Bedrock Geologic Map of the Green Knob Quadrangle, Latah and Nez Perce Counties, Idaho

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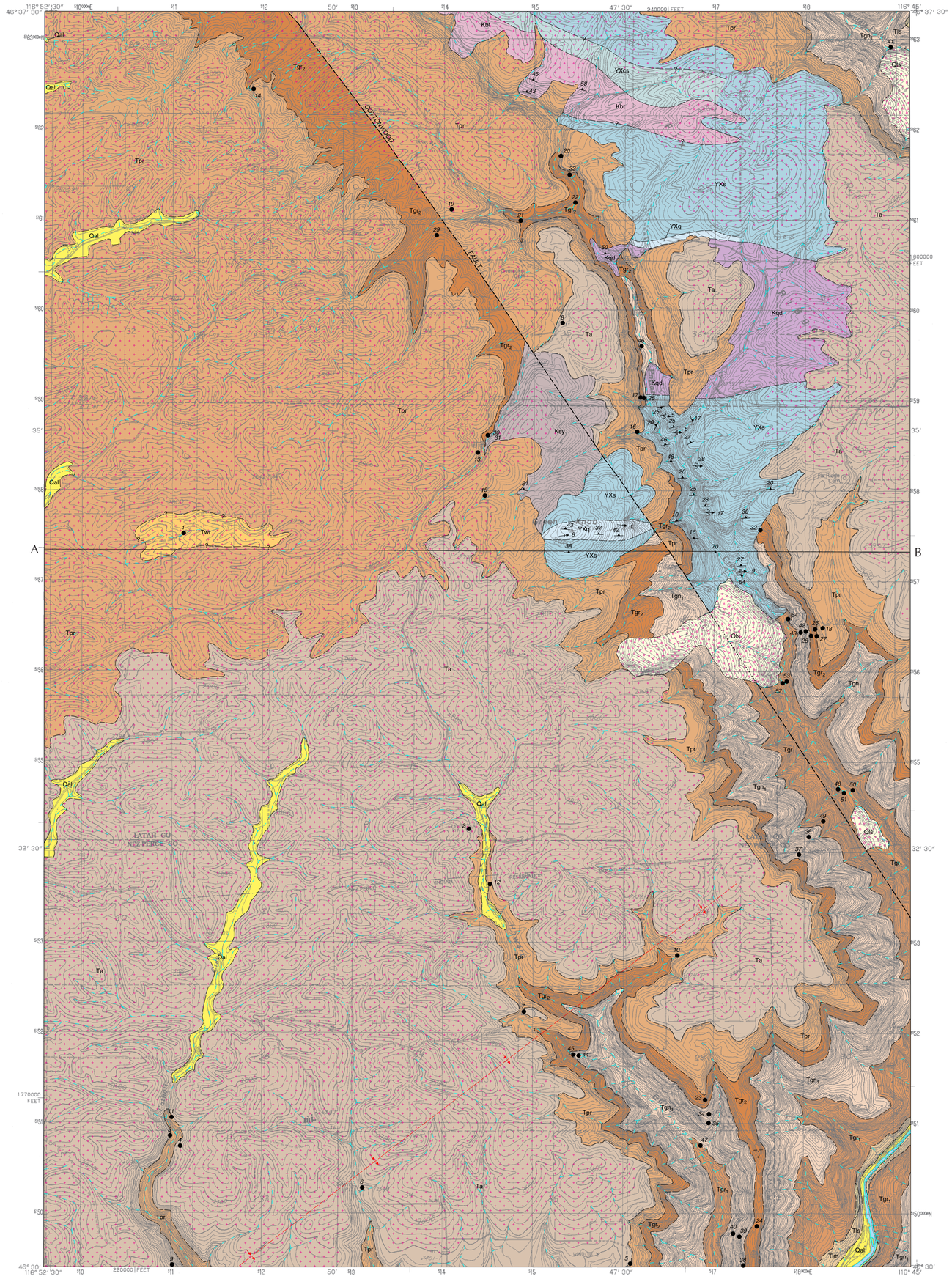
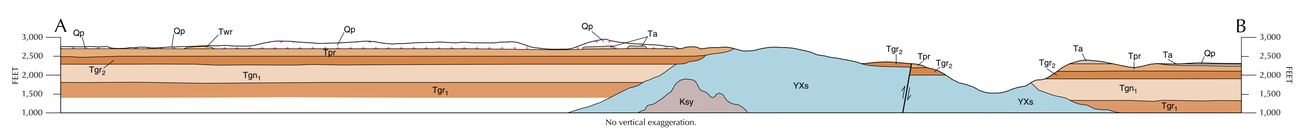
2001





