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SOUTH CAROLINA MATERIALS FOR FLOOR TILE

By

G. C. Robinson[1]

INTRODUCTION

The Southeastern States do not at present have a manufacturer of floor tile and therefore must import this product from Pennsylvania or Ohio. The growing market in the Southeast for the vitreous ceramic floor tile used in bathrooms and many other places in construction has caused increasing interest in the possibility of locating a manufacturing plant in South Carolina. Introduction of natural gas into the State has helped this interest, and recent improvements in raw material supply have now made South Carolina a very attractive location for a floor tile manufacturer.

The major raw materials for floor tile are quartz, feldspar, kaolin and ball clay. Quartz and feldspar make up between 60 to 85 percent of the raw material composition. The remaining portion of the body is composed of a mixture of ball clay and kaolin or a mixture of some plastic kaolin with a coarser textured kaolin. Sometimes auxiliary fluxes such as talc, dolomite, or magnesium carbonate are added as minor constituents in the batch.

A plant was recently established near Pacolet, South Carolina, for the production of feldspar and quartz from the by-products of a granite crushing operation. Use of the by-product materials as a raw material for this operation provides a low cost feed for the plant and a competitive advantage over producers of feldspar in other regions. An additional saving in cost is possible by taking advantage of their production of a natural mixture of quartz and feldspar from the granite rather than requiring individual separation of the quartz and feldspar constituents. It is quite possible that a floor tile manufacturer could utilize such a mixture. This would mean that a location in South Carolina would provide an unusually low-cost source of materials. Furthermore, it is quite possible that South Carolina kaolin could be used for a large portion of the batch. This would mean that it would be necessary to import only from 5 to 20 percent of out-of-state materials for this product.

It was desired to obtain a preliminary evaluation of the possibility of using South Carolina materials in floor tile manufacture.

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[1] Head, Ceramic Engineering Department, Clemson College, Clemson, South Carolina

PROCEDURE

The raw materials used for this investigation were all powdered raw materials essentially minus 200 mesh in size. They were used in the "as received" condition from the suppliers. The pulverized mixture of quartz and feldspar is designated as Paco Sand. This material was used for most of the compositions. South Carolina kaolin was obtained from the J. M. Huber Company and is designated as Huber S. C. Kaolin. A small particle size water-washed kaolin was used to impart plasticity and dry strength to the tile composition. This kaolin was designated as #600 Kaolin from the Southern Clay Company. Dolomite was used as an auxiliary flux and was obtained from the U. S. Gypsum Company as their Dolomite AA. One composition used pulverized Paco Feldspar in place of the Paco Sand. The compositions tested are shown in the attached table.

Compositions were blended by adding the material to a muller mixer and adding 10% of water to the batch during mixing. Mixing was continued for 5 minutes. At the conclusion of mixing the batches were formed into test bars measuring 5 inches by 1 inch by 1/4 inch. Test bars were formed at a pressure of 2,500 psi.

Test bars were allowed to air dry for 12 hours at the conclusion of pressing and were then dried at 150 degrees F for an additional 12 hours. Test bars were fired to a selection of maturing temperatures at a rate of 150 degrees F per hour. Bars were maintained at their maturing temperature for 2 hours. Maturing temperatures were at 50 degree intervals from 2050 degrees to 2250 degrees F.

The fired length of the bars was determined and the difference in the fired length and the pressed length divided by the pressed length was expressed as the percentage linear shrinkage. The fired strength was determined and reported as modulus of rupture. Halves of the bars remaining after the strength determination were used in the determination of fired absorption. Test bars were placed in a vacuum flask. After evacuation, water was introduced into the flask. Test bars remained in this environment for 15 minutes and then were allowed to continue to soak in water at atmospheric pressure for an additional 24 hours. The difference in weight between the bars saturated with water and the dry bars divided by the dry weight was used as the expression of absorption.

