POTENTIAL FELDSPAR RESOURCES IN NORTH-CENTRAL NORTH CAROLINA

NORTH CAROLINA GEOLOGICAL SURVEY

OPEN-FILE REPORT 95-1

DIVISION OF LAND RESOURCES

DEPARTMENT OF ENVIRONMENT, HEALTH
AND NATURAL RESOURCES

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JOHANTHAN B. HOWES, SECRETARY

CONTENTS

ILLUSTRATIONS

TABLES

POTENTIAL FELDSPAR RESOURCES IN NORTH-CENTRAL NORTH CAROLINA

by

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and P. Albert Carpenter, III[1]

ABSTRACT

Concentrations of sodium and potassium in stream sediment are an index of feldspar abundance in soils eroded into streams. Consequently, potential feldspar resources can be identified from stream sediment geochemical surveys. A review of the National Uranium Resources Evaluation (NURE) stream sediment database for North Carolina and comparison of element distribution patterns with published geologic maps, reveals that highest potassium concentrations are associated with biotite monzogranites which contain large megacrysts of potash feldspar. These include the Churchland plutonic suite in central North Carolina and the Rolesville granite in the Raleigh Metamorphic Belt in the eastern Piedmont. Highest concentrations of sodium in stream sediment are associated with metatonalite intrusives along the western margin of the Carolina slate belt in north-central North Carolina.

Saprolite developed on these granitoids contains potential economic feldspar resources. Previously, Neal and others (1973) obtained positive test results for potash spar in samples collected from the Churchland plutonic suite, including samples from the Mooresville, Landis, and Churchland plutons. Samples showing the highest degree of weathering contained the highest concentrations of K_2O (> 10 weight percent) and lowest concentrations of Na_2O (< 3 weight percent) in feldspar concentrates. Positive test results were also obtained for potash spar from the Rolesville granite. The Siloam granite in Georgia is a megacrystic, biotite monzogranite, lithologically similar to megacrystic phases of the Churchland plutonic suite and Rolesville granite. Saprolite developed on this intrusive is currently being mined for potash spar by the Feldspar Corporation.

Metatonalites and associated saprolite contain significant concentrations of soda spar that may be suitable for use in the glass industry. Feldspar concentrates from these rocks contain > 8 weight percent Na_2O and < 0.5 weight percent K_2O. Metallurgical problems associated with samples tested from tonalitic material include high iron content (> 0.1 weight percent Fe_2O_3) and low recovery of soda spar (< 42 weight percent).

INTRODUCTION

North Carolina is the leading feldspar producer in the U.S., accounting for approximately 65 percent of U.S. production (Potter, 1995a). However, growth of feldspar production in the state faces several obstacles. For example, in the Spruce Pine district, environmental problems are of major concern. Hydrofluoric acid, a critical reagent which depresses quartz in the flotation of feldspar, accounts for elevated concentrations of fluoride in mine effluents. Maximum allowable discharge of fluoride into the North Toe River by mining companies has been reached (Mike Parker, oral communication). Under current regulations, it is difficult for existing operations to increase production, and virtually impossible for a new mining operation to develop in the central portion of the district. Imports of lithium raw materials from

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South America may eventually eliminate by-product feldspar production from spodumene-bearing pegmatites in the Kings Mountain pegmatite district. Therefore, if North Carolina is to maintain its leading position in the feldspar industry, utilization of new reserves elsewhere in the state may be required.

This report describes potential feldspar resources in north-central North Carolina. It is based mainly on integration of pre-existing information that includes the following:

1) The National Uranium Resources Evaluation (NURE) database for stream sediment in North Carolina (Reid, 1991). Analyzed samples consist of -100 mesh (< 149 micron) sediment. This study evaluates the statewide distribution of sodium (6144 sites) and potassium (4609 sites), as well as other elements (U, Th, Hf, Al, Fe, Mn, Ti, V, Ba, Ca, Cr, Cu, K, Mg, P) in north-central North Carolina.

2) A survey of feldspar resources by the Minerals Research Laboratory (MRL), North Carolina State University (Neal and others, 1973).

3) Geologic mapping in north-central North Carolina and descriptions of granitoid rocks in this area. Principal sources of information include Carpenter (1982); North Carolina Geological Survey (1985); and Goldsmith and others (1988).

4) Properties and specifications of feldspar used by industry (Kaufman and Van Dyk, 1994; and Bolger, 1995).

In addition, three samples were collected in this study and analyzed by the MRL. The results are included in Appendix 1 and described in a subsequent section of this report.

THE FELDSPAR INDUSTRY

The status of the U.S. feldspar industry in 1994 is summarized by Potter (1995a). Domestic feldspar production in 1994 had an estimated value of $31.2 million. Approximately 63 percent of production was used in the glass industry, and the remaining 37 percent was used mainly in ceramics (glazes, whiteware, sanitary ware, dinner ware, and porcelain), fillers, and other uses. Feldspar prices at the end of 1994 were about as follows (Potter, 1995b):

$46/metric ton ($42/short ton) for glass-grade soda feldspar, 600 microns (30 mesh), f.o.b. Spruce Pine, North Carolina;

$67/metric ton ($61/short ton) for ceramic -grade soda feldspar, 90 to 75 microns, (170 to 200 mesh), f.o.b. Spruce Pine, North Carolina

$105/metric ton ($95/short ton) for ceramic-grade potash feldspar, -75 microns (200 mesh), f.o.b. Monticello, Georgia

The U.S. Bureau of Mines classifies feldspar as potash spar if K_2O exceeds 10 weight percent; and soda spar if Na_2O exceeds 7 weight percent. In North Carolina, feldspar produced from alaskite in the Spruce Pine district contains approximately 7 weight percent Na_2O and 4 weight percent K_2O. Feldspar produced from pegmatites in the Kings Mountain district as a by-product of spodumene mining is also sodium-rich and is marketed as a quartz-feldspar mixture to the glass industry. However, KMG Minerals, Inc., which mines a mixture of weathered coarse granite (Cherryville quartz monzonite) and pegmatite, produces potash spar with a K_2O content of 10.5 percent (Kaufman and Van Dyk, 1994).

Feldspar is an important, but relatively inexpensive ingredient in the manufacture of glass and ceramics. Principal glass raw materials are silica (SiO_2), soda ash (Na_2CO_3) and mixes of limestone and dolomite. Soda ash accounts for about 50 percent of costs of raw materials. Feldspar contains several important constituents. Alumina provides hardness, durability, resistance to chemical corrosion and devitrification, and enhances strength. Na_2O and K_2O are fluxing agents, lowering batch melting temperatures and reducing requirements for expensive soda ash. Soda spar is more widely used in glass manufacture. In ceramics, feldspar serves as a flux to form a glassy phase at lower temperatures than would otherwise be possible, and as a source of alkalies and alumina in glazes. The degree of vitrification, and ranges of firing temperatures, are determined by the composition and concentration of feldspar. Thus both soda spar and potash spar are used in varying proportions in the manufacture of ceramics (Bolger, 1995; Bourne, 1994; Kaufman and Van Dyk, 1994).

EVALUATION OF THE NURE DATA

This evaluation of the NURE stream sediment data demonstrates that soils which contain high concentrations of sodic plagioclase or potash feldspar are sources of stream sediment that contains high concentrations of sodium and potassium, respectively. In the development of feldspathic soils during weathering, feldspar is preserved instead of altering to kaolin and releasing contained alkalies to groundwater. Areas characterized by sodium-rich and potassium-rich sediment tend to be associated with specific granitoid rocks delineated on the Geologic Map of North Carolina (North Carolina Geological Survey, 1985). It will also be demonstrated that these granitoids and associated feldspathic soils constitute possible economic resources of feldspar.