CORRELATION OF MAP UNITS

Surficial Deposits	Columbia River Basalt Group	Prebasalt Rocks	Latah Formation			
Qal			HOLOCENE	QUATERNARY		CENOZOIC
Qp, Qls			PLEISTOCENE			
	Saddle Mountains Basalt: Twr, Ta					
	Wanapum Basalt: Tpr					
	Grande Ronde Basalt: Tgr_2, Tgn_1, Tgr_1		Tls	MIOCENE	TERTIARY	
	Imnaha Basalt: Tim					
		Intrusive-Metamorphic Rocks: Ksy, Kbt, Kqd		CRETACEOUS	MESOZOIC	
		Syringa Metamorphic Sequence: YXs, YXcs, YXq		PROTEROZOIC	PRECAMBRIAN	

INTRODUCTION

The bedrock map of the Green Knob quadrangle was compiled from field observations, published and unpublished research and mapping, and water well data. The distribution of the colluvium on steep canyon walls was not illustrated in keeping with the emphasis on bedrock mapping. The distribution of surficial deposits is illustrated by Othberg and others (2001). Locally, well-exposed outcrops occur in canyon areas. Contacts, however, are rarely exposed across much of the map, so most contact lines are interpretative.

Regional maps by Bond (1963), Rember and Bennett (1979), and Swanson and others (1977, 1979a, 1980) and larger scale maps by Anderson (1991) were consulted to assist with mapping and compilation. Foliation attitudes by Anderson (1991) were field checked in part, and some of his data were used in the compilation. Maps by Hooper and Webster (1982) and Hooper and others (1985) from nearby areas in Washington were also consulted for stratigraphic comparisons. The basalt chemistry was analyzed by x-ray fluorescence at the GeoAnalytical Laboratory at Washington State University (Table 1). Paleomagnetism was determined in the field with a fluxgate magnetometer, and in places paleomagnetic directions were measured in the Paleomagnetism Laboratory of the Idaho Geological Survey/University of Idaho.

The major geologic feature in the quadrangle is the northwest-southeast trending fault. The geomorphic expression and measured stratigraphic offset clearly indicate the presence of a high-angle fault with 200 to 400 feet of displacement. The trace of the fault or fault zone, which is covered by loess, colluvium, talus, and landslide deposits, is inferred from topographic expression and data collected from several outcrops. Bond (1963) first mapped the fault and referred to it as the Cottonwood fault. Swanson and others (1979a) also noted this fault.

The other major structural feature influencing rock patterns is a monoclinal bend that is part of a much larger anticlinal feature to the southwest on the Lewiston Orchards North quadrangle. That anticline is exposed in the Lewiston Hill area (Garwood and Bush, 2001) and was traced east and northeastward as it changes into a monocline on the Green Knob quadrangle (Bush and Garwood, 2001). The approximate axial trace of the monoclinal bend is mapped in the southern part of the quadrangle where the estimated southwesterly dip of basalt units changes from 1 to 4 degrees.

DESCRIPTION OF MAP UNITS

Prebasalt rocks on the Green Knob quadrangle have been mapped by Anderson (1991) at a scale of 1:24,000. He subdivided these rocks into five different units ranging in age from Precambrian to Cretaceous. Bush and Priebe (1995) describe three prebasalt units in the southern part of the adjoining Troy quadrangle. The units from both sources were modified, renamed, and given age designations primarily on the basis of regional mapping. The rest of the exposures belong primarily to the Columbia River Basalt Group. The stratigraphic nomenclature for the Columbia River Basalt Group is based on that presented by Swanson and others (1979b). The group is divided into four formations: from base upward, these are the Imnaha Basalt, Grande Ronde Basalt, Wanapum Basalt, and Saddle Mountains Basalt.

SURFICIAL DEPOSITS

Qal **Alluvium (Holocene)**—Primarily stream deposits in modern drainages, but includes slope wash and debris-flow deposits. Most deposits are composed of stratified and laterally discontinuous beds of pebbles, cobbles, sand, and silt. Stream deposits in the upland plateau areas are finer grained (silt dominated) and commonly grade laterally into loess of the Palouse Formation. In the canyon areas, poorly sorted cobbles and boulders grade into debris flow deposits near junctions with tributaries.