RESULTS OF TEST

Compositions number 1 through 4 (Table 1) have quantities of Paco Sand varying from 60 to 75 percent. In general it was found that the higher the quantity of sand the lower the fired absorption and the higher the strength for a particular maturing temperature. These

Table 1. -- Fired properties of floor tile composition (without additive)

		2150° F				2200° F				2250° F			
Sample	Composition	Linear Shrinkage (%)	Absorption (%)	MOR (psi)	Sag (inches)	Linear Shrinkage (%)	Absorption (%)	MOR (psi)	Sag (inches)	Linear Shrinkage (%)	Absorption (%)	MOR (psi)	Sag (inches)
1	75% Paco Sand, 15% #600 Kaolin, 10% Huber S. C. Kaolin	9.1	1.0	4900	0.11	9.8	0.90	5100	0.15	9.3	0.60	4100	0.31
2	70% Paco Sand, 15% #600 Kaolin, 15% Huber S. C. Kaolin	9.1	1.3	5300	.08	9.8	.92	4700	.12	9.7	.50	4700	.12
3	65% Paco Sand, 15% #600 Kaolin, 20% Huber S. C. Kaolin	8.7	1.5	4900	.06	9.7	.95	3900	.07	10.3	.53	5300	.08
4	60% Paco Sand, 15% #600 Kaolin, 25% Huber S. C. Kaolin	8.7	2.3	4400	.05	9.7	1.5	4500	.04	10.3	.68	5200	.05

desirable features of the Paco Sand were offset by an increasing amount of warpage or sag of the test samples. Test samples were supported only at their ends and allowed to sag out of shape during firing. The amount of sag was measured in inches. It was possible with composition 3 and 4, containing 65 and 60 percent Paco Sand, to fire to less than 0. 7 percent absorption with sags of less than 0. 08 inches. Similar maturity in composition 1 resulted in a sag of 0. 3 inches. It was, therefore, felt that composition 4 represents the most desirable mixture, though it would possibly require a somewhat higher maturing temperature than the compositions with higher quantities of Paco Sand.

Compositions number 5 through 8 (Table 2) determine the effect of dolomite addition in the base composition of 60% Paco Sand, 25% Huber Kaolin, and 15% #600 Kaolin. The additions of dolomite were quite effective in reducing maturing temperature and increasing fired strength. The addition of two percent dolomite made it possible to vitrify this composition at 2150 degrees F. Comparable results were obtained at 2250 degrees F with a composition without dolomite.

Composition number 8 used feldspar in place of Paco Sand. This gave a smoother textured bar, but otherwise there was no apparent advantage in using the feldspar as compared to the sand. It is possible that the feldspar would give a slightly lower maturing temperature than the Paco Sand and perhaps better resistance to cooling cracks during firing. It is also possible that blends of the sand and the feldspar may prove to be desirable.

Composition No. 6 appeared to be the best one of those tested. It produced products of less than 0. 5% absorption at 2150° F. Composition 7 showed some increase in strength but no improvement in absorption and no reduction in maturing temperature. Composition 8 using Paco Feldspar in place of Paco Sand did not develop the low absorption of Composition No. 6 at 2150° F. , and thus it is indicated that higher firing temperatures would be required. It is recommended that mixtures of Paco Sand and Paco Feldspar be investigated since mixtures may produce more desirable properties than are obtainable from the single materials.

It will be noticed that composition number 6 used 83 percent of South Carolina materials and showed promise for a South Carolina body for floor tile. These results are preliminary in nature and should serve only as a basis for future laboratory investigations for adopting actual production batches.

Table 2. -- Fired properties of floor tile composition[1]

		2050° F			2100° F			2150° F		
Sample	Composition	Linear Shrinkage (%)	Absorption (%)	MOR[2] (psi)	Linear Shrinkage (%)	Absorption (%)	MOR[2] (psi)	Linear Shrinkage (%)	Absorption (%)	MOR[2] (psi)
5	No additive	5.4	9.0	2600	7.5	4.3	4200	8.7	1.5	5800
6	2% dolomite	5.4	8.6	2700	7.5	3.3	4300	8.2	0.4	6000
7	4% dolomite	4.7	7.9	2700	7.7	3.5	5500	8.2	0.5	6700
8	Feldspar plus 4% dolomite	5.7	5.6	3800	7.5	1.8	5500	8.2	1.08	6100

1/ Basic composition was 60% Paco Sand, 15% #600 Kaolin, and 25% Huber S. C. Kaolin, except in #4A the Paco Sand was replaced by Paco Feldspar. The dolomite was added as a replacement for the feldspar or sand.

2/ Modulus of rupture.