Figure 1 shows sites which contain the highest concentrations of potassium in stream sediments in North Carolina. Most of the sites containing > 3 weight percent potassium (highest 1.6 percent of analyzed samples) are associated with biotite monzogranites in the Charlotte belt. These intrusives are collectively termed the Churchland plutonic suite and include the Churchland, Mooresville, and Landis plutons (North Carolina Geological Survey, 1985). Neal and others (1973) tested 218 samples of feldspathic rocks in the Piedmont and Blue Ridge provinces. They concluded that samples from 55 sites provided favorable test results in terms of feldspar yield (recovery) and grade (weight percent K_2O). These sites, which are shown in Figure 1, demonstrate a close correlation between the potassium content of stream sediment and granitoid rocks providing favorable test results for potash spar. Favorable test results were obtained for a number of sites in the Churchland, Landis, and Mooresville plutons, as well as sites associated with the Rolesville pluton in the eastern Piedmont. All of the granitoids noted above contain large megacrysts of potassium feldspar (up to 12 cm in maximum dimension). Large crystal size may enhance stability of potash feldspar during weathering, which could account for its high concentration in associated stream sediment.

Stream sediment sites containing the highest concentrations of sodium are shown in Figure 2. A prominent northeast trending band of sodium-rich sediment, which contains > 3.35 weight percent Na (highest 1 percent of analyzed samples), is associated with biotite metatonalite and felsic volcanic rocks near the western boundary of the Carolina slate belt. Samples tested from the biotite metatonalite indicate possible economic concentrations of soda spar in these rocks. These include tests of samples collected in the present study as well as test results previously reported by Neal and others (1973). These results are summarized in a subsequent section of this report.

DISCUSSION OF GRANITOID ROCKS - NORTH-CENTRAL NORTH CAROLINA

Figure 3 summarizes the relationship between high concentrations of potassium and sodium in stream sediment, and geologic units identified in north-central North Carolina. Most sites containing > 3 weight percent potassium are associated with the Churchland, Landis, and Mooresville intrusives in the Charlotte belt. Sites containing > 3.35 weight percent sodium are associated with biotite metatonalite in a large intrusive complex that occurs along the western margin of the Carolina slate belt. Some sites are associated with small granitoid

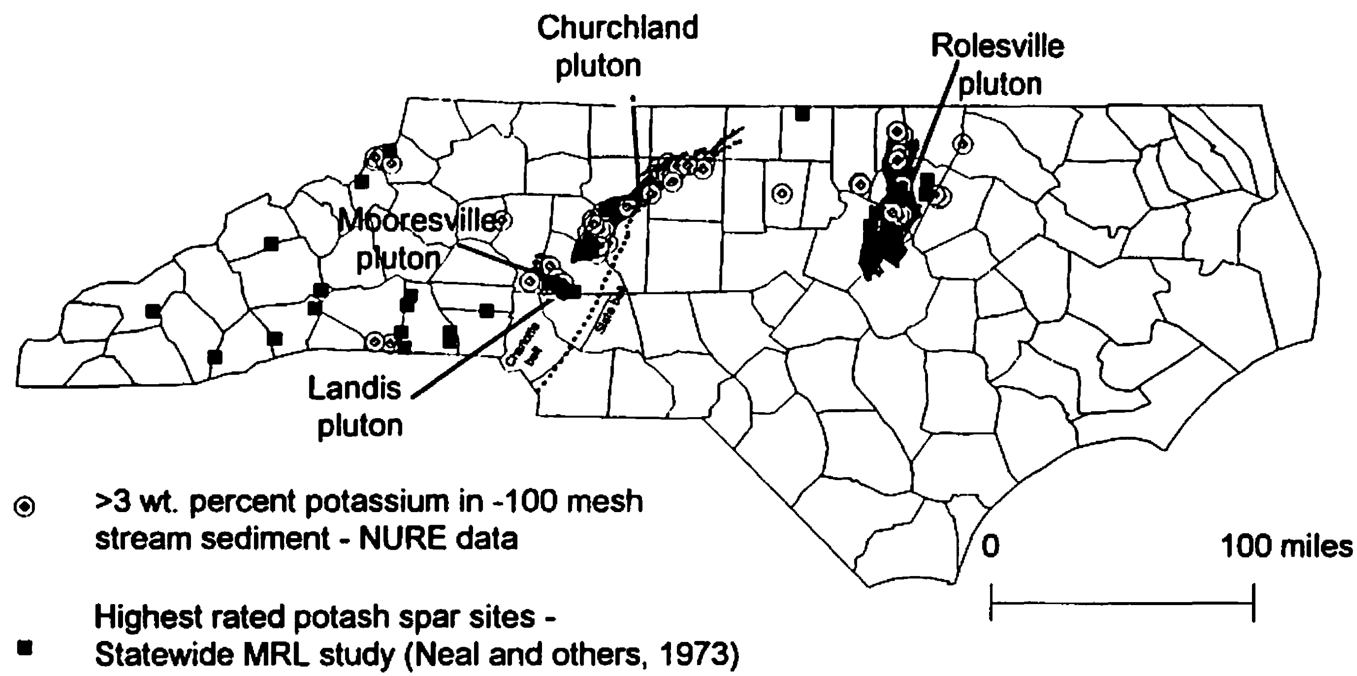

Figure 1. North Carolina Counties showing locations of stream sediment sites (NURE data) with potassium content > 3 wt. percent, and highest rated test sites for potash spar. Granitoid plutons showing a close correlation with these sites include the Churchland, Landis, Mooresville, and Rolesville plutons.