Qls **Landslide deposits (Pleistocene-Holocene)**—Highly varied rock and soil masses ranging from slumped coherent blocks to earth and debris flows common along steep canyon walls. Slump blocks consist primarily of intact and broken sections of basalt and interbed sediments. Earth and debris flows consist mainly of unstratified, unsorted gravel rubble in a clayey matrix derived from loess, Latah Formation sediments, and colluvium.

Qp **Palouse Formation (Holocene and Pleistocene)**—Silty and clayey loess of the Palouse hills. The unit blankets the Miocene basalt flows of the eastern Columbia Plateau and forms hills up to 250 feet in thickness on the western edge of the quadrangle. Distribution of the loess is taken from Othberg and others (2001).

LATAH FORMATION

Tls **Latah sediments (Miocene)**—Clay, silt, and sand composing interbeds between basalt flows. Basalt colluvium and talus typically cover these thin and nonresistant units; thus their lateral extent is greater than shown. Interbed exposures between the Grande Ronde Basalt and Imnaha Basalt along Idaho Highway 12 in the southeastern corner of the quadrangle locally contain plant fossils in thin-bedded, light-colored claystone.

COLUMBIA RIVER BASALT GROUP

Saddle Mountains Basalt

Twr **Weissenfels Ridge Member (Miocene)**—Medium- to coarse-grained basalt with microphenocrysts of plagioclase and olivine in an intergranular groundmass with minor glass (Hooper and others, 1985). One highly weathered exposure was noted on the Green Knob quadrangle and has chemistry and polarity similar to the basalt of Lewiston Orchards (Table 1).

Ta **Asotin Member (Miocene)**—Dense, aphyric basalt flow with microphenocrysts of plagioclase and olivine. Distinguished from the Priest Rapids flows by its normal magnetic polarity and distinct chemistry (Table 1). The Asotin Member is part of the Uniontown flows of Swanson and others (1975, 1979a, 1980) that they describe as filling a paleovalley on the Uniontown plateau. This paleovalley probably developed in the troughs of shallow synclinal features. In the Green Knob quadrangle, the distribution of the Asotin Member and the location of its onlap contact with the Priest Rapids Member are inferred from a regional trend identified by previous and new mapping of the adjoining Genesee (Bush, 2001), Lewiston Orchards North (Garwood and Bush, 2001), and Lapwai (Bush and Garwood, 2001) quadrangles. Swanson and others (1980) show the presence of the Wilbur Creek Member in the southern part of the quadrangle. None of the samples collected for this project has chemistry indicative of the Wilbur Creek Member.

Wanapum Basalt

Tpr **Priest Rapids Member (Miocene)**—Medium- to coarse-grained basalt of reverse polarity with microphenocrysts of plagioclase and olivine in a groundmass of intergranular pyroxene, ilmenite blades, and minor devitrified glass. Distinguished from Saddle Mountains Basalt and Grande Ronde Basalt by its reverse polarity and distinct chemistry (Table 1). Eleven exposures were analyzed (Table 1) and verified as the Lolo chemical type of Wright and others (1973). The unit ranges from 100 to 250 feet thick.

Grande Ronde Basalt

Tgr_2 **R_2 magnetostratigraphic unit (Miocene)**—One or two fine-grained to very fine-grained reverse magnetic-polarity flows of Grande Ronde chemical type (Wright and others, 1973, 1979; Swanson and others, 1979b; Reidel and others, 1989). The unit ranges from 150 to 200 feet thick. Although commonly fine-grained and glassy, the flows are abundantly plagioclase-microphyric. In comparison with other Grande Ronde units, these flows (Table 1) have intermediate to very low MgO (3.16 to 4.04 weight percent) and high to very high TiO_2 (2.22 to 2.58 weight percent). The flows may correlate with the Wapshilla Ridge unit of Reidel and others (1989).

Tgn_1 **N_1 magnetostratigraphic unit (Miocene)**—Several fine-grained aphyric normal magnetic-polarity flows of Grande Ronde chemical type (Wright and others, 1973). The unit's cumulative thickness ranges from 500 to 600 feet. The unit is dominated by the intermediate to high MgO and relatively low TiO_2 flows (Table 1) that are described by Reidel and others (1989) in the Grande Ronde River area south of Lewiston and may correlate to their China Creek unit.