RECENT LEAD-ALPHA AGE DETERMINATIONS ON ZIRCON FROM THE CAROLINA PIEDMONT

By William C. Overstreet, Henry Bell, III, Harry J. Rose, Jr., and Thomas W. Stern, Beltsville, Md., and Washington, D. C.

Lead-alpha ages have recently been determined for 21 zircon concentrates separated from granite, granodiorite, and syenite exposed in the Piedmont of North and South Carolina. The location of the samples is shown on figure 45.1, and descriptions of the sources of the zircon are listed in table 1. Results of the analyses and the calculated ages of the zircon crystals are given in table 2.

Radioactivity determinations on igneous or pyroclastic rocks in the Piedmont offer the only means of determining the ages of these rocks, as the intruded sedimentary rocks contain no fossils. The

Table 1.—*Sources of the zircon*

No. on fig. 45.1	*Source and sample no.*
1.	U.S. National Museum collection. Large zircon crystals stated to have come from a locality 4 miles east of Tigerville, Greenville County, S. C. Zircon-rich vermiculite deposits thought to be source of the specimen. Sample USNM 105674.
2.	U.S. National Museum collection. Large zircon crystals from the Jones Mine, Henderson County, N. C. Vermiculite-bearing syenite pegmatite. Sample USNM 80114.
3.	Zircon panned from 200 pounds of saprolite of fine-grained massive granite exposed in deep road cuts 0.9 mile southwest of Blackjack, Fairfield County, S. C. Rock is marginal phase of pluton represented by sample 59–OT–102. Sample was free of inclusions, but exposure shows blocky inclusions of amphibolite, biotite-hornblende schist, and feldspathic kyanite-muscovite schist. Sample 59–OT–107.
4.	Zircon panned from 290 pounds of saprolite of massive biotite-granite exposed at the intersection of S. C. Rte. 20–19 and the Rockton-Rion Railroad 5.5 miles S. 20° W. of Winnsboro, Fairfield County, S. C. Sample 59–OT–102.
5.	Zircon panned from 260 pounds of saprolite of coarse-grained massive porphyritic biotite granite having phenocrysts of pink microcline up to ¾ inch in length, exposed on S. C. Rte. 97 at a point 1.1 miles north of White Oak Creek, Kershaw County, S. C. Sample 59–OT–110.
6.	Zircon panned from 180 pounds of saprolite of very coarse grained massive porphyritic biotite granite exposed on the east side of Lowrys-Baton Rouge road at a point 0.5 mile west of the junction with U.S. Rte. 321 near Lowrys, Chester County, S. C. Sample 59–OT–101.
7.	Zircon panned from 220 pounds of saprolite of fine-grained massive biotite granite exposed in deep road cuts on both sides of the Leeds-Wilksburg road at a point opposite the Leeds Lookout Tower, Chester County, S. C. Sample 59–OT–100.
8.	Samples from Isenhour Quarry on N. C. Rte. 73 about 0.5 mile east of Concord, Cabarrus County, N. C. Samples are composites of 20-pound samples taken from different parts of the body of rock.
	Zircon panned from 60 pounds of saprolite of medium-grained biotite granite in the southern dike in quarry. Sample IPE.
	Zircon panned from 60 pounds of saprolite of biotite granite forming the northern dike in the quarry. Sample IPF.
	Zircon panned from 100 pounds of saprolite at the main body of biotite granite. Sample IPG.
	Zircon panned from 100 pounds of saprolite at the main body of biotite granite. Sample IPH.
	Zircon panned from 260 pounds of syenite in a dike cutting granite and gneissic granodiorite. Sample HB–39–59.
	Zircon panned from 60 pounds of saprolite of gneissic granodiorite; both the granite and the syenite intrude the gneissic granodiorite. Sample IPA.
	Zircon panned from 40 pounds of saprolite of gneissic grandiorite. Sample IPB.
	Zircon panned from 40 pounds of saprolite of gneissic granodiorite. Sample IPC.
	Zircon panned from 40 pounds of saprolite of gneissic granodiorite. Sample IPD.
9.	Zircon panned from 340 pounds of saprolite of coarse-grained, massive augite syenite exposed in a quarry on the north side of N. C. Rte. 49 just west of the intersection with U.S. Rte. 601 about 2.5 miles south of Concord, Cabarrus County, N. C. Sample 56–OT–11 and 56–OT–11a.
10.	Zircon panned from 200 pounds of saprolite of porphyritic granite exposed on county road between Watts and S. C. Rte 71 at a point 2 miles south of route 71 in Abbeville County, S. C. Nonmagnetic fraction at 1.5 amperes in Frantz Separator; sample 59–OT–111 (N.M. 1.5). Magnetic fraction at 1.5 amperes; sample 59–OT–111 (M 1.5).
11.	U.S. National Museum collection. Large zircon crystals from gneiss exposed 4.5 miles east of Iva on the line between Anderson and Abbeville Counties or in Abbeville County, S. C. Sample USNM 97589.