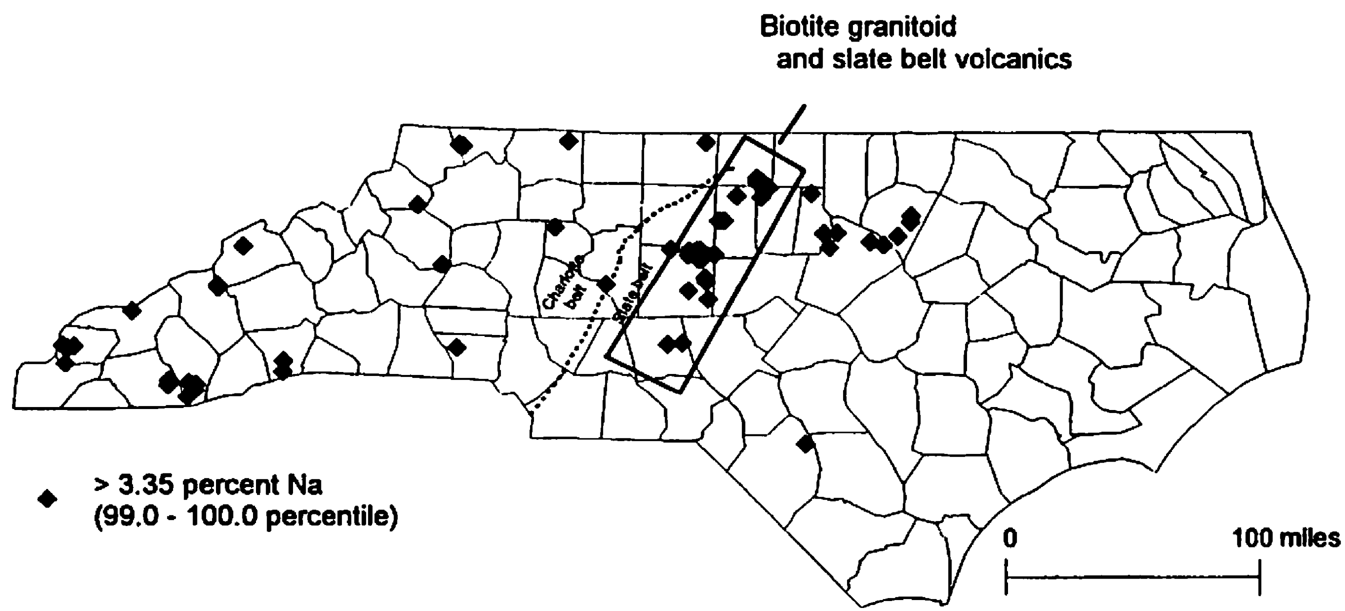

Figure 2. North Carolina Counties showing locations of stream sediment sites (NURE data) with sodium content > 3 wt. percent. A prominant belt of sodium-rich sediment is located in the western slate belt where associated rocks consist mainly of biotite metatonalite and slate belt volcanic rocks.

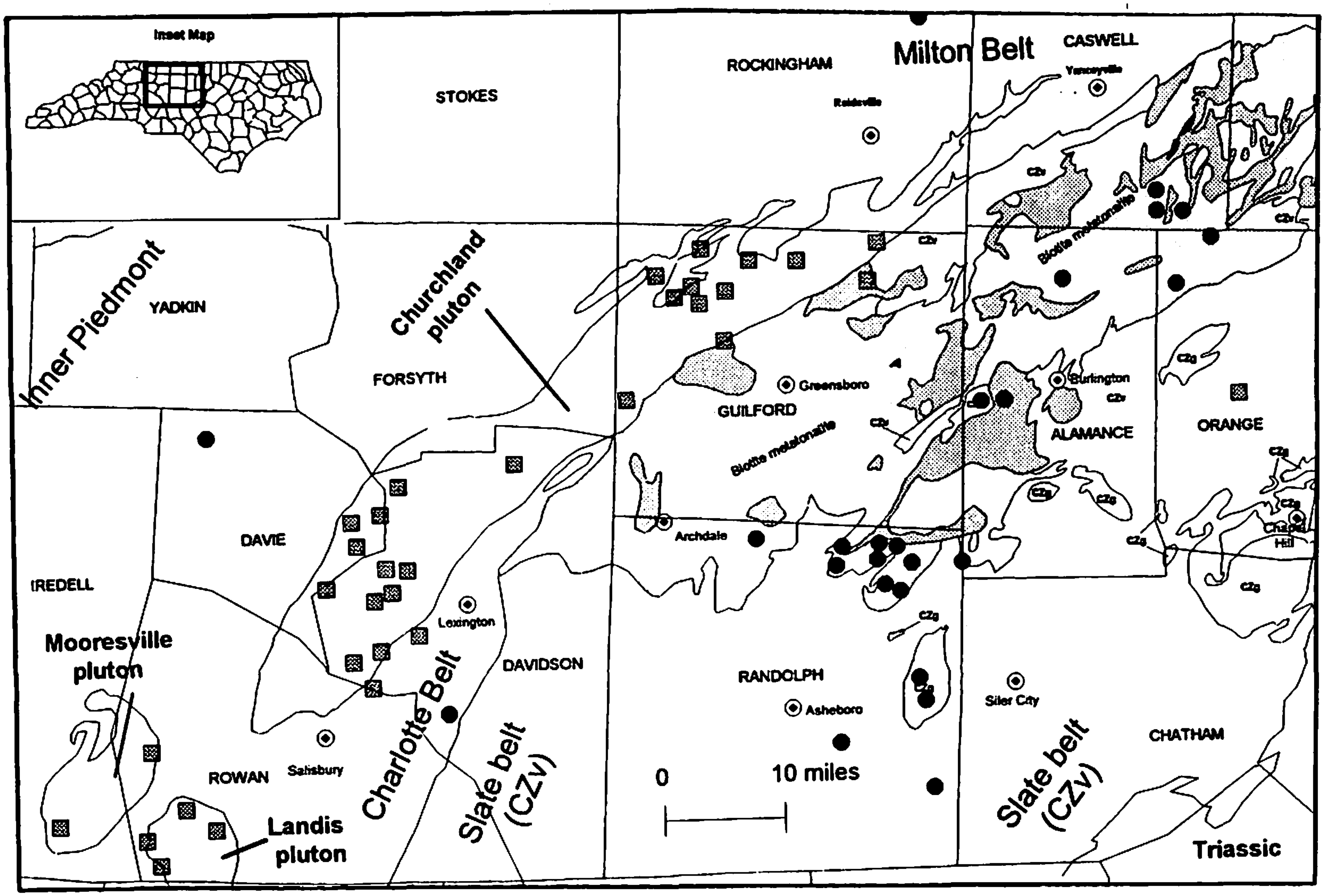

Figure 3. Geologic map of north-central North Carolina (see inset map). Shaded units comprise an igneous intrusive complex along the northwestern margin of the slate belt. Biotite metatonalite (light stippling), metadiorite-metagabbro (intermediate cross-hatched), meta-ultramafic rocks (black). Other granitoid rocks in slate belt indicated by symbol (CZg). Volcanic rocks in slate belt indicated by symbol (CZv). Major granitoid intrusives in the Charlotte belt are the Churchland, Landis, and Mooresville plutons. The Inner Piedmont and Milton belts consist largely of metamorphic rocks (gneisses and schists). Stream sediment containing >3.35 wt. percent sodium shown by circles; samples containing >3% wt. percent potassium shown by squares. Modified from North Carolina Geological Survey (1985).

Table 1.

COMPARISON OF STREAM SEDIMENT ASSOCIATED WITH GRANITOIDS - CENTRAL NORTH CAROLINA
NURE DATA

NORTH CAROLINA NURE DATA - SEDIMENT- SITES ASSOCIATED WITH BIOTITE METATONALITE - CAROLINA SLATE BELT

County	County ID	Lat	Long	U ppm	Th ppm	Hf ppm	Al wt. %	Fe wt. %	Mn wt. %	Na wt. %	Ti wt. %	V ppm	Ba ppm	Ca ppm	Cr ppm	Cu ppm	K wt. %	Mg wt. %	P wt. %
Alamance	AL006S1	36.2353	79.3226	2.2	3	82	5.56	6.83	0.48	3.07	3.11	200	12	500	27	2	0.05	0.24	0.10
Alamance	AL007S1	36.2081	79.3509	1.2	13	17	6.78	3.39	0.28	2.99	1.20	130	17	300	20	4	0.20	0.36	0.10
Alamance	AL008S1	36.1886	79.3944	1.5	8	6	8.63	4.23	0.54	3.81	0.68	140	45	400	6	6	0.10	0.16	0.10
Caswell	CS022S1	36.2524	79.3285	1.1	3	19	5.71	2.18	0.11	3.30	0.56	90	25	500	5	2	0.20	0.30	0.07
Caswell	CS023S1	36.2660	79.2576	1.8	2	23	9.58	5.18	0.28	3.57	1.82	180	15	800	3	3	0.10	0.51	0.08
Caswell	CS025S1	36.2894	79.2585	1.1	4	2	11.05	4.23	0.28	4.64	0.74	130	.	2500	.	9	.	.	.
Orange	OR012S1	36.1820	79.2298	1.5	14	4	8.81	2.81	0.12	3.89	0.28	80	25	600	8	4	0.30	0.14	0.10
Orange	OR016S1	36.2080	79.2533	1.0	7	13	5.72	1.62	0.10	2.50	0.38	70	10	400	7	3	0.20	0.27	0.08

