from pegmatite dike 25 contained 0.00X percent BeO by semiquantitative spectrographic analysis.

Quantitative spectrographic analyses of the BeO content of minerals from locality 3 (pl. 1), south of Laboratory, N. C., are as follows:

	BeO (percent)[1]
Large spodumene-free dike:	
Minerals from border zone:	
Muscovite	0.001
Albite	.01
Minerals from wall zone:	
Muscovite	.001
Albite	.006
Perthite	.0008
Minerals and rocks from core:	
Perthite	.0004
Muscovite	.002
Granite	.01
Aplite	.01
Small spodumene-bearing dike that cuts the large spodumene-free dike:	
Minerals from border zone:	
Muscovite	.002
Microcline	.0001
Spodumene	.0008
Minerals from core:	
Muscovite	.002
Albite	.01
Microcline	.0002
Spodumene	.0008

[1] Spectrographic analyses by A. A. Chodos, Geochemistry and Petrology Branch, U. S. Geological Survey.

On the basis of these data and the absence of any other known beryllium-rich mineral, it is assumed that at least 80 percent of the beryllium in the pegmatite is in the form of beryl.

BERYLLIUM RESOURCES

The beryllium content of the pegmatites in the tin-spodumene belt is remarkably uniform. Of 96 samples taken, only 11 had less than 0.02 percent BeO and 11 more than 0.07 percent. The average of all samples taken in the Kings Mountain area (pl. 3) is 0.054 percent. In the Beaverdam Creek area (fig. 3) it is 0.044 percent. It is probable, therefore, that the average BeO content for each of the main areas sampled—0.05 percent—can be taken as the average for all pegmatites in the belt. The average BeO content of the pegmatites might decrease progressively northeastward along the belt.

In computing the tonnage of pegmatite the figures for rock tonnage are given to the nearest 100,000 short tons, the figures for beryl to the nearest 1,000 short tons, and the figures for BeO to the nearest 100 short tons.

The beryllium resources were roughly estimated for the Kings Mountain area, the Beaverdam Creek area, and the entire pegmatite belt. In making these estimations it was assumed that the volume of 1 ton of spodumene-free pegmatite was 12 cubic feet and the volume of 1 ton of spodumene-bearing pegmatite was 10 cubic feet, that 80 percent of the BeO was in beryl, and that the pegmatites south of Kings Mountain contained 0.054 percent BeO and those farther north contained 0.044 percent BeO. The vertical extent was assumed to be 300 feet. Kesler's estimates of the tonnage of pegmatite that would be minable for spodumene and of the tonnage of the parts of spodumene-bearing dikes that would not profitably be minable for spodumene (Kesler, 1942, p. 268) were revised to include material to a 300 foot depth, as he included pegmatite down to only 100 feet, but his figures were not otherwise modified. The outcrop areas of spodumene-free pegmatite were determined from maps and the tonnage was computed using the assumptions listed above. The district estimate was made by comparing the size and number of pegmatite dikes in various parts of the belt with those on the Kings Mountain and Beaverdam Creek areas. The beryllium resources thus estimated are given in table 2.

A rough estimate of the spodumene resources of the belt might be made by assuming that one-third of the total tonnage of pegmatite, about 66,000,000 short tons, contains 10 percent spodumene, or 6,600,000 tons.

The amount of beryl estimated to be in the pegmatite of the tin-spodumene belt would satisfy the domestic beryllium requirements for many years if a satisfactory method is devised by which the beryl can profitably be extracted from the rock. The extraction will obviously require grinding the rock, and the values of the various minerals in a ton of average spodumene ore given in table 3 indicate that most of the cost of a milling operation will have to be repaid by sale of spodumene and feldspar. Beryl, mica, and heavy minerals will be byproducts. The production of beryl, therefore, will depend upon the market for spodumene and feldspar.