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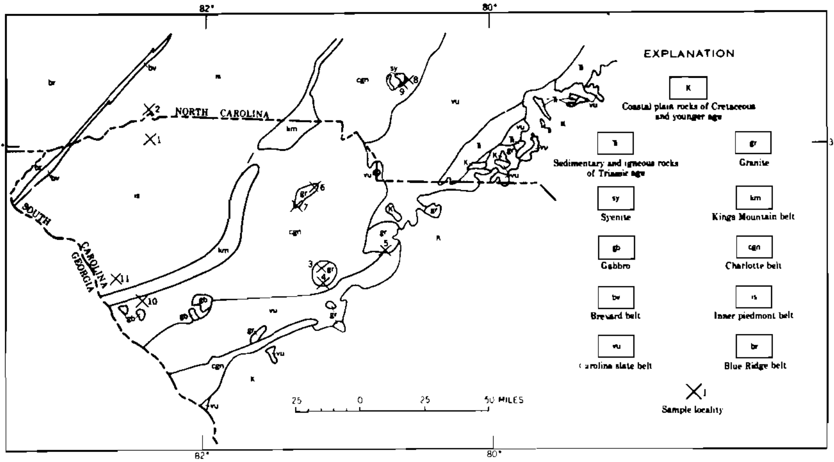

FIGURE 46.1.—Major rock units and location of zircon samples in the Piedmont of North and South Carolina.

rocks studied are now saprolite, so that only resistant minerals can be used for age determinations. Despite a lack of positive knowledge concerning the absolute ages of these rocks, many tentative ideas have been presented regarding their relative ages. Major syntheses of the regional geology of the Southeastern States evolved by Arthur Keith (1923, p. 309–380) and Anna I. Jonas (Mrs. G. W. Stose) (1932, p. 228–243), though profoundly different in tectonic and stratigraphic interpretation, generally attributed a Precambrian age to the bulk of the metasedimentary rocks and to some of the plutonic igneous rocks. The massive igneous rocks were considered to be late Paleozoic in age. Both Keith and Jonas recognized the polymetamorphic character of some of the schist and gneiss, and, despite differences in opinion as to the mechanics of the metamorphism, they attributed it to processes operating in Precambrian and in late Paleozoic time. Recently another major synthesis of Appalachian geology has been presented by P. B. King (1951, p. 119–144; 1955, p. 332–373) who proposes that the metamorphosed sedimentary and volcanic rocks of the Carolina Piedmont and the igneous rocks, intruded during several orogenic episodes, are Paleozoic in age.

Recent geologic observations in the Carolina Piedmont support King's view (Kesler, 1944, p. 755–782; Griffitts and Overstreet, 1952, p. 777–789; Kesler, 1955, p. 374–387; Overstreet and Griffitts, 1955, p. 549–577; Stuckey and Conrad, 1958, p. 3–51; Stromquist and Conley, 1959, p. 1–36; Bell and Overstreet, 1959, p. 1–5; Long, Kulp, and Eckelmann, 1959, p. 585–603; Bell, 1960, p. B189–B191; and Overstreet and Bell, 1960, p. B197–B199). They show 3 sequences or episodes of sedimentation, volcanism, igneous intrusion, folding, and metamorphism. Erosional unconformities bracket the 3 episodes. The Paleozoic geologic events shown schematically in table 3 were deduced by Overstreet and Bell as a result of reconnaissance mapping during which it was recognized that the metasedimentary rocks of the South Carolina Piedmont consist of slate-belt rocks of various ages raised to different grades of regional metamorphism, and that unconformities in the slate belt correlate with unconformities in the Kings Mountain belt.