NORTH CAROLINA NURE DATA - SEDIMENT- SITES ASSOCIATED WITH THE CHURCHLAND PLUTON - CHARLOTTE BELT

County	County ID	Lat	Long	U ppm	Th ppm	Hf ppm	Al wt. %	Fe wt. %	Mn wt. %	Na wt. %	Ti wt. %	V ppm	Ba ppm	Ca ppm	Cr ppm	Cu ppm	K wt. %	Mg wt. %	P wt. %
Guilford	GU021S1	36.1963	79.9818	3.6	10	3	8.00	4.48	0.13	0.56	M	30	532	400	10	13	5.20	0.23	0.07
Guilford	GU051S1	36.2132	79.8467	7.7	12	142	4.46	3.52	0.14	0.81	1.05	100	292	400	10	5	4.70	0.29	0.07
Guilford	GU054S1	36.1778	79.8820	5.2	17	20	7.05	4.05	0.19	0.68	0.44	50	388	100	10	12	5.50	0.14	0.11
Guilford	GU055S1	36.1642	79.9195	5.2	9	19	5.98	3.39	0.06	1.97	0.31	40	367	1000	10	9	3.80	0.22	0.14
Guilford	GU056S1	36.1713	79.9553	6.4	15	42	5.18	3.29	0.07	0.87	0.51	60	138	600	15	9	6.60	0.48	0.05
Guilford	GU077S1	36.2325	79.6631	1.1	17	3	2.56	1.48	0.01	0.61	M	M	247	50	10	2	5.50	0.14	0.01
Guilford	GU083S1	36.2121	79.7790	9.8	19	103	5.49	2.24	0.04	0.97	0.71	50	947	500	5	3	3.30	0.85	0.08

NORTH CAROLINA NURE DATA - SEDIMENT- SITES ASSOCIATED WITH THE MOORESVILLE PLUTON - CHARLOTTE BELT

County	County ID	Lat	Long	U ppm	Th ppm	Hf ppm	Al wt. %	Fe wt. %	Mn wt. %	Na wt. %	Ti wt. %	V ppm	Ba ppm	Ca ppm	Cr ppm	Cu ppm	K wt. %	Mg wt. %	P wt. %
Iredell	IR019S1	35.5703	80.8461	7.2	19	92	6.31	2.30	0.02	0.51	0.46	70			2.5	10	3.10	0.16	0.62
Rowan	RW078S1	35.6539	80.7128	23.4	42	446	5.27	2.51	0.04	0.83	0.59	70			8	3	3.50	0.39	0.23

NORTH CAROLINA NURE DATA - SEDIMENT- SITES ASSOCIATED WITH THE LANDIS PLUTON - CHARLOTTE BELT

County	County ID	Lat	Long	U ppm	Th ppm	Hf ppm	Al wt. %	Fe wt. %	Mn wt. %	Na wt. %	Ti wt. %	V ppm	Ba ppm	Ca ppm	Cr ppm	Cu ppm	K wt. %	Mg wt. %	P wt. %
Rowan	RW071S1	35.5645	80.6209	19.6	23	166	2.56	0.81	0.01	0.39	0.09	10			5	3	3.20	0.03	0.46
Rowan	RW072S1	35.5234	80.7012	9.3	25	30	6.53	0.68	0.01	1.09	0.29	40			2.5	3	3.60	0.02	0.39
Rowan	RW074S1	35.5524	80.7210	8.2	12	44	6.03	1.93	0.02	1.03	0.40	50			9	4	3.30	0.22	0.17
Rowan	RW075S1	35.5878	80.6644	6.4	11	16	5.59	1.01	0.01	1.02	0.29	40			2.5	3	3.50	0.27	0.09

AVERAGES

	U ppm	Th ppm	Hf ppm	Al wt. %	Fe wt. %	Mn wt. %	Na wt. %	Ti wt. %	V ppm	Ba ppm	Ca ppm	Cr ppm	Cu ppm	K wt. %	Mg wt. %	P wt. %
HIGH SODIUM-BIOTITE METATONALITE	1.4	6.8	20.8	7.73	3.81	0.27	3.47	1.10	127.5	18.6	750.0	9.5	4.1	0.14	0.25	0.08
HIGH POTASSIUM-CHURCHLAND PLUTON	5.6	14.1	47.4	5.53	3.21	0.09	0.82	0.43	47.1	415.9	435.7	10.0	7.6	4.94	0.23	0.08
HIGH POTASSIUM MOORESVILLE PLUTON	15.3	30.5	269.0	5.79	2.40	0.03	0.67	0.53	70.0			5.3	6.5	3.30	0.27	0.43
HIGH POTASSIUM-LANDIS PLUTON	10.9	17.8	64.0	5.18	1.16	0.01	0.88	0.27	35.0			4.8	3.3	3.40	0.13	0.28

Explanation: M denotes missing value; . denotes very high detection limit intrusives (CZg) and felsic volcanic rocks.

Table 1 summarizes elemental data for representative stream sediment samples as well as averages for sites associated with the biotite metatonalite and the three granitoid plutons in the Charlotte belt. Elements enriched at sites associated with biotite metatonalite include sodium, aluminum, iron, manganese, titanium, vanadium, and calcium. From a mineralogical standpoint, these analyses indicate an abundance of Na-rich plagioclase (high sodium and aluminum), ilmenite (high iron and titanium), and magnetite (high iron). Potassium is uniformly low, relative to sodium, suggesting that potash feldspar is a minor constituent.

Sediment associated with the granitoid plutons in the Charlotte belt is enriched in uranium, thorium, hafnium, barium, and potassium. The potassium content is high relative to sodium. This suggests that potash feldspar is much more abundant than plagioclase in stream sediment.

CHURCHLAND, MOORESVILLE, AND LANDIS PLUTONS - CHARLOTTE BELT

Geologic Descriptions. Brief descriptions of these intrusives are presented by Watson and Laney (1906) and Butler and Ragland (1969). The most complete petrographic description is by Privett (1973). His descriptions are restricted to extensive porphyritic, or megacrystic, phases of the intrusives. Non- porphyritic phases subsequently have been identified (Speer and others, 1980; Carpenter, 1982). These intrusives are collectively referred to as the Churchland plutonic suite on the Geologic Map of North Carolina (North Carolina Geological Survey, 1985) and the Charlotte 1° x 2° quadrangle (Goldsmith and others, 1988). The dominant phase is biotite monzogranite, but some occurrences of quartz monzonite and hornblende-bearing phases are present (Goldsmith and others, 1988).

