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SURFACE CHEMISTRY OF MAJOR ROCK TYPES OF SONORA PASS TEST SITE, CALIFORNIA

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OF SONORA PASS TEST SITE, CALIFORNIA

INTRODUCTION

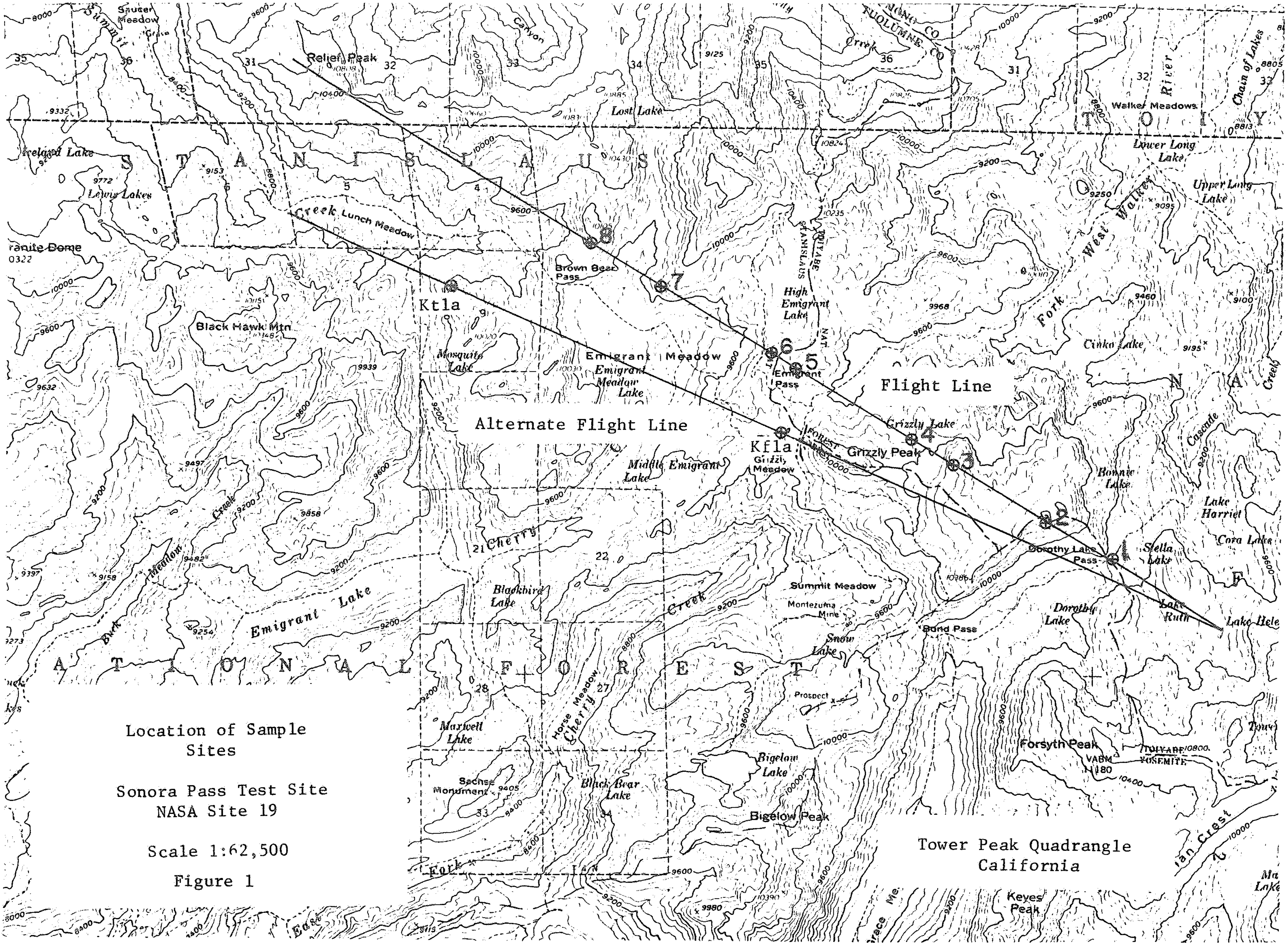
During the summer of 1966 a number of sample nodes were chosen at the Sonora Pass Test Site (Site #19) for infrared spectrometer measurements. The nodes were selected by Dr. Whitten of Northwestern University and Jack Quade of the University of Nevada (See Figure #1). At a later date, Dr. R.J.P. Lyon of Stanford University obtained spectra of the rocks on the test site. In the spring of 1967 spectra of many of the samples were retaken under field conditions in Reno.

