

Descriptions and Analyses of Eight New USGS Rock Standards

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*Twenty-eight papers present analytical data on new
and previously described whole-rock standards*



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NEPHELINE SYENITE, STM-1, FROM TABLE MOUNTAIN, OREGON

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A sample of peralkaline nepheline syenite for the reference sample program of the U.S. Geological Survey was collected from a sill that underlies Table Mountain (Georgia-Pacific quarry, SE $\frac{1}{4}$ sec. 36, T. 12 S., R. 10 W., Tidewater 15-min quadrangle, lat. 44°28.6' N.; long 123°50.2' W. see fig. 1) in the

and intrudes graded sandstone and siltstone beds of the Tye Formation (middle Eocene). The Table Mountain sill is a remnant of a much larger sill that may have underlain an area of more than 50 mi². Numerous small dikes of nepheline syenite, shonkinite, and camptonite that crop out in the Tidewater and adjoining quadrangles appear to be consanguineous with the nepheline syenite at Table Mountain.

Nepheline syenite from a dike in Indian Creek, Mapleton quadrangle (approximately 18 miles south of Table Mountain), has a potassium-argon age of 33.6 m.y. (determined by R. W. Kistler, U.S. Geol. Survey) and this probably is also the age of the nepheline syenite at Table Mountain. The petrography, petrochemistry, and field relations of nepheline syenite in the central part of the Oregon Coast Range are briefly described by Snavely and Wagner (1961).

The fresh nepheline syenite is light to medium gray and has a glassy luster; weathered surfaces are pitted because of leaching of nepheline and analcime. The nepheline syenite is holocrystalline and very fine to fine grained and has a very pronounced trachytic texture. According to grain size and texture, it might more properly be termed phonolite, but, because it is intrusive and somewhat coarser grained in places, it is referred to as nepheline syenite. The rock is composed of alkali feldspar, nepheline, analcime, aegirine, riebeckite-arfvedsonite, biotite, olivine, opaque minerals, and apatite.

Alkali feldspar, about Ab₃₀-Or₇₀, constitutes 75-80 percent of the nepheline syenite and occurs as flow-aligned laths. A more potassic feldspar, revealed by sodium cobaltinitrite staining, is interstitial to the albitic feldspar. Nepheline constitutes 5-10 percent of the nepheline syenite and occurs as euhedral to subhedral crystals and as smaller anhedral grains interstitial to feldspar. Analcime constitutes about 5 percent and is generally associated with nepheline.



FIGURE 1.—Source of STM-1 on Table Mountain, Oreg. Shaded areas indicate outcrops of nepheline syenite. Base from U.S. Geological Survey, Tidewater 15-min quadrangle, 1942-56.

Oregon Coast Range. The nepheline syenite sill is 250-400 ft thick, underlies an area of about 1½ mi²,

The mafic minerals occur surrounding larger nepheline and analcime crystals and as anhedral grains optically intergrown with alkali feldspar. Aegirine makes up about 10 percent of the rock, and riebeckite-arfvedsonite about 3 percent. Olivine is less than 1 percent of the rock and has reaction rims of biotite surrounded by alkali amphibole. Biotite (less than 0.5 percent) also occurs optically intergrown with feldspar and rimming nepheline or analcime crystals. Opaque minerals and apatite make up less than 0.5 percent.

Sieve analyses of portions of the processed sample are given in table 1. Chemical analyses of two bottles of the sample and CIPW norms computed from these analyses are given in table 2. For calculation of the norms, total water was removed from the analyses, and the remaining oxides were recalculated to 100 percent.