SUGGESTIONS FOR PROSPECTING

Outcrops of relatively unweathered beryl- and spodumene-bearing pegmatite are common in the tin-spodumene belt where hill slopes toward nearby streams are moderately steep. Thus, the valley walls along parts of Kings, Dixon, and Mill Creeks south of Kings Mountain and along parts of Indian Creek, Long Creek, the South Fork River, and some of their tributaries north of Kings Mountain have many outcrops of pegmatite. Surface sampling for beryl and exploration of depth by diamond drilling of promising deposits should prove the presence of large tonnages of beryllium-bearing rock.

The possibility that the dikes may plunge at a gentle angle should be kept in mind while planning any exploration of the dikes at depth. Southwest of Kings Mountain the thickest part of a dike at depth will generally be north of the thickest part of the outcrop because of the northerly plunge. The direction and angle of plunge in the part of the belt north of Kings Mountain must be determined for the dikes following each of the common trends. Inasmuch as exploitation of the deposits will require milling the rock, it will be necessary to mine large tonnages as cheaply as possible. Small dikes that would support small-scale mining operations if the minerals could be separated by hand cobbing would, therefore, be of little value. Attention should naturally be given first to the largest dikes, to closely spaced small dikes that could be mined as one operation, and to dikes that are favorably situated for cheap mining.

Detailed studies of internal structure are of less help in planning exploration and development than in

