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GEOLOGIC MAP OF THE SASQUATCH STEPS AREA, NORTH FLANK OF
MOUNT ST. HELENS, WASHINGTON

By

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INTRODUCTION

The 1980 eruption of Mount St. Helens resulted in both new volcanic deposits and deeply incised exposures into pre-1980 deposits. These exposures were produced by excavation of the crater by the 1980 landslides and lateral explosion as well as the subsequent erosion of Step and Loowit Creeks by northerly stream flow out of the horseshoe-shaped crater. The map covers the area known as the Sasquatch Steps (commonly called the "Steps"), which lies between the Pumice Plain on the north and the lowermost portion of the crater on the south. Rapid alluvial aggradation at the base of the Steps is presently burying some of the lowest exposures, and erosion is stripping many of the upland deposits.

The stratigraphic sequence exposed in the map area includes deposits from the following eruptive periods (Crandell, 1987).

Table 1. Eruptive history of Mount St. Helens

[from Crandell, 1987]

ERUPTIVE STAGES, PERIODS, AND DORMANT INTERVALS	APPROXIMATE ¹⁴ C AGE IN YEARS BEFORE A.D. 1950	TEPHRA UNIT	NATURE OF VOLCANISM
Eruptions that began in 1980 (Dormant interval of 123 years)		1980	Laterally directed blast from cryptodome followed by eruptions of dacite tephra and pyroclastic flows and development of dome in new crater.
Goat Rocks eruptive period ----- (Dormant interval of about 200 years)	¹ 180-123	T	Eruptions of dacite tephra, andesite lava flow, dacite dome.
Kalama eruptive period ----- (Dormant interval of about 650 years)	² 500-350	X W	Eruptions of dacite and andesite tephra, dacite dome(s) and pyroclastic flows, andesite lava flows.
Sugar Bowl eruptive period ----- (Dormant interval of about 600 years)	1,150	unnamed	Eruption of dacite dome, laterally directed blast, pyroclastic flow(s), air-fall tephra.
Castle Creek eruptive period ----- (Apparent dormant interval of about 300 years)	2,200-1,700	B	Eruptions of andesite, dacite, and basalt tephra, andesite and basalt lava flows, andesite and dacite pyroclastic flows.
Pine Creek eruptive period ----- (Apparent dormant interval of about 300 years)	3,000-2,500	P	Eruption of dacite tephra, dacite domes, pyroclastic flows.
Smith Creek eruptive period -----	4,000-3,300	Y	Eruptions of dacite tephra, dacite domes, pyroclastic flows, probably included dormant intervals as long as several centuries.

¹Years before 1980, based on tree-ring dates and historic records.²Years before 1980, based on tree-ring dates and ¹⁴C dates.

Assignment of deposits to the various eruptive periods is based on lithology and ferromagnesian-mineral suites typical for each of the eruptive periods (Mullineaux and Crandell, 1981; Mullineaux, 1986), as well as three ^{14}C dates from wood included in the deposits.

Table 2. Radiocarbon Ages

(Analyses by Meyer Rubin, USGS, Reston, VA)
See Plate 1 for Locations

SPECIMEN	MATERIAL	RADIOCARBON AGE (years)	ERUPTIVE PERIOD	MAP UNIT ¹
W-6221	Charcoal	1940±90	Castle Creek	ca
W-6032	Wood	2590±120	Pine Creek	pya
W-6222	Charcoal	2840±90	Pine Creek	ca/poa

¹ See Description of Map Units

Faults displayed on the map are largely confined to the older part of the stratigraphic section. These older units are highly shattered, with an extremely complicated fracture pattern and it is only possible to show the largest and most distinctive of these structures at the map scale (1:4000).

Interpretation of the stratigraphy and structure of this area is given by Hausback and Swanson (1990).