TABLE 1.—Sieve analyses of STM-1 (percent)

Thirds.....	1	2	3	Avg
Sieve size:				
+100 ---	0.1	0.1	0.1	0.1
-100+120 ---	.1	.1	.1	.1
-120+170 ---	.9	1.3	1.0	1.1
-170+200 ---	1.9	2.3	2.2	2.1
-200 -----	96.9	96.2	96.5	96.5
Total -----	99.9	100.0	99.9	99.9

TABLE 2.—Chemical analyses and norms of STM-1

In weight percent. Chemical analyses by methods of Peck (1964). Analysts: bottle 9/17, E. L. Munnson; bottle 29/31, V. C. Smith

Bottle No.....	9/17	29/31
Chemical analyses		
SiO ₂ -----	59.62	59.46
Al ₂ O ₃ -----	18.61	18.60
Fe ₂ O ₃ -----	2.86	2.87
FeO -----	2.10	2.08
MgO -----	.10	.10
CaO -----	1.16	1.15
Na ₂ O -----	9.01	8.92
K ₂ O -----	4.27	4.21
H ₂ O+ -----	1.41	1.38
H ₂ O- -----	.18	.19
TiO ₂ -----	.13	.14
P ₂ O ₅ -----	.16	.16
MnO -----	.23	.22
CO ₂ -----	.01	.02
Cl -----	.05	.05
F -----	.10	.10
S -----	.00	.00
BaO -----	.05	.05
Subtotal -----	99.95	99.70
Less O -----	.05	.05
Total -----	99.90	99.65

TABLE 2.—Chemical analyses and norms of STM-1—Continued

Bottle No	9/17	29/31
CIPW norm		
Orthoclase -----	25.65	25.35
Albite -----	50.75	52.43
Nepheline -----	12.13	11.48
Halite -----	.08	.08
Acmite -----	3.51	2.58
Wollastonite -----	1.74	1.70
Enstatite -----	.16	.18
Ferrosilite -----	1.77	1.70
Forsterite -----	.06	.05
Fayalite -----	.75	.54
Magnetite -----	2.46	2.95
Ilmenite -----	.25	.27
Apatite -----	.39	.39
Fluorite -----	.18	.18
CaCO ₃ -----	.02	.05
Total -----	99.90	99.93

Quantitative spectrographic determinations are presented in table 3. The data for the 13 elements for which our three spectrographic laboratories reported duplicate determinations on their three bottles were treated by the analysis of variance. These tests showed that without exception the variation attributable to samples selected from the three thirds was not significant. We may therefore conclude that the samples are homogeneous for the 13 elements. Because of the random selection of the bottles, the conclusions may be extended to the entire sample.

The variation due to laboratories was not significant for Ba, Cu, Mo, Nb, and Sr, and the laboratories may use the grand average to estimate these elements. The variation due to laboratory means for the remaining eight elements was significantly greater than the error mean square, and the laboratories estimate these elements differently. Inspection of the data in table 3 shows that the tests of significance for some elements served only to confirm visual judgments that significant differences might be attributed to laboratory means.

Laboratory averages are given in table 4 for all elements for which quantitative determinations were reported, and grand averages, standard deviations and conclusions from the analysis of variance are given for the 13 elements for which tests were made. Although the variation due to laboratories was significant for eight elements, some differences among the laboratory means are not unduly large, and the grand average may be used as the estimate. The laboratories should use their own estimates for Zr and Ti.

Means of the La data for two laboratories agree well between themselves and both differ markedly

TABLE 3.—Spectrochemical determinations of elements in STM-1

[In parts per million. Method of Bastron and others (1966)]