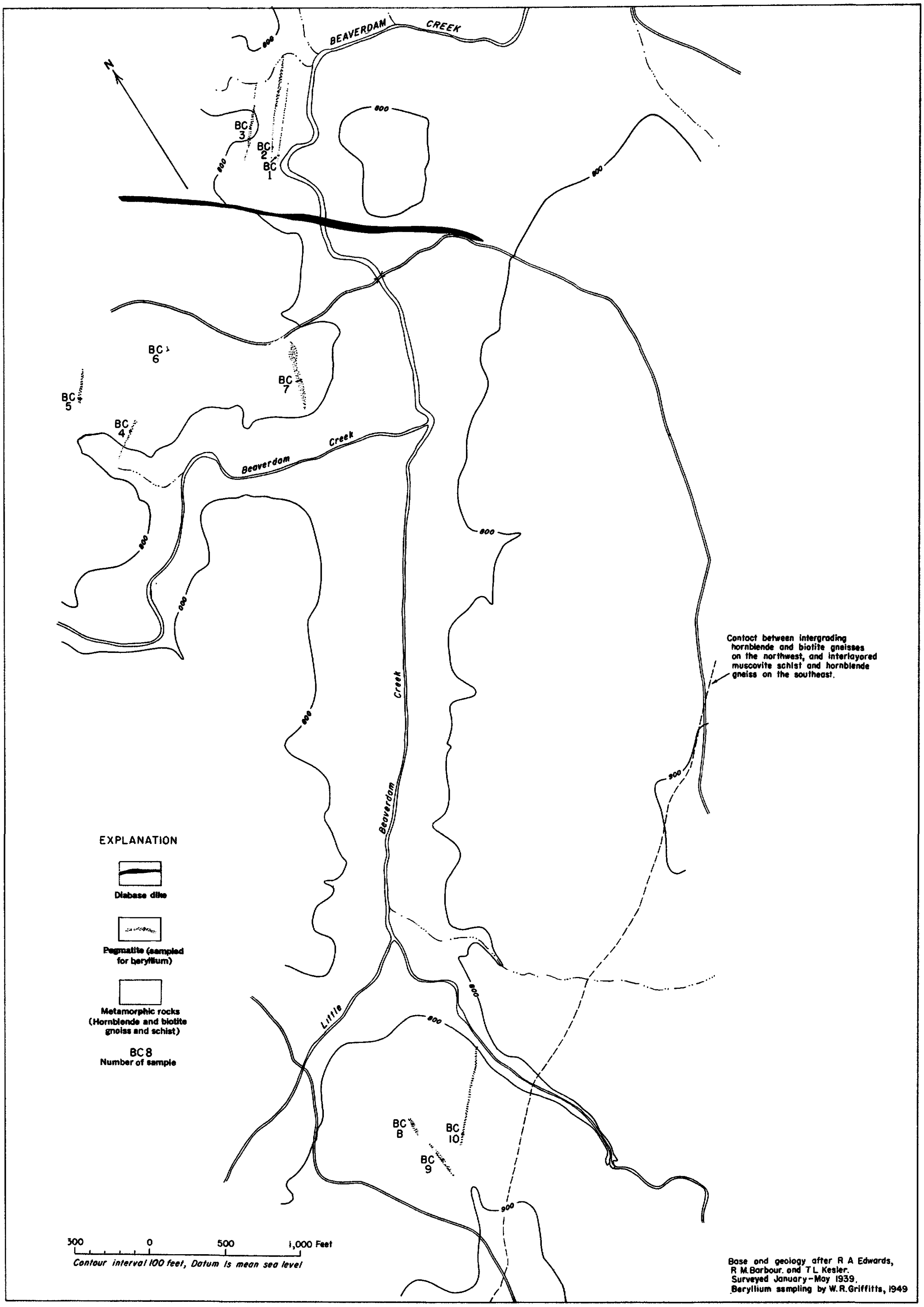


Figure 3. —Geologic map of the Beaverdam Creek area, North Carolina.

Table 2.—BeO resources of the tin-spodumene belt, North Carolina

Area and kind of pegmatite	Pegmatite (short tons)	Beryl (short tons)	BeO (short tons)
Kings Mountain and Beaverdam Creek areas (pl. 3, fig. 3)			
(A) Kings Mountain area:			
Spodumene-rich	11,100,000	40,000	6,000
Spodumene-poor	44,400,000	160,000	24,000
Spodumene-free	22,000,000	78,000	11,900
Total	77,500,000	278,000	41,900
(B) Beaverdam Creek area:			
Spodumene-rich	1,900,000	6,000	800
Spodumene-poor	1,900,000	6,000	800
Spodumene-free	100,000	1,000	100
Total	3,900,000	13,000	1,700
Entire belt (pl. 1)			
(C) Entire area southwest of Kings Mountain, including (A): All kinds	155,000,000	745,000	111,700
(D) Between Kings Mountain and (B): All kinds	15,200,000	26,000	3,700
(E) (B) and area to north: All kinds	30,500,000	52,000	7,400
Total	200,700,000	823,000	122,800

Table 3.—Value of minerals in 1 ton of average spodumene-bearing pegmatite from the tin-spodumene belt, North Carolina[1]

Mineral	Quantity in pegmatite		Value per unit		Value per short ton (nearest $0.25)
	Percent	Units per short ton	Value	Unit	
Spodumene	20	1.45	$7.00	unit Li_2O.	$10.00
Beryl	.4	.03	46.00	unit BeO.	1.50
Feldspar	45	---	12.00	short ton.	5.50
Mica	3	---	50.00	--do--	1.50
Columbite	.006	---	4.10	pound	.50 (Columbite and Cassiterite)
Cassiterite	.024	---	.90	pound contained tin.	
Total					$19.00

[1] The value of tailings as sand is not included.

other beryl- and spodumene-producing districts because of the uniformity of beryl distribution in the pegmatite. The mineralogy of the pegmatite is a moderately reliable indicator of beryllium-bearing pegmatite, however. Pegmatites that have more than a few percent of muscovite in books larger than one-half inch in diameter, pegmatites in which the plagioclase contains less than 90 percent albite, or pegmatites in which all the potash feldspar is distinctly perthitic, are not apt to contain very much beryl. The uncommon pockets of beryl that are in muscovite or perthite-rich pegmatites are moderately coarse grained and as a consequence the beryl is recoverable by hand methods, but few pockets are likely to yield as much as a ton of beryl.