Tgr_1 **R_1 magnetostratigraphic unit (Miocene)**—Several fine-grained aphyric reverse magnetic-polarity flows of Grande Ronde chemical type (Wright and others, 1973; Swanson and others, 1979b; Reidel and others, 1989). Regional chemical comparisons eastward towards Juliaetta suggest that they correlate to the Center Creek unit of Reidel and others (1989) and Bond (1963). Based on analyses of eight samples (Table 1), the TiO_2 content is between 2.21 and 2.26 weight percent, similar to that reported for Center Creek flows by Reidel and others (1989). However, the MgO content (<3.00 weight percent) is lower than all the R1 units reported by Reidel and others (1989).

Imnaha Basalt

Tim **Imnaha Basalt (Miocene)**—A basalt flow that is typically plagioclase phyric and has transitional magnetic polarity. The unit is exposed along the Potlatch River in the very southeastern part of the quadrangle.

PREBASALT ROCKS

Intrusive-Metamorphic Rocks

Ksy **Syenite (Cretaceous)**—Consists of a light-colored, fine- to medium-grained syenite poorly exposed in an area that covers approximately one-third of a square mile north and west of Green Knob. The syenite is composed of 95 percent microcline-microperthite, 3 percent plagioclase, minor amounts of zircon, and traces of muscovite, opaques, and possible hematite. The rock has a weak directional fabric and a locally developed mortar texture (Bill Bonnichsen, written commun., 1999). According to Anderson (1991), the syenite has an anhedral granular to crystalloblastic texture with evidence of metamorphism. Anderson (1991) suggested the syenite is Cretaceous in age and related to the Gem Stocks in the Wallace mining district and Gold Hill intrusive rocks in northern Latah County. Among the limited exposures, the rock locally contains well-formed megascopic zircon crystals. U-Pb isotopic analyses on four zircon fractions (Table 2) from the syenite are discordant and define a nonlinear array (Figure 1). Discordance is attributed to inheritance of xenocrystic components. The residue (R) obtained during a partial dissolution experiment (Table 2) yielded a concordant analysis (Figure 1). On the basis of the concordant residue, an age of 74 ± 1 Ma is assigned to the syenite intrusion.

Kbt **Foliated biotite tonalite and granodiorite (Cretaceous)**—Primarily foliated biotite tonalite with minor amounts of foliated biotite granodiorite. The unit corresponds to the tonalite gneiss unit of Anderson (1991). Thickness of the gneissic banding is fairly consistent within a range of 1 mm to 5 cm. Locally, the hand specimens have more massive, igneouslike textures. Anderson (1991) reports that the tonalite gneiss along Middle Potlatch Creek is composed of about 45 percent unzoned andesine (An_{33}), 25 percent biotite, 25 percent quartz, and 5 percent garnet.

Kqd **Hornblende-biotite quartz diorite (Cretaceous)**—Massive to foliated, medium- to coarse-grained, hornblende-biotite quartz diorite. The diorite is composed of about 15 percent quartz, 71 percent plagioclase, 2 percent biotite, and 12 percent hornblende. Within individual outcrops, the gneissic banding in the tonalite may be equally spaced or highly varied. Biotite layers range from 2 mm to 10 cm in thickness.

Syringa Metamorphic Sequence

YXs **Schist and gneiss of the Syringa metamorphic sequence (Proterozoic)**—Medium- to coarse-grained muscovite-biotite schist and gneiss. Biotite dominates at most places, with larger, apparently older muscovite porphyroblasts common. Variants include rocks with either mica exclusively. Locally, megacrysts of corundum and garnet are common. These rocks are poorly exposed. Typically weathers rusty, orange-red.

YXcs **Calc-silicate rocks of the Syringa metamorphic sequence (Proterozoic)**—Varied diopside, actinolite, hornblende, garnet and scapolite-bearing granofels, gneiss, and quartzite. Includes meter-parting, centimeter-layered diopside gneiss and diopside quartzite. According to Anderson (1991), typically contains 30-60 percent plagioclase and 8 percent or less potassium feldspar. Exposures are rare, primarily limited to small roadcuts.

YXq **Quartzite of the Syringa metamorphic sequence (Proterozoic)**—Quartzite and schist. The quartzite is composed of 95-99 percent recrystallized quartz with up to 5 percent biotite. In hand sample, the quartzite is medium to coarse grained. Resembles vein quartz in places. Thickness of quartzite layers range from 5 cm to 1 m. Interlayered schist is muscovite rich, but rarely exposed because it is commonly covered by a lag of orange-weathered quartzite boulders and cobbles.