The porphyritic (megacrystic) biotite monzogranite is dominant in these intrusives. It consists of phenocrysts of microcline up to 9 cm long by 5 cm wide (Privett, 1973). The porphyritic granitoid is composed of microcline (10 - 50 per cent), plagioclase (15 - 30 per cent), quartz (20 - 25 percent), biotite (5 - 20 percent), plus accessory sphene, zircon, ilmenite, muscovite, and hornblende and some secondary minerals (chlorite, epidote, and leucoxene). Plagioclase occurs in the groundmass as zoned crystals with calcium-rich cores and sodium-rich (albite) rims (Privett, 1973). Plagioclase inclusions (Ab_{3-20}) are also abundant in microcline phenocrysts. These are also zoned with calcic centers (Ab_{10-20}) and sodic rims (Ab_{3-10}). According to Speer and others (1980), the Landis pluton is uniformly coarse, and amphibole is present in the coarse granitoid of the Churchland pluton along the southern and western boundaries. They also note the presence of massive fine - to medium - grained granitoid in the eastern portion of the Churchland pluton.

Porphyritic phases of the intrusives are extensively weathered (Privett, 1973). Fresh outcrops are exposed mainly along major streams and rivers, or in deep road cuts. Saprolite thickness may exceed a hundred feet in some areas. Saprolite typically contains fresh phenocrysts of microcline and smaller crystals of quartz in a matrix of clay formed by weathering of less resistant plagioclase and some of the potash feldspar in the groundmass. Depending on the extent of weathering, biotite may also occur in saprolite.

Test Results. Table 2 (Part I) presents test results of samples from the Churchland, Landis, and Mooresville intrusives reported by Neal and others (1973). It also cites chemical analyses for commercial potash spar from Georgia and North Carolina.

Samples from each intrusive contain > 10 percent K_2O and are comparable to commercial potash spar products. Neal and others (1973) note that samples containing > 10 percent K_2O are "highly weathered," and those containing < 10 percent K_2O are described as "partly weathered". This relationship indicates the greater stability of microcline versus plagioclase during weathering,

Table 2.

FELDSPAR ANALYSIS - QUANTITATIVE RESULTS

PART I
COMMERCIAL POTASH SPAR PRODUCTS AND FELDSPAR CONCENTRATES FROM THE LANDIS, MOORESVILLE AND CHURCHLAND PLUTONS

Lab Sample I.D.	Nonmag Qtz %Wt.	Nonmag Spar %Wt	Chemical Analysis Nonmag Spar %AL2O3	%Fe2O3	%Na2O	%K2O	%CaO	SOURCE OF INFORMATION
Commercial Products:								
FELDSPAR CORP - GA.			18.00	0.10	2.85	10.50	1.02	INDUSTRIAL MINERALS AND ROCKS, 1994
KMG MINERALS - NC			18.00	0.07	3.60	10.10	0.14	INDUSTRIAL MINERALS AND ROCKS, 1994
Landis Intrusive:								
3139	15.7	47.3		0.24	2.30	6.40		NEAL AND OTHERS, 1973
3141	26.6	30.2		0.09	2.70	10.40		NEAL AND OTHERS, 1973
Mooresville Intrusive:								
3360	26.1	28.6		0.06	2.20	12.00		NEAL AND OTHERS, 1973
3361	32.5	27.1		0.07	2.60	12.10		NEAL AND OTHERS, 1973
3362	18.2	29.8		0.09	1.80	11.20		NEAL AND OTHERS, 1973
Churchland Intrusive:								
3145	20.2	33.2		0.13	3.20	9.60		NEAL AND OTHERS, 1973
3148	16.6	38.2		0.10	3.40	7.80		NEAL AND OTHERS, 1973
3340	18.7	26.3		0.11	3.00	11.10		NEAL AND OTHERS, 1973
3370	4.2	64.9		0.09	1.80	12.90		NEAL AND OTHERS, 1973
3358	16.2	29.1		0.08	2.90	10.50		NEAL AND OTHERS, 1973
3365	28.1	32.0		0.08	2.80	10.40		NEAL AND OTHERS, 1973

PART II
COMMERCIAL SODA SPAR PRODUCTS AND FELDSPAR CONCENTRATES FROM BIOTITE METATONALITE

Lab Sample I.D.	Nonmag Qtz %Wt.	Nonmag Spar %Wt	Chemical Analysis Nonmag Spar %AL2O3	%Fe2O3	%Na2O	%K2O	%CaO	SOURCE OF INFORMATION
Commercial Products:								
VIRGINIA "APLITE"			22.00	0.10	6.00	2.60	5.50	INDUSTRIAL MINERALS AND ROCKS, 1994
UNIMIN CORP-SPRUCE PINE, NC			19.30	0.08	6.90	4.80	1.70	INDUSTRIAL MINERALS AND ROCKS, 1994
Biotite Metatonalite:								
GRB-1-1	15.4	28.7	20.43	0.49	7.25	2.26	2.72	MRL-1995-SCHLANZ STUDY
GRB-2-1	15.4	29.3	23.10	0.22	7.61	0.12	4.73	MRL-1995-SCHLANZ STUDY
CHP-2-1	13.3	31.5	20.13	0.62	8.37	0.74	2.37	MRL-1995-SCHLANZ STUDY
JAMESTOWN QUARRY (A)	22.6	42.3		0.14	8.60	0.40		NEAL AND OTHERS, 1973
JAMESTOWN QUARRY (B)	18.5	42.1		0.30	8.20	0.40		NEAL AND OTHERS, 1973
DAVIDSON CO. -3369	20.8	40.1		0.16	8.30	0.40		NEAL AND OTHERS, 1973

NOTE: JAMESTOWN (A) MINUS 1/2 INCH PRODUCT, WEATHERED; JAMESTOWN (B) MINUS 1/2 INCH PRODUCT, FRESH UNWEATHERED which is well established in the literature (Loughnan, 1969). It also appears that breakdown of calcic plagioclase in the groundmass, and in inclusions in microcline phenocrysts, may have occurred in the highly weathered samples. Na_2O preserved in feldspar concentrates prepared from highly weathered samples probably represents albite (in rims of plagioclase grains) which is more stable to weathering than more calcic oligoclase (Loughnan, 1969). Recovery of potash feldspar probably depends on the percentage of potash feldspar phenocrysts in the granitoid prior to weathering. According to Privett (1973), the potash feldspar content of coarse granitoid is between 10 percent and 50 percent in the Churchland plutonic suite.

BIOTITE METATONALITE - CAROLINA SLATE BELT

Geologic Descriptions. The rocks referred to as biotite metatonalite in Figure 3 are termed "metamorphosed granitic rock" on the Geologic Map of North Carolina (North Carolina Geological Survey, 1985), "felsic intrusive complex" on the Geologic Map of Region G, North Carolina (Carpenter, 1982), and "metamorphosed quartz diorite and tonalite" on the Charlotte 1° x 2° quadrangle (Goldsmith and others, 1988). Megascopically, they are medium - to coarse - grained, equigranular, and consist of gray and bluish gray translucent quartz, cream colored feldspar, and brown biotite. Clots of more mafic composition contain epidote and amphibole. Foliation is locally conspicuous and indicates that these rocks have been subjected to the same regional metamorphic event as enclaves of slate belt volcanic rocks present in portions of the intrusive complex. These rocks were classified as granite, granodiorite, quartz monzonites, and quartz diorites by Carrilho (1973). Relative proportions of potassium and sodium in stream sediment, as well as compositions of samples of these rocks reported in Table 2 (Part II) indicate that quartz and plagioclase (oligoclase-andesine) are the principal minerals contained in these rocks. Biotite is present in most outcrops and probably accounts for most of the potassium present. If classified according to molecular normative anorthite-albite-orthoclase after Barker (1979), (meta)tonalite is probably the dominant phase present. Associated igneous rocks include a suite of intermediate (metadiorite) - mafic (metagabbro) - and meta-ultramafic rocks.