The chemical study of the weathered or altered surface layer of selected samples from this suite of rocks is embodied in this report (See Table #1). The chemical compositions are reported as oxide percentages. In addition, reconstitution to normative minerals are shown. The normative minerals do not reflect all aspects of the true mineralogy, but variations in normative minerals may reflect subtle changes in several of the oxides.

SPECIAL SAMPLE PREPARATION

Chemical analyses of infrared spectrometer samples should include only material obtained from the first 10μ below the surface of a rock, the approximate optical depth of 8μ to 14μ radiation. In practice 10μ samples have not been obtained, however, care was taken to obtain only surface material, and more than 50% of the sample came from the top 50μ .

One corner of the rock surface of which the spectra was taken was scraped with a small ultrasonic chisel. From each sample approximately one-quarter of a gram of fine powder was obtained. This powder was placed in a special die and a small amount of bakelite was poured around the sides and on top of the rock powder. It was then compressed to 30,000 psi,



Location of Sample
Sites

Sonora Pass Test Site
NASA Site 19

Scale 1:62,500

Figure 1

yielding a smooth wafer of rock powder cased in a bakelite jacket. These pellets were run for Na_2O, MgO, SiO_2, Al_2O_3, K_2O, CaO, TiO_2, and Fe_2O_3 on NASA's sequential X-ray spectrometer, and are being retained if further analysis is deemed necessary .

SITE #1 CINKO LAKE GRANODIORITE

The Cinko Lake is a dark gray, medium grained granodiorite with a largely hypidiomorphic-granular (relic)texture. It contains shreds and blebs of biotite and hornblende that define a relic lineation.

Four samples were chosen from the Cinko Lake test node for surface chemistry analysis. They include a surface on which epidote is developed, one intensely weathered surface and two fresh or relatively unweathered surfaces (See Tables #2 and #3).

TABLE 2

Surface Chemistry of Cinko Lake Granodiorite

	N476	N477	N478	N482
SiO_2	46.71	58.41	58.84	61.65
Al_2O_3	17.61	14.27	13.74	16.25
*Fe_2O_3	10.84	9.50	8.57	5.85
MgO	1.97	3.27	3.34	2.31
CaO	10.99	6.92	6.65	5.63
Na_2O	.91	3.51	3.11	3.85
K_2O	1.80	2.51	2.80	2.67
TiO_2	.79	1.13	1.32	.74
Total	91.62	99.52	98.37	98.95

* Total Iron as Fe_2O_3. Fe^{+2} and Fe^{+3} cannot be differentiated.