Two plates are included with this publication:

- | | |
|---------|--|
| Plate 1 | Geologic Map (with locations of chemically and isotopically analyzed specimens; analyses given in table 3) |
| Plate 2 | Geologic Cross Section |

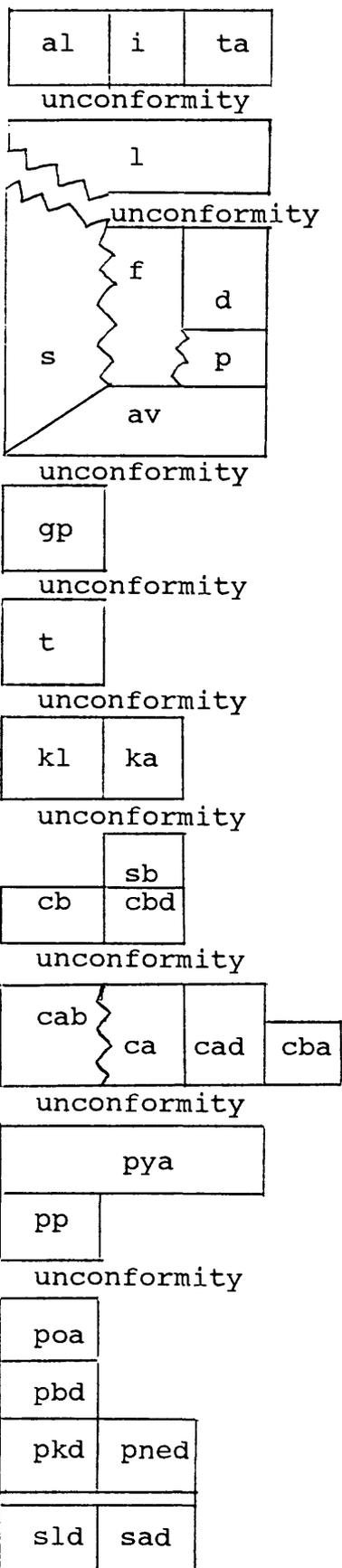
The following nomenclature is used in compositional classification of volcanic rock types:

<u>Rock Type</u>	<u>Percent SiO₂</u>
Rhyolite	>72
Rhyodacite	68-72
Dacite	62-68
Andesite	57-62
Basaltic andesite	52-57
Basalt	50-52

Acknowledgements

The author is sincerely grateful to Don Swanson, Rick Hoblitt, and Ed Wolfe for their advice, technical review, help, encouragement, and good humor throughout this project.

CORRELATION OF MAP UNITS



Map and Cross Section Symbols

	Contact, dashed where approximately located
	Fault, offset not apparent; dashed where approximately located
	Normal fault, tick and ball on downthrown block
	Thrust fault, teeth on upper plate
	Orientation of May 18, 1980 avalanche-scoured grooves and striations
	Limit of mapping
	Strike and dip of layering or dike orientation
	Horizontal layering
	Hot spring
	Cross section line
	Geochemical sample location
	Radiocarbon dated sample location

DESCRIPTIONS OF MAP UNITS

Deposits formed during and since 1980 --

- i Ice (Quaternary) -- Permanent or long-lasting ice fields. Confined to deep stream cuts of upper Step Creek. Deposited after May 18, 1980. 0 - 7 m thick
- al Alluvium (Quaternary) -- Stream deposits, minor lahars and talus. Includes rapidly accumulating fan at northern margin of the Sasquatch Steps. Deposited after May 18, 1980. Thickness unknown
- ta Talus (Quaternary) -- Contains minor alluvium. Deposited after May 18, 1980. Thickness unknown
- l Lahar deposits (Quaternary) -- Unconsolidated to moderately consolidated, poorly sorted, crudely-stratified, massive to lensoidal-bedded gravel and sand. Clasts are lithic and pumiceous heterogeneous rock types, subangular, up to 1 m in diameter, matrix-supported, and set in a medium-gray, silty to sandy lithic groundmass; commonly contains blocks of gray, porphyritic, prismatic jointed dacite (largely derived from the 1980-86 lava dome). Unit interfingers with, but mostly younger than, unit f. Unit formed after May 18, 1980; much of the unit probably deposited on March 19, 1982. 0-5 m thick
- f Pyroclastic flow deposits from May 18, 1980 and later (Quaternary) -- Light colored (white, tan, and pink), poorly sorted, block, lapilli, and ash deposits (mostly pumiceous). Individual flow units are 0-8 m thick, channel-filling, commonly reversely graded, clast supported at the top and matrix supported below. Lithic-block lag deposits are common at the bases of flow units. Flow unit formed on July 22 has a pink or brown oxidized upper zone which forms a resistant horizon in the southern part of the map area. Pumice clasts are subrounded, dacitic; lithic clasts are mostly porphyritic dacite, commonly with breadcrust surface or prismatic jointing, but also include accidental andesitic or other dacitic lithologies. Unit is best exposed along stream cuts in the upper and middle parts of the Sasquatch Steps. Locally includes May 18, 1980 blast deposit (recognized by the abundance of blue-gray "blast dacite"). Unit grades laterally to laminated, lapilli-ash surge deposits (s) on the steep slopes of the east and west sides of the Steps. Also contains minor laharc deposits. Formed during May 18, May 25, June 12, July 22, August 7, and October 16-18 eruptions. 0-25 m thick