The same areas that are favorable for beryl prospecting are also favorable for spodumene prospecting. The perthite-rich and muscovite-rich pegmatites are as unfavorable as sources of spodumene as they are of beryl. Indirect mineralogical evidence is not needed, however, as the spodumene itself can readily be recognized in the outcrops. The former presence of spodumene in thoroughly kaolinized pegmatite can be determined from the shape of the masses of clay that have replaced the spodumene. The shape of the spodumene grains in any area must be determined by an examination of the fresh outcrops as the shapes differ in different parts of the belt. It is possible to estimate the spodumene content of the outcrops and quickly determine what dikes are worthy of further exploration for that mineral.

BERYLLIUM CONTENT OF NON-PEGMATITIC ROCKS IN THE PIEDMONT PROVINCE

Samples were taken of various types of rocks in North and South Carolina, but economically important beryllium concentrations were found only in pegmatite. The results of this sampling are given in table 4. The importance of the amount of beryllium contained in these samples may be judged by comparing them with the average beryllium content of igneous rocks, about 0.0006 percent (Rankama and Sahama, 1951, p. 443), and of clays, 0.004 to 0.0036 percent (p. 447).

Table 4.—BeO content of rocks other than pegmatite of the tin-spodumene belt, North Carolina

Rock	Locality: District	Locality: Mine	Locality: Pit or area	BeO (percent)[1]
Barite	Kings Creek, S. C.			[2]<0.0003
Altered quartzite	Jefferson Mountain, S. C. (Kings Mtn. quadrangle).			< .0003
Andalusite-hematite rock.	do			.0032
Kyanite quartzite	Henry Knob, S. C.			[3]<.0001
Kyanite concentrate	do			[3]<.0001
Sericite schist	North Carolina	Kings Mountain gold mine.		.0005
Dense sericite	do	do		.0015
Tactite (near Cherryville quartz monzonite).	2 miles northwest of Kings Mountain, N.C.			.0072
Tactite (near Toluca quartz monzonite).	8 miles northwest of Shelby, N. C.			.0019
Pyrite and sericite schist.	Near Crouse, N. C.	Sloan pyrite mine		<.0003
Yorkville granite	Near Dallas, N. C.			.0005
Tourmaline schist	3 miles northeast of Lincolnton, N. C.			.0027
Vein quartz	3 miles east of Lincolnton, N. C.			<.0003
Tourmaline schist	8 miles northwest of Shelby, N. C.			.0022
Quartz	Jefferson, S. C.	Brewer mine[4]	Topaz pit	<.0003
Topaz	do	do	do	<.0003
Do	do	do	Float area 1	.0003
Do	do	do	Float area 2	.0008
Do	do	do	Float area 3	<.0003
Do	do	do	Float area 4	<.0003
Do	do	do	Northeasternmost pit.	<.0003
Kyanite	do	do	North of Brewer pit.	<.0003
Ottrelite sericite schist.	do	do	do	<.0003
Quartz	do	do	Tanyard pit	<.0003
Do	Kershaw, S. C.	Haile gold mine		<.0003
Pyrite	do	do		<.0003
Sericite rock	Gold Hill, N. C.	Emmons mine		<.0003
Pyrophyllite-quartz rock.	Staley, N. C.			<.0003

[1] BeO determinations by Strock Laboratories, Inc. except as noted.
[2] Not detected spectrographically.
[3] BeO determinations by Janet D. Fletcher, U. S. G. S.; BeO not detected, hence less than 0.0001 percent.
[4] Map designation used by Carl Fries (1942, pl. 7).

LITERATURE CITED

Fries, Carl, 1942, Topaz deposits near the Brewer mine, Chesterfield County, South Carolina: U. S. Geol. Survey Bull. 936-C, p. 59-78.

Griffitts, W. R. and Overstreet, W. C., 1952, Granitic rocks of the western Carolina Piedmont: Am. Jour. Science, v. 250, p. 777-789.

Keith, Arthur, and Sterrett, D. B., 1931, Description of the Gaffney and Kings Mountain quadrangles, South Carolina and North Carolina: U. S. Geol. Survey Geol. Atlas, folio 222.