TABLE 1

NASA NUMBER	FIELD NUMBER	DESCRIPTION
* N476	1-1	Epidote on granodiorite surface
* N477	1-2	Fresh granodiorite
* N478	1-3	Fresh granodiorite
N479	1-4	Tourmaline on grandiorite surface
N480	1-5	Granodiorite with lichen
N481	1-6	Highly weathered granodiorite
* N482	1-7	Glacial pavement
* N483	2-1	Fresh alaskite
* N484	2-2	Tourmaline on alaskite surface
N485	2-3	Fresh alaskite
* N486	2-4	Limonite on alaskite surface
N487	2-5	Granodiorite
N488	2-6	Glacially polished alaskite
* N489	3-1	Green phase, folded
* N490	3-2	Dark phase
N491	3-3	Face of schistosity plane
N492	3-4	Green phase
* N493	3-5	Dark phase
* N494	3-6	Green phase, horizontal
N495	3-7	Green phase, vertical
* N496	3-8	Pink phase
N463	4-1	Clean monzonite
N464	4-2	Grus
N465	4-3	Clean monzonite
* N466	4-4	Iron-stained, polished surface
N467	4-5	Aplite dike
N468	4-6	Fresh, pink monzonite
N497	5-1	Fresh monzonite
N498	5-2	Grus on monzonite
* N499	5-3	Iron-stained monzonite
N500	5-4	Glaciated monzonite
* N601	5-5	Grus on monzonite
* N602	5-6	Fresh pink monzonite
N603	6-1	Agglomerate
N604	6-2	Agglomerate
N605	6-3	Soil and rock fragments
* N606	6-4	Agglomerate
* N607	6-5	Agglomerate
N608	6-6	Rock fragments on loose surface
N609	7-1	Fresh monzonite
N610	7-2	Fresh monzonite
* N611	7-3	Limonite on monzonite surface
* N612	7-4	Fresh monzonite
N613	7-5	Fresh monzonite
N614	7-6	Glacially polished monzonite face
N615	7-7	Fresh monzonite
* N616	8-1	Brown basalt
* N617	8-2	Brown basalt
N618	8-3	Brown basalt
* N619	8-4	Brown basalt
N620	8-5	Brown basalt
N621	8-6	Brown basalt

*run for surface chemistry

	NASA NUMBER	FIELD NUMBER	DESCRIPTION
	N622	Kfla-1	Iron stained monzonite
	N623	Kfla-2	Grus
	N624	Kfla-3	Monzonite, glacially polished
*	N625	Kfla-4	Weathered monzonite
	N626	Kfla-5	Xenolith
	N627	Kfla-6	Fresh monzonite
	N628	Kfla-7	Fresh aplite dike
	N629	Kfla-8	Fresh monzonite
	N469	Ktla-1	Glacially polished,iron stained monzonite
	N470	Ktla-2	Fresh monzonite
	N471	Ktla-3	Decomposed monzonite
	N472	Ktla-4	Weathered monzonite
	N473	Ktla-5	Fresh monzonite
	N474	Ktla-6	Grus
	N475	Ktla-7	Grus

* run for surface chemistry

TABLE 3

Normative Mineralogy of Cinko Lake Granodiorite

	N476	N477	N478	N482
Quartz	10.45	11.61	13.74	14.79
Orthoclase	11.61	14.99	16.80	15.94
Albite*	8.41	30.01	26.73	32.92
Anorthite*	42.18	15.93	15.50	19.38
Augite	14.25	15.02	14.34	7.08
Hypersthene	2.88	3.72	4.03	4.18
Magnetite	8.58	6.56	6.31	4.29
Ilmenite	1.64	2.17	2.55	1.42

* % Anorthite 83.39 - N476; 34.68 - N477; 36.71 - N478;37.05 - N482

SITE #2 DOROTHY LAKE ALASKITE

The Dorothy Lake is an alaskitic granite, with locally aplitic phases. Mineralogically it contains plagioclase, perthitic feldspar and minor quartz and biotite. The extremely low mafic mineral content gives the rock a light pink color. Although it is an intrusive unit it is locally fine grained with a saccharoidal texture and no where achieves a coarse grain size typical of many of the Sierran granitic rocks.

Three specimens were chosen for surface analysis; a glacially polished surface, a fresh surface, and a surface which has developed a mafic mineral concentration (See Tables #4 and #5).