The unconformities correlated between the slate and the Kings Mountain belts are those below episodes B and C, table 3. A postulated unconformity beneath episode A has not been observed in the

TABLE 2.—*Lead-alpha ages of zircon from rocks in the Piedmont of North and South Carolina*

[Alpha activity measurements by T. W. Stern; spectrographic analyses of lead by H. J. Rose, Jr., T. W. Stern, and H. W. Worthing.]

No. on fig. 45.1	Sample No.	Alpha counts per milligram per hour	Average lead content from duplicate determinations (parts per million)	Calculated age [1] (millions of years)
1	USNM 105674	269	28	255 ± 30
2	USNM 80114	439	51	280 ± 30
3	59–OT–107	346	37	260 ± 30
4	59–OT–102	477	53	270 ± 30
5	59–OT–110	170	17	245 ± 30
6	59–OT–101	306	32	255 ± 30
7	59–OT–100	145	28	460 ± 50
8	IPE	377	68	445 ± 50
	IPF	458	68	360 ± 40
	IPG	433	78	430 ± 50
	IPH	398	49	300 ± 35
	HB–39–59	262	49	450 ± 50
	IPA	132	28	505 ± 55
	IPB	123	25.5	495 ± 55
	IPC	117	19	380 ± 100
	IPD	'32	26	470 ± 55
9	56–OT–11	24	3.0	305 } 425 ± 110
	56–OT–11a	22	5.0	540
10	59–OT–111 (NM 1.5)	344	82	565 ± 65
	59–OT–111 (M 1.5)	481	102	505 ± 55
11	USNM 97589	172	40	550 ± 60

[1] Lead-alpha ages (rounded to nearest 5 million years) were calculated from the equations:

(1) $t = \frac{C\,Pb}{\alpha}$ where t is the calculated age in millions of years, C is a constant based upon the U/Th ratio and has the value 2485, Pb is the lead content in parts per million and α is the alpha counts per milligram per hour; and

(2) $T = t - 1/2\,kt^2$ where T is the age in millions of years corrected for decay of uranium and thorium, and k is a decay constant based upon the U/Th ratio and has a value of 1.56×10^{-4}.

U/Th ratio from X-ray fluorescence analyses by F. J. Flanagan is 1.0 for samples 59–OT–100, 59–OT–101, 59–OT–102, 59–OT–110, and 59–OT–111 (M 1.5); assumed 1.0 for other samples.

Piedmont of southern North Carolina or in South Carolina. Some measure of the probable age of the unconformities and of the sedimentary and pyroclastic rocks they bracket have been sought by the authors through the lead-alpha ages of zircons from plutonic igneous rocks emplaced during one or another of the three episodes listed in table 3. Many pounds of saprolite were panned to obtain each zircon concentrate. In addition, three samples of coarse-grained zircon were kindly given to the writers by G. S. Switzer of the U.S. National Museum.

Direct measurements of the ages of the sediments in the three episodes is being attempted by A. A. Stromquist, A. M. White, and T. W. Stern by analyzing zircon from felsic lavas interbedded with the sediments. This work, however, is not yet completed.

The results of lead-alpha age determinations on 17 of the 21 samples fall into three groups (table 4) which correspond to the position of their host rocks in the three geologic episodes shown on table 3. The analyses are most consistent and seem to show the best agreement with presently available field data in the youngest group of samples, and increasingly less consistent in the older groups.

The results from four samples do not fit with the recognized field relations. One sample of zircon (59–OT–100) with an age of 460 ± 50 m.y. (million years) was collected from fine-grained granite thought to be a marginal phase of the oval pluton represented by sample 59–OT–101 having an age of 255 ± 30 m. y. The older sample may be contaminated by nonradiogenic lead or by an older generation of zircon. The samples of zircon from Cabarrus County, N. C., 56–OT–11 and 56–OT–11a (425 ± 110 m.y.), HB–39–59 (450 ± 50 m. y.), are thought to come from rocks occupying structural positions similar to the episode-C syenite. Low lead and alpha activity of the zircon from samples 56–OT–11 and 56–OT–11a make satisfactory analysis very difficult, but sample HB–39–59 was satisfactory for analysis, and it also gave an unexpectedly old age. Possibly some syenite was emplaced during episode B, but the field evidence presently restricts syenite to episode C.