Kesler, T. L., 1942, The tin-spodumene belt of the Carolinas: U. S. Geol. Survey Bull. 936-J., p. 245-269.

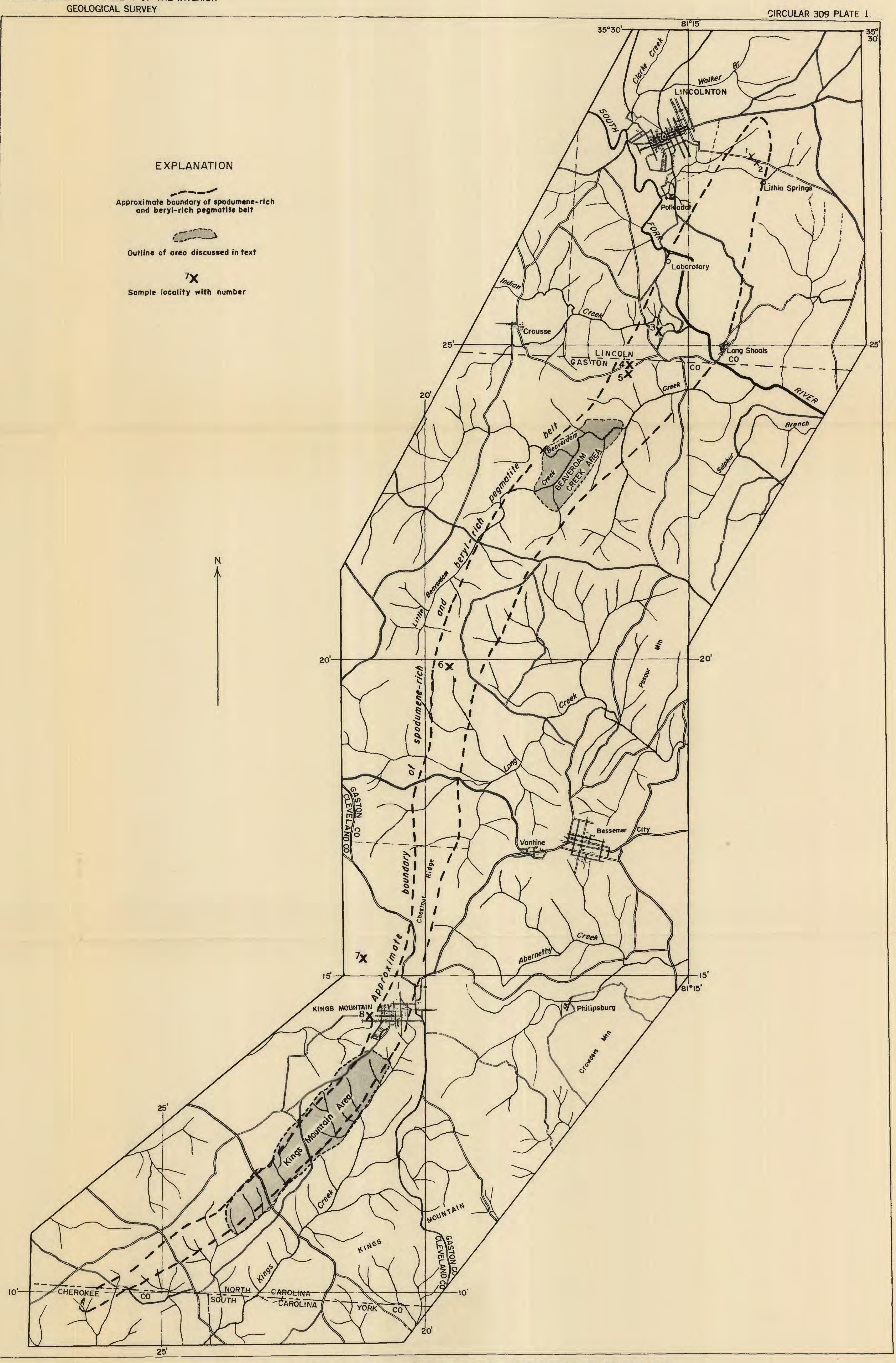
Rankama, Kalervo, and Sahama, T. G., 1950, Geochemistry: Univ. Chicago Press.