TABLE 4

Surface Chemistry of the Dorothy Lake Alaskite

	N483	N484	N486
SiO_2	77.38	67.96	71.70
Al_2O_3	12.34	11.35	12.50
Fe_2O_3	1.16	10.92	4.08
MgO	3.15	.54	6.80
CaO	0.00	.66	0.00
Na_2O	3.33	1.74	2.70
K_2O	4.79	3.56	4.93
TiO_2	.18	.41	.25
Total	102.33	97.14	102.96

* Total Iron as Fe_2O_3. Fe^{+2} and Fe^{+3} cannot be differentiated.

TABLE 5

Normative Mineralogy of Dorothy Lake Alaskite

	N483	N484	N486
Quartz	34.06	40.97	25.49
Orthoclase	27.66	21.65	28.29
Albite*	27.53	15.16	22.19
Anorthite*	0.00	3.37	0.00
Augite	0.00	0.00	0.00
Hypersthene	7.95	6.36	18.05
Magnetite	.82	8.15	2.87
Ilmenite	.33	.80	.46

* % Anorthite 0.00 - N483; 18.19 - N484; 0.00 - N486

TABLE 7 (cont.)

	N489	N490	N493	N494	N496
Augite	14.81	12.34	20.47	7.01	8.71
Hypersthene	0.00	9.11	1.98	.18	0.00
Magnetite	2.56	4.01	4.80	1.51	1.61
Hematite	0.00	0.00	0.00	.08	0.00
Ilmenite	1.18	1.44	1.40	1.38	1.17

* % Anorthite 100.00 - N489; 100.00 - N490; 72.48 - N493; 100.00 - N494; 100.00 -N496

SITES #4, #5, AND KFLA FREMONT LAKE QUARTZ MONZONITE

The Fremont Lake quartz monzonite is normally an hypidiomorphic granular (relic textured) medium grained rock containing 50 to 80 percent plagioclase. The remainder of the rock is composed of orthoclase, microcline, quartz, and mafic minerals, including hornblende and biotite, with minor apatite, zircon, sphene, and magnetite. The relic textures are outlined by euhedral hornblende and biotite crystals forming elongated and platy phenocrysts.

Five Fremont Lake samples were analized for surface chemistry. The first sample, from test node #4 has a glacially polished,iron-stained surface. The next three are from test node #5. They are clean monzonite, apalite dike rock and a freshly broken monzonite surface respectively. The final sample is from the Kfla test node on the alternate flight line. It has a typical weathered surface (See Tables #8 and #9).

SITE #3 METAMORPHIC ROCKS

The metamorphic rocks occur on the test site as a series of Triassic (?) age metasediments and metavolcanics. The parent material of the majority of the rocks can no longer be recognized. They are now dense, hard schistose materials that are here divided into three basic catagories; dark phase, green phase, and pink phase. Two dark phase, two green phase, and one pink phase metamorphic has been chosen for surface chemistry analysis (See Tables #6,#7).

TABLE 6

Surface Chemistry of the Metamorphic Rocks

	N489	N490	N493	N494	N496
SiO_2	68.34	66.02	64.54	71.74	69.52
Al_2O_3	11.44	10.88	12.35	12.84	13.48
Fe_2O_3*	3.59	5.56	6.74	2.25	2.24
MgO	2.53	5.39	3.91	1.38	1.60
CaO	9.33	5.17	9.37	5.44	5.65
Na_2O	----	----	.91	----	----
K_2O	5.70	6.70	3.16	5.79	7.86
TiO_2	.63	.76	.75	.73	.62
Total	101.56	100.48	101.73	100.17	100.97

* Total Iron as Fe_2O_3. Fe^{+2} and Fe^{+3} cannot be differentiated.