SYMBOLS

- Contact, approximately located
- Approximate fault trace
- Approximate monocline trace
- 45 — Attitude of major foliation trends
- 4 — Approximate attitude of basalt flows
- 5 — Location of chemistry reported in Table 1
- 5 — Bearing and plunge of mineral lineation
- 25 — Bearing and plunge of small fold axis

Table 1. Major Chemical Elements* of Sampled Basalt Units

Map Number	Unit	Sample	SiO_2	Al_2O_3	TiO_2	FeO**	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5
1	Twr	Mule	48.85	15.38	2.14	11.19	0.18	11.14	7.97	0.37	2.32	0.47
2	Ta	GK1	51.02	16.53	1.46	8.70	0.16	11.46	7.52	0.50	2.45	0.19
3	Ta	GK3	50.30	16.29	1.49	9.62	0.16	10.93	8.06	0.52	2.42	0.21
4	Ta	GK4	50.59	16.05	1.46	9.52	0.16	11.13	8.02	0.53	2.34	0.20
5	Ta	GK6	50.89	16.47	1.43	9.30	0.15	11.33	7.41	0.50	2.34	0.17
6	Ta	GK7	50.58	16.28	1.43	9.12	0.16	11.31	8.15	0.47	2.32	0.18
7	Ta	GK9	51.11	16.51	1.47	9.27	0.16	11.02	7.44	0.50	2.36	0.19
8	Ta	GK11	51.16	16.50	1.48	8.66	0.15	11.33	7.45	0.57	2.48	0.21
9	Ta	GK200	52.46	17.01	1.45	7.77	0.14	11.48	6.49	0.53	2.47	0.20
10	Tpr	GK2	50.44	13.62	3.30	13.36	0.23	9.15	5.20	1.23	2.69	0.79
11	Tpr	GK5	50.46	13.99	3.33	12.50	0.23	9.52	5.26	1.16	2.76	0.79
12	Tpr	GK8	50.70	13.71	3.30	12.75	0.24	9.31	5.27	1.18	2.75	0.80
13	Tpr	GK10	50.75	13.90	3.30	12.65	0.22	9.37	5.27	1.03	2.72	0.79
14	Tpr	GK13	50.13	13.68	3.30	13.23	0.30	10.24	4.41	1.15	2.75	0.81
15	Tpr	GK23	50.58	13.89	3.28	13.12	0.20	9.26	5.04	1.13	2.70	0.79
16	Tpr	GK24	49.97	13.45	3.21	14.29	0.23	9.01	5.17	1.08	2.82	0.77
17	Tpr	GK30	49.59	13.90	3.17	13.73	0.24	9.28	5.26	1.16	2.91	0.77
18	Tpr	GK31	49.63	13.82	3.25	14.04	0.24	9.34	4.93	1.18	2.79	0.79
19	Tpr	GK38	50.09	14.27	2.92	13.14	0.23	9.51	5.21	1.12	2.83	0.68
20	Tpr	G1	49.63	13.49	3.28	14.71	0.25	9.23	4.74	1.11	2.76	0.79
21	Tgr2	GK12	55.61	13.82	2.50	11.68	0.20	7.10	3.39	1.99	3.24	0.47
22	Tgr2	GK14	54.98	13.78	2.23	11.88	0.23	7.73	3.97	1.62	3.18	0.40
23	Tgr2	GK15	56.53	13.87	2.47	11.04	0.20	6.84	3.16	2.08	3.33	0.47
24	Tgr2	GK25	55.80	14.11	2.58	10.82	0.19	7.24	3.43	2.02	3.32	0.49