Anonymous, 1952, More spodumene from Kings Mountain: Eng. and Min. Jour., v. 153, p. 95.

INT.-DUP. SEC., WASH., D.C 54793

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

CIRCULAR 309 PLATE 1

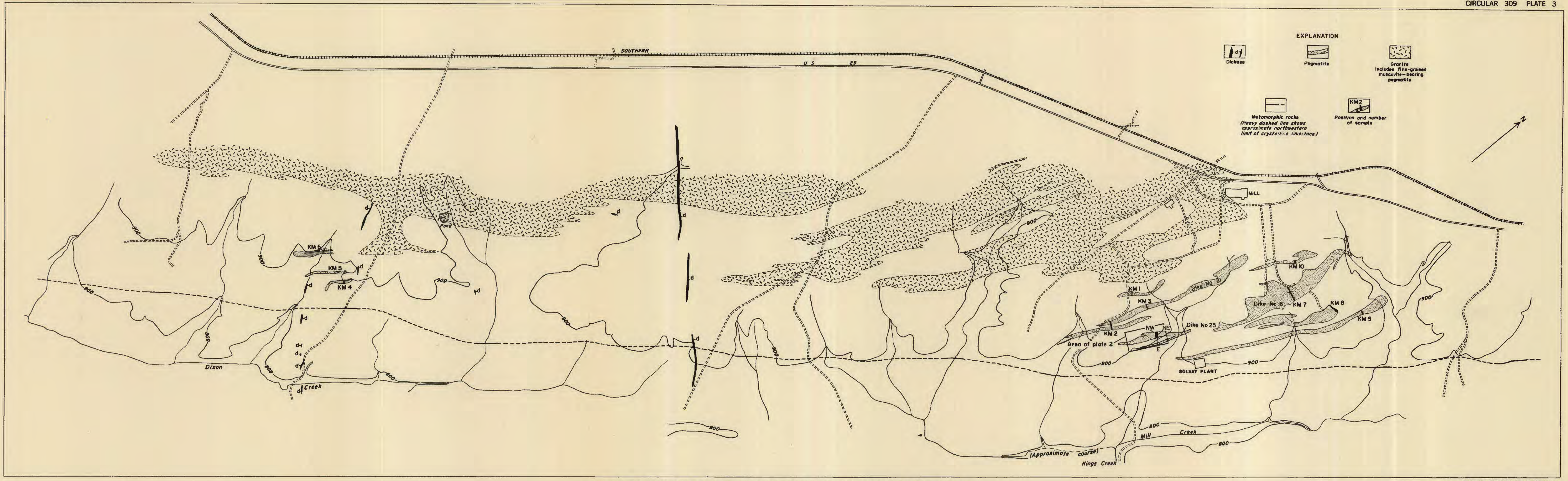


SAMPLE LOCALITIES IN THE TIN-SPODUMENE BELT

Topography by R. E. Burns and W. R. Griffitts

Geology by W. R Griffitts

GEOLOGIC MAP OF THE SOLVAY PROCESS COMPANY OPENCUT, KINGS MOUNTAIN AREA, NORTH CAROLINA



GEOLOGIC MAP OF PART OF THE TIN-SPODUMENE BELT SOUTHWEST OF KINGS MOUNTAIN, NORTH CAROLINA

500 0 1000 2000 3000 4000 5000 Feet

Contour interval 100 feet, Datum is mean sea level

Base and geology after P. M. LeBaron, H. E. LeGrand, J. C. Morris and T. L. Kesler, 1938–1940; beryllium sampling by W. R. Griffitts, 1949.