Test Results. Locations of samples tested by MRL are presented in Figure 4. Test results for samples GRB1-1, GRB2-1, and CHP2-1 are contained in Appendix 1 and are also included in Table 2 (Part 2). Table 2 (Part 2) also includes: 1) test results described by Neal and others (1973) for samples collected from the Jamestown quarry (see Figure 4); 2) a sample from Davidson County, and 3) analyses of commercial soda spar products from Virginia and Spruce Pine, North Carolina.

Feldspar concentrates from the biotite metatonalite (Table 2) contain more sodium and less potassium than the commercial products shown in Table 2. Sodium is a suitable fluxing agent in glassmaking; therefore the lack of potassium does not preclude use of this feldspar in the glass industry (oral communication, James Tanner, Minerals Research Laboratory). Iron is of more serious concern. Concentrates from all of the test samples contain > 0.1 percent Fe_2O_3, exceeding most specifications for iron in soda spar used by the glass industry. Iron may occur as ilmenite and/or magnetite inclusions in feldspar concentrates. These minerals may also account for feldspar losses in the iron float products and magnetics, as noted in Appendix A. The aluminum content of feldspar concentrates from the biotite metatonalite compares favorably with Virginia "aplite".

Sample GRB2-1 is saprolite. The texture of the granitoid is preserved, but the material is sufficiently weathered to be easily disaggregated by hand. This material is exposed over a wide area at the site. Depending on depth-of-weathering, a significant reserve of saprolite may be present.

Feldspar concentrates prepared from samples from the Jamestown quarry reveal Fe_2O_3 as low as 0.14 percent with Na_2O as high as 8.6 percent (Table 2). Sample 3369 from Davidson County has a

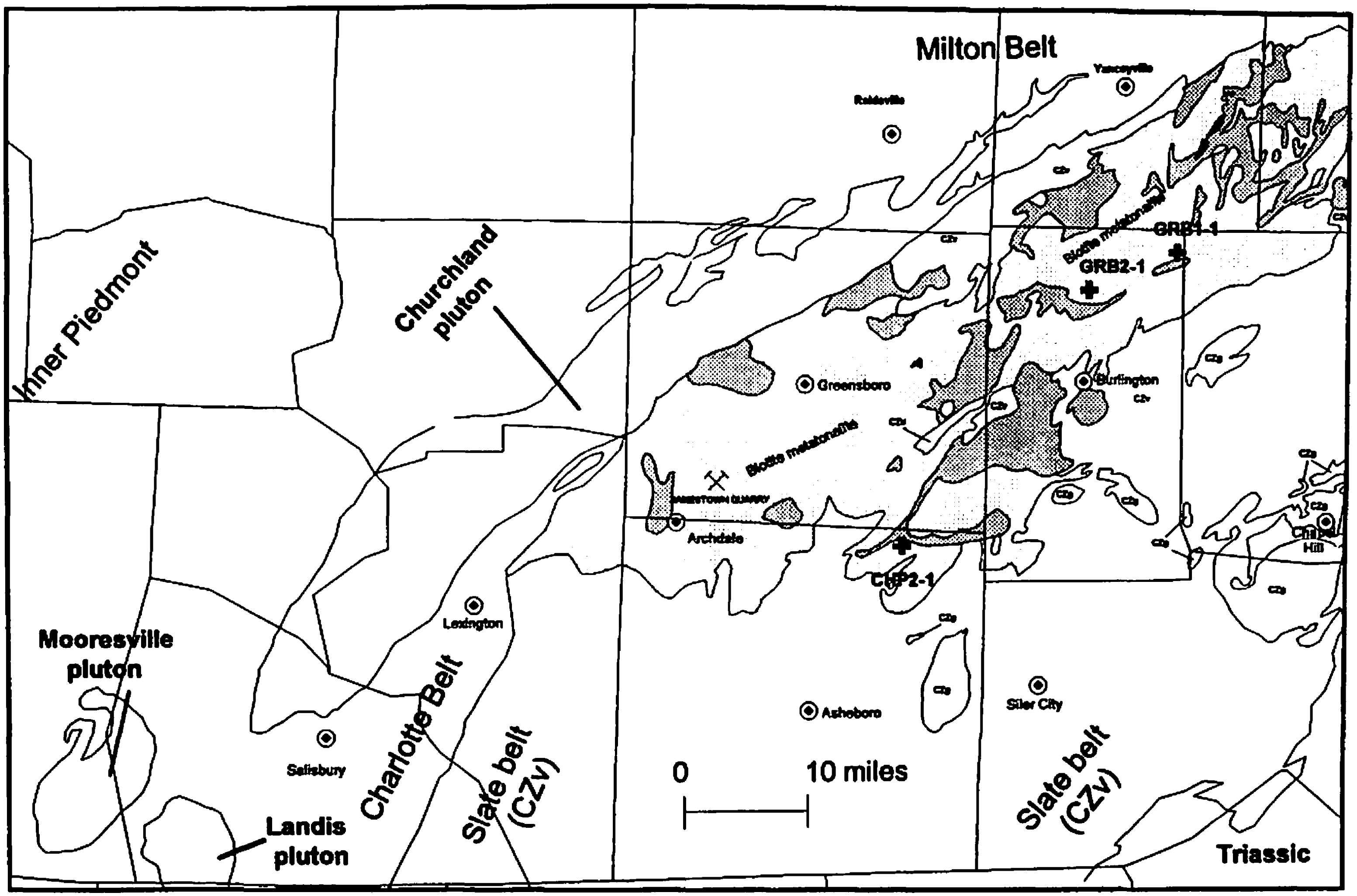

Figure 4. Geologic map of north-central North Carolina (see Figure 3 for explanation). Locations of test samples (GRB1-1, GRB2-1, and CHP2-1) are shown as well the Jamestown quarry where test results are reported by Neal and others (1973).

composition similar to other samples tested from the biotite metatonalite.

CONCLUSIONS

Growth of feldspar production in North Carolina may require discovery of new reserves outside of established areas of production. This study focuses attention on two geologic regimes in north-central North Carolina which warrant additional exploration and evaluation of feldspar resources. Potash spar (up to 12.9 percent K_2O) is recoverable from three megacrystic, biotite monzogranite plutons in the Charlotte belt in portions of Guilford, Rowan, Davidson, and Iredell Counties. Soda spar (up to 8.6% Na_2O) is recoverable from biotite metatonalite along the northwest margin of the Carolina slate belt in portions of Davidson, Randolph, Guilford, Alamance, and Caswell Counties.

Some technical problems have been identified. For the biotite metatonalite, iron, possibly in the form of ilmenite and magnetite, probably accounts for Fe_2O_3 concentrations in excess of 0.1 percent, and low recoveries of non-magnetic spar (25 percent - 35 percent). Potash spar recovery from rock and saprolite associated with megacrystic granitoids in the Churchland plutonic suite is also in the 25 percent to 35 percent range for highly weathered material where plagioclase has altered mainly to clay. Highest recoveries may be associated with phases of the granitoid containing the highest concentration of potassium feldspar megacrysts. Iron contamination is commonly below 0.1% Fe_2O_3.