The probable ages of the unconformities between the three episodes can be interpreted from the three groups of ages shown on table 4. The unconformity between episodes C and B apparently formed between 400 and 260 m.y. ago. In order to allow for the deposition of the sediments in which episode-C syenite and granite is emplaced, the unconformity is probably closer to 400 than to 260 m.y. old. It apparently was formed between Ordovician and Devonian time.

The ages of the zircon crystals from rocks in episode A doubtless are modified by loss of lead during the profound metamorphism of episode B. We do not yet know when these rocks were emplaced, but it is likely that they were intruded into sediments of late Precambrian and Cambrian age. The unconformity between episodes B and A may have been formed between Cambrian and Ordovician time.

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TABLE 3.—*Summary of Paleozoic geologic events in the Carolina Piedmont*

Era	Episode of folding, metamorphism, and igneous activity	Rock		Metamorphism	
		Sedimentary	Igneous	Regional	Contact
Paleozoic	Unconformity				
	C		Syenite, gabbro, pyroxenite, norite; granitic rocks, typically form circular plutons and elongate cross-cutting bodies; felsic and mafic flows and dikes associated with the pyroclastic and sedimentary rocks.	Syenite, gabbro, pyroxenite, norite and granites unaffected by progressive regional metamorphism, but show some retrogressive features chiefly resulting from cataclasis; felsic and mafic dikes and flows show effects of low-grade regional metamorphism.	None attributable to syenite; feeble local contact effect from gabbro, pyroxenite, and norite; feeble increase in metamorphism at granite contacts; no metamorphism attributable to felsic and mafic feeder dikes.
		Argillite, graywacke, pyroclastic rocks.		Progressive, seldom exceeding greenschist facies; slight retrogressive.	
	Unconformity				
	B		Granitic rocks, typically concordant plutons; gabbro, pyroxenite, andesite dikes; mafic flows, and felsic dikes and flows associated with pyroclastic and sedimentary rocks.	Widespread migmatization; retrogressive effects such as recrystallization of biotite attributable to episode C.	Granites of episode B react retrogressively on inclusions of gabbro and pyroxenite of episode B; may have large contact aureoles in greenschist and albite-epidote amphibolite zones; little or no aureoles in higher grade zones; no evidence of metamorphism induced by feeder dikes for mafic and felsic flows; retrogressive effects associated with the granites of episode C.
		Argillite, graywacke, pyroclastic rocks, local sandstone and limestone; now seen as schists, gneisses, migmatites, quartzites and marble.		Progressive, ranging from greenschist facies to sillimanite-garnet subfacies; retrogressive features attributable to episode C locally common; highest-grade rocks show some recrystallization of biotite and retrogression of sillimanite to sericite.	
	Unconformity				
?	A		Granitic rocks.	Apparently strongly metamorphosed in episode B.	Relations essentially unknown.
Late Precambrian		Graywacke, pyroclastic rocks, local limestone; now seen as schists, gneisses, calc-silicate rocks; migmatites common.		Progressive, ranging from greenschist facies to sillimanite-garnet subfacies; locally retrogressive.	
	Unconformity, widespread erosion				
Precambrian	Basement unobserved in the Carolina Piedmont				

Table 4.—*Correlation of selected lead-alpha ages of zircon crystals*

Episode of folding, metamorphism, and igneous activity (table 3)	Rock	Sample No.	Lead-alpha age (millions of years)
Unconformity below sedimentary rocks of Late Triassic age			
C	Syenite	U.S.N.M. 105674	255 ± 30
	Syenite	U.S.N.M. 80114	280 ± 30
	Granite	59-OT-107	260 ± 30
	Granite	59-OT-102	270 ± 30
	Granite	59-OT-110	245 ± 30
	Granite	59-OT-101	255 ± 30
Unconformity			
B	Granite	IPE	445 ± 50
	Granite	IPF	360 ± 40
	Granite	IPG	430 ± 50
	Granite	IPH	300 ± 35
Unconformity			
A	Gneissic granodiorite	IPA	505 ± 55
	Gneissic granodiorite	IPB	495 ± 55
	Gneissic granodiorite	IPC	380 ± 100
	Gneissic granodiorite	IPD	470 ± 55
	Granite	59-OT-111 (N.M. 1.5)	565 ± 65
	Granite	59-OT-111 (M 1.5)	505 ± 55
	Gneiss	USNM 97589	550 ± 60

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