25	Tgr2	GK29	54.63	13.94	2.24	12.00	0.21	7.85	4.04	1.57	3.14	0.39
26	Tgr2	GK32	55.48	13.65	2.39	12.21	0.20	7.08	3.34	1.94	3.25	0.46
27	Tgr2	GK33	55.56	13.68	2.41	12.04	0.20	7.15	3.35	1.84	3.31	0.45
28	Tgr2	GK34	54.68	13.84	2.24	12.22	0.21	7.77	3.94	1.46	3.25	0.40
29	Tgr2	GK37	55.87	13.85	2.53	11.55	0.20	7.05	3.31	1.94	3.24	0.47
30	Tgr2	GK202	57.03	14.10	2.53	10.26	0.18	6.94	3.31	1.94	3.24	0.46
31	Tgr2	GK2002	56.11	13.86	2.53	11.56	0.19	7.00	3.16	1.97	3.16	0.46
32	Tgr2	GK5001	54.83	13.74	2.22	12.03	0.21	7.74	3.94	1.60	3.28	0.40
33	Tgr2	G2	55.24	13.93	2.27	11.34	0.20	7.87	3.99	1.68	3.08	0.39
34	Tgn1	GK16	55.23	14.27	1.84	10.66	0.20	8.40	4.40	1.44	3.23	0.32
35	Tgn1	GK17	55.34	14.09	1.91	11.33	0.20	8.08	4.18	1.40	3.12	0.34
36	Tgn1	GK21	56.63	14.49	1.82	9.82	0.18	7.94	4.18	1.55	3.13	0.26
37	Tgn1	GK22	55.26	14.17	1.86	11.32	0.20	8.20	4.12	1.39	3.14	0.33
38	Tgn1	GK26	55.08	14.58	1.72	10.22	0.19	8.72	4.84	1.16	3.22	0.27
39	Tgn1	GK27	55.52	14.23	1.88	10.98	0.20	8.22	4.01	1.40	3.23	0.34
40	Tgn1	GK28	56.67	14.35	1.80	9.99	0.18	7.95	4.08	1.54	3.20	0.25
41	Tgn1	GK333	55.02	13.96	1.86	11.65	0.20	8.03	4.29	1.39	3.25	0.35
42	Tgn1	GK35	55.34	14.14	1.89	10.99	0.20	8.14	4.20	1.52	3.24	0.35
43	Tgn1	GK36	56.23	14.35	1.79	10.10	0.19	7.98	4.19	1.70	3.22	0.26
44	Tgn1	GK203	55.91	14.28	1.86	10.40	0.20	8.20	4.32	1.35	3.15	0.33
45	Tgn1	GK204	56.00	14.32	1.85	9.79	0.19	8.34	4.42	1.46	3.31	0.33
46	Tgn1	GK5000	54.85	14.07	1.91	11.76	0.20	7.96	4.13	1.53	3.24	0.34
47	Tgr1	GK18	57.34	13.54	2.21	11.46	0.19	6.64	2.97	1.88	3.46	0.32
48	Tgr1	GK19	57.32	13.48	2.26	11.68	0.18	6.65	2.91	1.99	3.20	0.34
49	Tgr1	GK20	57.66	13.62	2.23	11.28	0.18	6.55	2.95	1.92	3.30	0.32
50	Tgr1	GK5002	57.25	13.56	2.24	11.63	0.18	6.61	2.94	1.95	3.31	0.33
51	Tgr1	GK5003	57.38	13.60	2.25	11.36	0.18	6.59	2.91	2.03	3.37	0.33
52	Tgr1	GK5004	57.04	13.54	2.22	11.74	0.19	6.61	2.96	2.00	3.38	0.33
53	Tgr1	GK5005	57.12	13.41	2.21	11.87	0.19	6.59	2.91	1.96	3.43	0.32
54	Tgr1	GK5006	57.29	13.58	2.22	11.45	0.19	6.64	2.98	1.97	3.34	0.33