Both potash spar and soda spar can occur in high concentrations in saprolite, which usually contains enough clay formed by weathering of some of the contained feldspar to be readily disaggregated into a quartz-feldspar-clay mixture. Saprolite may be quite thick in some areas. Feldspathic saprolite could be mined with conventional earth moving equipment without drilling and blasting. In recent years, a new feldspar mining operation (potash spar), which utilizes hydraulic mining methods, has been successfully developed in feldspathic saprolite associated with the Siloam granitoid in central Georgia by the Feldspar Corporation (Kaufman and Van Dyk, 1994; Cocker, 1995). The Siloam granitoid is similar in composition and texture to the Churchland plutonic suite (Speer and others, 1980). In the Kings Mountain area, KMG Minerals, Inc., recovers potash spar from saprolite developed on the Cherryville quartz monzonite as a by-product of its muscovite mining operations (Kaufman and Van Dyk, 1994). KMG Minerals, Inc., also recovers clay as a by-product which is used in the manufacture of brick, and quartz which has been sold as a glass raw material (James Tanner, oral communication). Advantages of mining saprolite versus unweathered granite include lower mining costs and natural liberation of feldspar, quartz, and other minerals. Brick clay and quartz are possible by-products of a saprolite mining operation. The geographical proximity of soda spar and potash spar occurrences in north-central North Carolina might enable an integrated operation that could produce both high grade soda spar and potash spar, or any combination of the two that might be required.

Finally, this study is an example of the value of regional stream sediment geochemical surveys in dealing with natural resource issues. The specific association of high potassium concentrations in stream sediment with megacrystic granitoid rocks containing large megacrysts of potassium feldspar has not been previously noted in the literature. The relationships outlined here may offer a basis for feldspar exploration that has not previously been utilized. Regional surveys, such as the NURE survey, can be used to identify favorable rock-types and areas for feldspar exploration. Additionally, detailed stream sediment surveys that include relatively small drainage basins (0.25 - 0.5 square miles), may serve to delimit saprolite containing the highest concentrations of feldspar.

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REFERENCES

Barker, F., 1979, Trondhjemite: Definition, environment and hypotheses of origin: *in* Barker, F., ed., Trondhjemites, dacites, and related rocks: Amsterdam, Elsevier, p. 1 - 12.

Bolger, R., 1995, Feldspar and nepheline syenite: Industrial Minerals, No. 332, p. 25 - 45.

Bourne, Lyn H., 1994, Glass raw materials: in Carr D.D., and others, eds., Industrial Minerals and Rocks (6th Edition): Littleton, Colorado, Society for Mining, Metallurgy, and Exploration, Inc., p. 543 - 550.

Butler, J.R., and Ragland, P.C., 1969, A petrochemical survey of plutonic intrusions in the Piedmont, southeastern Appalachians, U.S.A.: Contrib. Mineral. Petrol., vol. 24, p. 164 - 190.

Carrilho, C., 1973, The geology of the Burlington NE quadrangle, North Carolina: (Unpublished M.S. Thesis), North Carolina State University, Raleigh, North Carolina, 58 p.

Carpenter, P. Albert, III, 1982, Geologic map of Region G, North Carolina: North Carolina Department of Natural Resources and Community Development, Division of Land Resources, Geological Survey Section, Regional Geology Series 2., map scale 1:125,000.

Cocker, Mark D., 1995, Geological setting and geochemical trends in the Jasper County Pegmatite District, Georgia: *in* Walker, B.J., ed., Proceedings 28th Forum on the Geology of Industrial Minerals, Morganton, West Virginia, West Virginia Geological and Economic Survey and U.S. Bureau of Mines, p. 85 - 94.

Goldsmith, R., Milton, D. J., and Horton, J.W., Jr., 1988, Geologic map of the Charlotte 1° x 2° quadrangle, North Carolina and South Carolina: U.S. Geological Survey, Map I-1251-E. map scale 1:250,000.

Kaufman, R.A., and Van Dyk, D., 1994, Feldspars: *in* Carr. D.D., and others, eds., Industrial Minerals and Rocks (6th Edition): Littleton, Colorado, Society for Mining, Metallurgy, and Exploration, Inc., p. 473 - 481.

Loughnan, F.C., 1969, Chemical weathering of the silicate minerals: New York, American Elsevier Publishing Company, Inc., 154 p.

Neal, P.J, Wiener, L.S., Carpenter, P.A., III, Wilson, W.F., Parker, J. M., III, 1973, Evaluation of Potential North Carolina Feldspar Resources: Report MRL-3, Minerals Research Laboratory, School of Engineering, North Carolina State University, 67 p.

North Carolina Geological Survey, 1985, Geologic Map of North Carolina: Department of Natural Resources and Community Development, scale 1:500,000.

Potter, M.J., 1995a, Feldspar and nepheline syenite: *in* Mineral Industry Surveys, U.S. Department of the Interior, U.S. Bureau of Mines, 2 p.

Potter, M.J., 1995b, Feldspar and nepheline syenite: *in* Industrial Minerals 1994, Mining Engineering, vol. 47, no. 6, p. 543-544.

Privett, D.R., 1973, Petrogenesis of porphyritic granitic plutons in the central Piedmont of North Carolina: Elisha Mitchell Scientific Society Journal, vol. 89, p. 172 - 178.

Reid, Jeffrey C., 1991, A geochemical atlas of North Carolina: Bulletin 91, North Carolina

Geological Survey, Division of Land Resources, 45 plates.

Speer, J.A., Becker, S.W., and Farrar, S.S., 1980, Field relations and petrology of the post metamorphic, coarse grained granitoids and associated rocks of the southern Appalachian Piedmont: *in* Wones, D.R., ed., Proceedings Caledonides in the U.S.A., Blacksburg, Virginia, Memoir 2, Department of Geological Sciences, Virginia Polytechnic Institute and State University, p. 137 - 148.

Watson, T.L., and Laney, F.B., 1906, The building and ornamental stones of North Carolina: North Carolina Geological Survey Bulletin Number 2, 283 p.

APPENDIX 1
TESTS FOR FELDSPAR AND QUARTZ RECOVERY

TESTS FOR FELDSPAR AND QUARTZ RECOVERY

SAMPLES

Tests were completed on samples designated as GRB1-1, GRB2-1, and CHP2-1 (See Figure 4 for location).

TEST PROCEDURES

Standard feldspar/quartz recovery procedures were employed in this limited evaluation. These procedures included crushing and grinding to 30 mesh (600 mictons), attrition scrubbing and desliming, and flotation of mica, iron-bearing minerals, and feldspar. All feldspar and quartz products were subjected to dry magnetic separation on a rare earth roll permanent magnet.

These procedures are detailed in Tables 1-1 through 1-4.

RESULTS

Summary results are presented in Table 1-1. Detailed results are contained in Tables 1-2, 1-3, and 1-4. Recoveries of both feldspar and quartz were consistent over the three samples tested, with spar yields ranging from 28.7 to 31.5 weight percent. Corresponding quartz yields were 13.3 to 15.4 weight percent. Major losses were experienced in the iron float products and magnetics.

All three feldspar concentrates were high in soda spar at 7.25 to 8.37 percent Na_2O. K_2O values were relatively low at 0.1 to 2.3 percent. CaO values were relatively high, ranging from 2.3 to 4.7 percent. The high sodium/potassium ratios are responsible for the high aluminas, which were all > 20 percent Al_2O_3.

Feldspar iron values were considered high in all three samples. Sample GRB2-1 contained the lowest iron at 0.223 percent Fe_2O_3, while samples GRB1-1 and CHP2-1 assayed 0.494 and 0.619 percent Fe_2O_3, respectively.