Laboratory	Washington			Denver			Menlo Park		
	10/13	29/22	50/11	10/12	20/10	49/28	9/20	20/32	54/14
Ba	500	470	470	480	420	440	460	480	460
	370	390	420	760	620	620	480	440	440
Be	7	11	14	10	17	7	5	6	5
	14	10	8	11	12	6	6	6	7
Ce	800	400	600	----	----	----	----	----	----
	500	600	300	----	----	----	----	----	----
Cr	----	----	----	2	3	2	1	1	1
	----	----	----	3	3	3	1	1	1
Cu	4	3	2	5	3	2	2	2	2
	4	3	2	3	3	2	2	3	3
Ga	35	36	37	42	46	46	40	32	32
	35	29	31	41	45	45	26	26	26
La	260	260	300	110	150	160	190	160	150
	280	240	210	160	160	160	140	140	160
Mo	6	4	3	15	<5	7	5	6	6
	5	5	4	12	5	7	5	7	6
Nb	280	290	350	310	330	330	280	260	300
	290	240	250	310	340	300	300	320	280
Ni	----	----	----	----	----	----	3	2	2
	----	----	----	----	----	----	1	1	1
Pb	----	----	----	30	20	20	14	11	8
	----	----	----	20	20	20	10	8	9
Sn	----	----	----	----	----	----	13	12	12
	----	----	----	----	----	----	9	11	12
Sr	740	420	380	840	1,100	640	900	840	740
	400	500	590	1,400	1,000	900	800	880	740
Y	70	70	70	58	62	54	40	50	50
	80	60	50	52	60	67	60	40	40
Yb	5	5	5	5	4	4	4	4	4
	6	4	4	5	5	4	4	3	4
Zr	1,000	990	1,000	1,500	1,500	1,500	1,300	1,100	1,300
	960	1,000	900	1,500	1,500	1,500	1,100	1,200	1,300
Mn	1,600	1,600	1,700	1,700	1,700	1,800	1,600	1,500	1,400
	1,700	1,800	1,400	1,800	2,000	1,500	1,400	1,600	1,500
Ti	840	820	1,100	1,200	1,100	1,200	840	720	790
	940	860	690	1,200	1,100	1,200	800	840	830

from the third. These two laboratories may wish to recalculate a single estimate for their common use. Although the variation in the Sr data attributable to both thirds of the lot and to the laboratories were declared not significant, the pooled mean square for error is larger than those attributable to thirds and laboratories. After partitioning the variation due to laboratories into its two components of laboratory and error variance, the laboratory standard deviation was entered in the table as negative, but because of the poor precision for Sr, the laboratories

might wish to estimate their own means and standard deviations.

Before the processing of this sample had been completed, a request was received for a portion, and two 1-oz bottles were dipped into the ground and partly mixed, but unbottled, bulk sample. Data for several trace elements obtained by neutron activation on these two unnumbered bottles are given in table 5 and lend further credence to the above claims of sample homogeneity.

TABLE 4.—Averages and standard deviations for spectrophotographic data for STM-1
 [In parts per million. S, significant; NS, not significant, when tested against *F*-test, d.f., degrees of freedom]

Element	Laboratory averages			Grand average	Conclusion from analysis of variance		Standard deviation	
	Washington	Denver	Menlo Park		Thirds	Laboratories	Laboratories (d.f. = 2)	Error (d.f. = 13)
Ba	437	557	460	484	NS	NS	53	86
Be	10.7	10.5	6.2	9.1	NS	S	2.2	2.6
Ce	530	---	---	---	---	---	---	---
Cr	---	2.6	1	---	---	---	---	---
Cu	3.0	3.0	2.3	2.8	NS	NS	.24	.74
Ga	34	44	30	36	NS	S	7.0	4.1
La	258	150	156	188	NS	S	60	25.6
Mo	4.5	8.5	5.8	6.3	¹ NS	¹ NS	1.3	3.9
Nb	283	320	290	298	NS	NS	15.6	28.8
Ni	---	---	1.6	---	---	---	---	---
Pb	---	22	10	---	---	---	---	---
Sn	---	---	12	---	---	---	---	---
Sr	505	980	817	767	NS	NS	Neg.	940
Y	67	59	47	57.4	NS	S	9.5	8.5
Yb	4.8	4.5	3.8	4.4	NS	S	.46	.51
Zr	975	1,500	1,217	1,230	NS	S	265	63.6
Mn	1,600	1,800	1,500	1,600	NS	S	110	120
Ti	875	1,166	803	948	NS	S	189	88.5

¹The significant interaction was used to test the variation due to thirds and to laboratories.