TABLE 7

Normative Mineralogy of the Metamorphic Rocks

	N489	N490	N493	N494	N496
Quartz	28.86	23.85	25.48	37.75	27.76
Orthoclase	33.16	39.40	18.35	34.15	46.00
Albite*	0.00	0.00	7.57	0.00	0.00
Anorthite*	14.16	9.85	19.94	17.93	13.44
Wollastonite	5.27	0.00	0.00	0.00	1.32

TABLE 8

Surface Chemistry of the Fremont Lake Quartz Monzonite

	N466	N499	N601	N602	N625
SiO_2	60.00	71.65	62.67	69.78	68.53
Al_2O_3	15.10	11.63	16.55	15.40	15.62
Fe_2O_3*	7.57	8.70	4.88	2.20	2.57
MgO	2.31	.21	2.00	.70	.84
CaO	4.82	2.28	3.93	2.41	3.33
Na_2O	2.98	3.19	4.03	3.31	3.61
K_2O	3.01	3.03	2.84	3.95	4.25
TiO_2	.71	.10	.87	.46	.25
Total	96.50	100.84	97.77	98.21	99.01

* Total Iron as Fe_2O_3. Fe^{+2} and Fe^{+3} cannot be differentiated.

TABLE 9

Normative Mineralogy of the Fremont Lake Quartz Monzonite

	N466	N499	N601	N602	N625
Quartz	17.87	34.72	17.05	29.58	23.29
Orthoclase	18.43	17.76	17.16	23.76	25.37
Albite *	26.13	26.78	34.88	28.52	30.85
Anorthite*	19.62	8.40	19.11	12.17	14.01
Corundum	0.00	0.00	0.00	1.32	0.00
Augite	4.16	2.47	.66	0.00	2.16
Hypersthene	6.70	3.42	5.83	2.13	1.97
Magnetite	5.69	6.26	3.62	1.62	1.88
Ilmenite	1.40	.19	1.69	.89	.48

* % Anorthite 42.89 - N466; 23.88 - N499; 35.40 - N601; 29.92 - N602;
31.22 - N625

SITE #6 RELIEF PEAK ANDESITE

The Relief Peak Formation, as seen on the test site, consists of hornblende-augite and hornblende-hypersthene andesites. The formation consists not only of flows but agglomerates and autobreccias of the same compositions. The two samples selected for surface chemistry determinations are both slightly weathered agglomerates (See Tables #10 and #11).

TABLE 10

Surface Chemistry of the Relief Peak Andesite

	N606	N607
SiO_2	61.55	61.71
Al_2O_3	16.14	15.88
Fe_2O_3*	4.73	5.32
MgO	1.07	1.44
CaO	4.15	5.38
Na_2O	3.42	3.43
K_2O	3.32	3.55
TiO_2	.66	.61
Total	95.04	97.32

* Total Iron as Fe_2O_3. Fe^{+2} and Fe^{+3} cannot be differentiated.

TABLE 11

Normative Mineralogy of the Relief Peak Andesite

	N606	N607
Quartz	19.20	16.17
Orthoclase	20.64	21.55
Albite*	30.45	29.82
Anorthite*	19.87	17.93

TABLE 11 (cont.)

	N606	N607
Augite	1.45	7.67
Hypersthene	3.47	1.70
Magnetite	3.61	3.96
Ilmenite	1.32	1.19

* % Anorthite 39.49 - N606; 37.55 - N607

SITE #7 TOPAZ LAKE PORPHYRITIC QUARTZ MONZONITE

The Topaz Lake quartz monzonite is typified by large zoned microcline phenocrysts up to four inches in length in a matrix primarily of plagioclase, quartz, orthoclase with minor amounts of biotite, hornblende, magnetite, sphene, chlorite, and apatite.

Two specimens have surface chemistry analyses; one is a slightly weathered surface, the other is limonite stained (See Tables #12 and #13).

TABLE 12

Surface Chemistry of the Topaz Lake Porphyritic Quartz Monzonite

	N612	N611
SiO_2	59.68	61.44
Al_2O_3	15.95	15.70
Fe_2O_3*	7.13	5.35
MgO	2.99	1.87
CaO	5.46	2.89
Na_2O	3.38	2.69
K_2O	4.40	5.56
TiO_2	.84	.79
Total	99.83	96.29

* Total Iron as Fe_2O_3. Fe^{+2} and Fe^{+3} cannot be differentiated.