* Weight-percent analysis at Washington State University's GeoAnalytical Laboratory by X-ray fluorescence under the direction of P.R. Hooper. Analyses are normalized on a volatile-free basis.
** Total Fe is expressed as FeO.

Figure 1. Pb / U concordia diagram for GS-98 syenite sample. See Table 2 and text for explanation.

Table 2. U-Pb Isotopic Data and Apparent Ages

Fraction-Size[a] (µm)	Wt (mg)	Concentration[b] U	Concentration[b] Pb*	Isotopic Composition[c] $^{206}Pb/^{204}Pb$	Isotopic Composition[c] $^{206}Pb/^{207}Pb$	Isotopic Composition[c] $^{208}Pb/^{206}Pb$	Apparent Ages (Ma)[d] $^{206}Pb^*/^{238}U$	Apparent Ages (Ma)[d] $^{207}Pb^*/^{235}U$	Apparent Ages (Ma)[d] $^{207}Pb^*/^{206}Pb^*$	Th-corrected Ages (Ma)[e] $^{206}Pb^*/^{238}U$	Th-corrected Ages (Ma)[e] $^{207}Pb^*/^{206}Pb^*$
Sample 98GS Genesee syenite											
A 63-80A	0.1	104	3.5	1,145 ± 1	15.562	0.623	94.8	101.5 ± 0.4	262	94.9 ± 0.2	260 ± 7
B 80x100	0.1	99	2.7	652 ± 1	13.724	0.731	84.5	89.1 ± 0.4	213	84.6 ± 0.2	211 ± 8
C 100x350	0.3	95	1.5	701 ± 1	14.362	1.811	75.7	77.5 ± 0.3	131	75.8 ± 0.2	128 ± 9
D 100x350	0.7	85	2.0	518 ± 1	12.934	0.909	83.6	85.7 ± 0.4	144	83.7 ± 0.2	141 ± 10
Partial Dissolution Results:		% U									
L1		20	42	0.3	203 ± 0.3	8.161	3.752	45.4	48.6 ± 0.5	212	45.4 ± 0.1	209 ± 24
L2		8	16	0.2	979 ± 0.4	15.533	1.832	50.9	53.4 ± 0.2	169	51.0 ± 0.2	166 ± 3
L3		22	46	1.2	1,634 ± 1	17.431	0.957	93.8	94.7 ± 0.3	117	93.9 ± 0.3	116 ± 4
L4		39	84	2.4	902 ± 1	15.393	0.848	96.7	98.1 ± 0.4	131	96.7 ± 0.3	130 ± 6
R		12	25	0.5	1,514 ± 1	17.474	1.043	73.7	73.8 ± 0.2	76	73.8 ± 0.2	74 ± 4
T	100x350	4.4	49	1.0	720 ± 1	14.471	1.018	79.8	81.6 ± 0.4	133	79.9 ± 0.2	131 ± 7

[a] A, B, etc. = conventional multigrain zircon fractions, L1-4 = leach steps; R = residue; T = mathematically recombined steps; A = abraded to 30% - 60% of original diameter. Dissolution schedule: 1 = 24 hours at 110 °C; 2 = 18 hr at 150 °C; 44 hr at 220 °C; 4 = 18 hr at 245 °C, and R = 60 hr at 245 °C. Fractions are nonmagnetic on Frantz magnetic separator at 1.8 amps, 15° forward slope, and side slope of 5°. Analyses by W.C. McClelland, University of Idaho, at facilities of the University of California, Santa Barbara. Analytical procedures are outlined in McClelland and Mattinson (1996).

[b] Pb* is radiogenic Pb. Pb and U expressed as ppm for conventional analyses and mathematically recombined partial dissolution totals. For partial dissolution steps, Pb and U expressed as nanograms and percent of total U.

[c] Reported ratios corrected for fractionation (0.125 ± 0.018%/AMU) and spike Pb. Ratios used in age calculation were adjusted for 2 pg of blank Pb with isotopic composition of $^{206}Pb/^{204}Pb = 18.6$, $^{207}Pb/^{204}Pb = 15.5$, and $^{208}Pb/^{204}Pb = 38.4$; 2 pg of blank U, 0.25 ± 0.049%/AMU fractionation for UO_2, and initial common Pb with isotopic composition approximated from Stacey and Kramers (1975) with an assigned uncertainty of 0.1 to initial $^{207}Pb/^{204}Pb$ ratio.

[d] Uncertainties reported as 2 sigma. Error assignment for individual analyses follows Mattinson (1987) and is consistent with Ludwig (1991). An uncertainty of 0.2% is assigned to the $^{206}Pb/^{238}U$ ratio based on our estimated reproducibility unless this value is exceeded by analytical uncertainties. Calculated uncertainty in the $^{207}Pb/^{206}Pb$ ratio incorporates uncertainty due to measured $^{208}Pb/^{206}Pb$ and $^{207}Pb/^{206}Pb$ ratios, initial $^{207}Pb/^{204}Pb$ ratio, and composition and amount of blank. Decay constants used: $^{238}U = 1.5513$ E-10, $^{235}U = 9.8485$ E-10. $^{238}U/^{235}U = 137.88$.

[e] A 75% ± 25% efficiency in ^{230}Th exclusion during zircon crystallization is assumed, and $^{207}Pb^*/^{206}Pb$ and $^{206}Pb^*/^{238}U$ ratios have been adjusted accordingly. Age assignments presented are derived from the Th-corrected ratios.

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