TABLE 5.—Published determinations by neutron activation analysis of STM-1
 [In parts per million, except where indicated]

Element	Determinations	Average	References
Ce	296, 296, 308	297	Brunfelt and Steinnes (1967a), Johansen and Steinnes (1967).
Cl	430, 432	431	Brunfelt and Steinnes (1967).
Co	<1	---	Brunfelt and Steinnes (1964).
Cr	---	1.4	Brunfelt and Steinnes (1967b).
Cu	2.6, 1.8, 2.1	2.3	Brunfelt, Johansen, and Steinnes (1967).
Eu	4.0, 3.9, 4.2	4.1	Brunfelt and Steinnes (1967a), Brunfelt, Johansen, and Steinnes (1967).
Ga	36, 39, 39	38	Brunfelt, Johansen, and Steinnes (1967).
In	0.6032, 0.6079	.607	Johansen and Steinnes (1966).
La	133, 155, 141	143	Brunfelt and Steinnes (1966).
Mn	1,429, 1,540, 1,440	1,479	Do.
Na (percent)	6.12, 6.54, 5.99, 5.74, 5.68, 6.39	6.48	Do.
PrO ₃ (percent)	¹ (3.178, 4.0160), ¹ (0.194, 8.176)	.182	Brunfelt and Steinnes (1968).
Se	0.6, 0.6	.6	Brunfelt and Steinnes (1964).
Se	0.912, 0.808	.810	Brunfelt and Steinnes (1967c).
Sm	17.3, 18.3, 16.6	17.4	Brunfelt and Steinnes (1966).
Zn	204, 206, 218	209	Brunfelt, Johansen, and Steinnes (1967).

¹Two irradiations

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REFERENCE MATERIALS FOR TRACE
ANALYSIS BY RADIOANALYTICAL
METHODS: U.S. GEOLOGICAL SURVEY
ROCK STANDARDS

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A new series of eight rock standards was recently issued by the U.S.G.S. These materials were prepared in much larger quantities than the previous standard rocks, and will presumably be available for a considerable number of years. A description of the various materials and results from analysis of homogeneity, mineralogy and chemical composition are given in a report from the U.S.G.S. (3). The following materials are included in the new series:

BHVO-1 is prepared from a sample of basaltic lava originating from the Kilauea volcano, Hawaii. This sample has a quite similar elemental composition to that of W-1, and should be a useful reference material for basaltic rocks.

MAG-1 is a sample of fine-grained clayey mud from the gulf of Maine, which may be a suitable reference material for marine sediment analyses.

QLO-1 consists of quartz latite, a black volcanic rock, collected in Lake County, Oregon. For most elements its composition is somewhere in between BHVO-1 and RGM-1, and it should be a generally useful standard with special reference to intermediate rocks.

RGM-1 was prepared from a rhyolite glass from Glass Mountain, California. Its major element composition is very similar to that of G-1, and it is considered to be a suitable reference material for rocks of granitic composition.

SCo-1 was collected from a silty marine shale in Natrona County, Wyoming.

SDC-1 is a sample of mica schist from Rock Creek Park, Washington, D.C.

SGR-1 is a sample of oil shale from the Green River formation. In addition to the inorganic constituents shown in Table 1, this sample contains about 40 % of organic material. In view of the current interest for oil production from shale this sample may be an interesting reference material.

STM-1 is a sample of peralkaline nepheline syenite from Table Mountain, Oregon. Among the characteristic compositional features of this rock are high contents of Na and most of the incompatible trace elements such as Zr, Nb, Th and the rare earths. On the other hand several elements such as Sc, Cr, V and Cu show quite low concentrations. STM-1 may therefore in many cases be considered to be a difficult material for analysis, and should as such be a valuable sample for the testing of new methods.

The major element composition of the eight samples, as estimated from available analytical data (3-9), is given in Table 1. As far as these elements are concerned, the composition is already fairly well established in most cases.

A corresponding list for trace elements is presented in Table 2. The basis of each value in the table is indicated in the following manner:

=== Good agreement (Note b) between three different analytical techniques, or by at least two independent values from each of two different analytical techniques.

— Good agreement between two different analytical techniques, or at least three values from the same technique obtained in different laboratories.

No sign: Good agreement between two different laboratories using the same technique.

() Only single values available, or poor agreement between different laboratories.

From Table 2 it appears that rather well-established data are already available for some trace elements in these samples. In general, however, there is still much work to do before a set of recommended values can be established

Note b: Agreement within $\pm 10\%$ for concentrations above 10 ppm and $\pm 20\%$ for concentrations below 10 ppm.