Iron values in the quartz products were lower, with samples GRB2-1 and GRB1-1 assaying less than 0.1 percent Fe2O3. As with feldspar, sample CHP2-1 produced the highest iron at 0.171 percent Fe_2O_3. Alumina and total alkalis remaining in the quartz products were low, indicating a good flotation separation.

COMMENTS

The following comments are based on the data generated from the three samples tested, and do not necessarily represent all of the geologic formation in the area.

1) All three samples tested produced relatively low yields of feldspar at approximately 30 percent by weight. Although additional testing could improve upon these yields, the extensive processing required would necessitate much improved weight recoveries for an economically feasible deposit.

2) Iron values were considered high for commercial feldspar markets. Typical feldspar specifications for the ceramic and glass industries require iron values of less than 0.08 percent Fe_2O_3.

3) Relative proportions of sodium, potassium, and calcium are atypical for traditional glass and ceramic markets, particularly the high calcium values, which would be considered a detriment to the ceramic industry. The corresponding high alumina values may be attractive to the glass industry, although this is the lower priced end of the market.

4) Although iron values were lower in the quartz products, they were not low enough to meet most commercial specifications, particularly the higher priced markets.

5) Most operating feldspar deposits rely on the higher priced ceramic, filler, and other value added markets to achieve profitability. Some also rely on

niche markets created from unique properties of the products, which can increase the market value. Although this was a limited evaluation, these factors should be noted if exploration efforts are to continue.

Table 1-1. Summary of Results - Feldspar Recovery
Lab No. 6241

TEST	PRODUCT	WT%	$\%Fe_2O_3$	$\%Al_2O_3$	$\%K_2O$	$\%Na_2O$	$\%CaO$
GRB1-1	Feldspar	28.7	0.494	20.43	2.26	7.25	2.72
	Quartz	15.4	0.070	0.587	0.112	0.208	0.063
GRB2-1	Feldspar	29.3	0.223	23.10	0.123	7.61	4.73
	Quartz	15.4	0.052	0.233	0.004	0.075	0.034
CHP2-1	Feldspar	31.5	0.619	20.13	0.738	8.37	2.37
	Quartz	13.3	0.171	0.883	0.118	0.218	0.150

NOTE: Detailed analytical results, weight balances, and test procedures are presented in Tables 1-2, 1-3, and 1-4.

Table 1-2. Recovery of Feldspar - Sample GRB1-1

Test No. GRB1-1 Lab No. 6241 Operator : D.G. Date: 3/7/95

TEST PRODUCTS	WT.%	Al_2O_3	Fe_2O_3	Na_2O	K_2O	CaO	SiO_2	LOI	MgO	TiO_2
+30 mesh	3.6									
Mica F.P.	5.4									
Iron Float Prod.	12.8									
Spar Magnetics	13.2									
Spar Non-Mags	28.7	20.43	0.494	7.25	2.26	2.72	66.3	0.710	0.068	0.033
Quartz Non-Mags	15.4	0.587	0.070	0.208	0.112	0.063	-	0.070	0.021	0.017
Quartz Magnetics	2.6									
Spar Mids	3.9									
Losses	14.4									
Total	100.0									

PROCESS	TIME	% SOLIDS	pH	NaOH	H_2SO_4	HM-70	F-65	11C	H.F.
Screen 30 Mesh									
Rod Mill +30	*	50							
Dilute and Deslime @ 200 Mesh									
Attrition Scrub	7 Min.	70-75		0.0					
Deslime @ 200 M X 2									
Condition	4 Min	50	2.6		1.0			0.3	
Float Mica							0.1		
Condition	6 Min	60-65	2.3		1.0	0.5			
Float Iron							0.1		
Condition	5 Min	50	2.3					0.7	1.5
Float Spar							0.1		
Mag. Sep. - Spar X 2									
Mag Sep. Qtz X 2									

Comments: Rod mill and screening (30 mesh) repeated until everything passed 30 Mesh - 2 grinding periods @ 2 min.

Magnetic separation performed dry on Bateman Permroll Rare Earth

Table 1-3. Recovery of Feldspar - Sample GRB2-1

Test No. GRB2-1 Lab No. 6241 Operator : D.G. Date: 3/7/95

TEST PRODUCTS	WT.%	Al_2O_3	Fe_2O_3	Na_2O	K_2O	CaO	SiO_2	LOI	MgO	TiO_2
+30 mesh	2.9									
Mica F.P.	6.7									
Iron Float Prod.	5.4									
Spar Magnetics	7.9									
Spar Non-Mags	29.3	23.1	0.223	7.61	0.123	4.73	63.9	0.375	0.026	0.033
Quartz Non-Mags	15.4	0.233	0.052	0.075	0.004	0.034	-	0.065	0.009	0.002
Quartz Magnetics	2.1									
Spar Mids	3.9									
Losses	24.5									
Total	100.0									

PROCESS	TIME	% SOLIDS	pH	NaOH	H_2SO_4	HM-70	F-65	11C	H.F.
Screen 30 Mesh									
Rod Mill +30	•	50							
Dilute and Deslime @ 200 Mesh									
Attrition Scrub	7 Min.	70-75		0.0					
Deslime @ 200 M X 2									
Condition	4 Min	50	2.5		1.0			0.3	
Float Mica							0.1		
Condition	6 Min	60-65	2.4		1.0	0.5			
Float Iron							0.1		
Condition	5 Min	50	2.4					0.7	1.5
Float Spar							0.1		
Mag. Sep. - Spar X 2									
Mag Sep. Qtz X 2									

Comments: Rod mill and screening (30 mesh) repeated until everything passed 30 Mesh - 2 grinding periods @ 2 min.

Magnetic separation performed dry on Bateman Permroll Rare Earth

Table 1-4. Recovery of Feldspar - Sample CHP2-1
Test No. CHP2-1 Lab No. 6241 Operator : D.G. Date: 3/7/95

TEST PRODUCTS	WT.%		Al_2O_3	Fe_2O_3	Na_2O	K_2O	CaO	SiO_2	LOI	MgO	TiO_2
+30 mesh	0.6										
Mica F.P.	6.8										
Iron Float Prod.	16.8										
Spar Magnetics	9.0										
Spar Non-Mags	31.5		20.13	0.619	8.37	0.738	2.37	66.5	0.660	0.109	0.033
Quartz Non-Mags	13.3		0.883	0.171	0.218	0.118	0.150	-	0.140	0.060	0.010
Quartz Magnetics	2.4										
Spar Mids	3.9										
Losses	24.5										
Total	100.0										

PROCESS	TIME	% SOLIDS	pH		NaOH	H_2SO_4	HM-70	F-65	11C	H.F.
Screen 30 Mesh										
Rod Mill +30	*	50								
Dilute and Deslime @ 200 Mesh										
Attrition Scrub	7 Min.	70-75			0.0					
Deslime @ 200 M X 2										
Condition	4 Min	50	2.4			1.0			0.3	
Float Mica								0.1		
Condition	6 Min	60-65	2.3			1.0	0.5			
Float Iron								0.1		
Condition	5 Min	50	2.2						0.7	1.5
Float Spar								0.1		
Mag. Sep. - Spar X 2										
Mag Sep. Qtz X 2										

Comments: Rod mill and screening (30 mesh) repeated until everything passed 30 Mesh - 2 grinding periods @ 2 min.

Magnetic separation performed dry on Bateman Permroll Rare Earth