TABLE 13

	N612	N611
Quartz	8.57	15.48
Orthoclase	26.04	34.12
Albite *	28.65	23.64
Anorthite *	15.38	14.89
Augite	9.39	0.00
Hypersthene	5.19	6.29
Magnetite	5.18	4.03
Ilmenite	1.60	1.56

* % Anorthite 34.94 - N612; 38.65 - N611

SITE #8 BROWN BEAR PASS BASALT

The Brown Bear Pass basalt is a dark olivine basalt. The basalts weather brown but are very dark gray on fresh surfaces. Three samples were run for surface chemistry; one is a relatively fresh black surface, the other two are weathered brown surfaces (See Tables #14 and #15).

TABLE 14

Surface Chemistry of the Brown Bear Pass Basalt

	N616	N617	N619
SiO_2	50.81	51.01	58.09
Al_2O_3	15.52	15.33	15.77
Fe_2O_3*	10.58	10.85	9.63
MgO	5.36	5.20	1.92
CaO	9.52	8.76	4.88
Na_2O	2.93	2.97	2.44

TABLE 14 (cont.)

	N616	N617	N619
K_2O	2.17	2.51	2.46
TiO_2	1.18	2.19	2.07
Total	98.07	98. 82	97.26

* Total Iron as Fe_2O_3. Fe^{+2} and Fe^{+3} cannot be differentiated.

TABLE 15

Normative Mineralogy of the Brown Bear Pass Basalt

	N616	N617	N619
Quartz	1.35	1.61	21.09
Orthoclase	12.98	15.01	14.94
Albite *	25.10	25.43	21.23
Anorthite *	23.07	21.34	24.89
Corundum	0.00	0.00	.23
Augite	19.58	17.87	0.00
Hypersthene	6.54	6.57	6.40
Magnetite	7.77	7.96	7.18
Ilmenite	3.62	4.21	4.04

* % Anorthite 47.90 - N616; 45.62 - N617; 53.97 - N619

APPENDIX I

Sources of Analytical Error

Oxide weight percentages calculated from X-ray spectrographic data contain both systematic and random error. For each sample X-rays are counted and compared with two known standards a total of four times. In this case the standards G-1, a granite, and W-1, a diabase, were used. For the elements determined, the individual oxide analyses should total between 97% and 99%. Most of the analyses in this report total in an acceptable range, between 96% and 100%, however, a few deviate as far as 92% and 103%.

The largest source of error is a systematic error which occurs when samples have greater or less concentrations of a given oxide than either of the standards. Two factors contribute to the systematic error; (1) due to matrix effects the counts to percent composition relationship is not quite linear; this approximation is good enough for compositions between those of the standards, but noticable at very high or low concentrations where extrapolations beyond the standards are necessary, and (2) slight errors in the analyses of the standards cause the error at very high or low oxide concentrations.

Another source of error is the random error. Table 16 shows the average analysis, standard deviation, and standard error for each of a number of samples for each of the elements run.

TABLE 16

Analysis of Random Error for Selected Surface Chemistry Samples

Element	Number of Samples	Mean	Standard Deviation	Standard Error *
SiO_2	15	65.31	0.27	0.41%
Al_2O_3	15	13.80	0.42	3.04%

TABLE 16 (cont.)

Element	Number of Samples	Mean	Standard Deviation	Standard Error *
Fe_2O_3	15	5.40	0.07	1.29%
MgO	15	1.76	0.05	2.84%
CaO	13	5.76	0.25	4.34%
Na_2O	12	2.82	0.15	5.32%
K_2O	15	3.89	0.09	2.31%
TiO_2	15	0.63	0.01	2.78%

$$* \frac{\text{Standard Deviation}}{\text{Mean}} \times 100 = \text{Standard Error In Percent}$$

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