- d Debris flow deposit of June 4 - July 18, 1980 (Quaternary) -- Medium-gray, massive, tabular deposit, very poorly sorted, matrix-supported diamict. Basal 0.5 m is medium-brown, well-sorted lithic ash that grades upward into the massive, blocky upper part. Clasts are irregularly-shaped, subrounded to angular, and range in size from coarse ash in the matrix to blocks up to 2 m in diameter, up to 3 m in the westernmost exposures. Clasts are monolithologic, frothy gray porphyritic dacite with extremely rough, friable exteriors; locally flow banded and contain about 10 percent phenocrysts of plagioclase > hornblende, 1-5 mm in diameter. Also contains localized, shattered, irregularly-shaped blocks of orange-brown, oxidized, aphyric and phenocryst-rich andesites. This unit probably resulted from a debris flow initiated in deposits of the Kalama eruptive period in the northwestern crater wall. Located on the upper and middle Sasquatch Steps. Typically in sharp contact with underlying unit av; locally overlies units p and pkd. Unit d did not exist on June 4, 1980 (photo by Sandia Labs, #201), but had been emplaced by July 18, 1980 (photo by M. Doukas, Cascades Volcano Observatory: D-80.06.1). 0-9 m thick
- s Pyroclastic surge and minor blast deposits of May 18, 1980 (and younger?) (Quaternary) -- Surge deposits are tan lapilli tuff which is laminated and cross-bedded and in places forms large dunes. Lapilli are up to 3 cm in diameter, consisting of lithic fragments and dacite pumice. Surge deposits are probably mostly younger than the May 18, 1980 blast deposits. On top of Sugar Bowl dome, unit consists only of the May 18 blast deposit, recognized by abundant lapilli and blocks of light blue-gray dacite in ashy matrix. 0-8 m thick
- p Pumiceous pyroclastic flow deposit (Quaternary) -- White, lenticularly-shaped deposit. Consists of two flow units, each about 2.5 m thick, separated by indistinct subhorizontal contact. Both flow units are massive, poorly-sorted lapilli-ash deposits. Locally, the lowest 10 cm is a laminated coarse lithic-pumiceous ash, overlying a lithic ash bed. Lapilli are largely rounded pumice, up to 20 cm in diameter in lower flow unit, 2 cm in the upper unit; with a few lithic clasts of varying lithologies (glassy and porphyritic dacites, vesicular andesites). Lapilli are supported in a matrix of lithic-pumiceous ash. Locally contains minor mafic-lithic lahar deposits below unit d. Localized in the southwestern part of the Sasquatch Steps. Sharp contacts with both underlying unit av and overlying unit d. Distinguished from unit f by presence of overlying unit d; where unit d was not deposited, unit p may be mapped as part of unit f. Unit deposited on May 18, May 25, or June 12, 1980. 0-5 m thick

- av Debris avalanche deposit of May 18, 1980 (Quaternary) -- Dark brown, gray, yellow, red-brown, and green diamict composed of various rock types found in present crater walls. The unit contains blocks ranging from cobble size to more than 100 m in diameter supported by very poorly sorted matrix of silt to pebble size. Blocks are internally shattered and many large blocks contain relict, contorted contacts between differing rock types. Unit is wholly lithic, predominantly composed of various andesites, minor basalts, and minor phyrlic and aphyric dacites. Surfaces of many clasts are noticeably gouged. The surface character is hummocky, with mounds ranging in shape from pointed-conical to extremely elongate-downslope. Emplacement of the avalanche left underlying surfaces striated and locally polished. Striations are best displayed in lower Steps on surfaces of units gp, cb, and cab. Passage of avalanche over poorly-consolidated units gp and cab appears not to have significantly plucked or quarried the loose blocks; instead fracturing, planing, striating, and polishing their upper surfaces. 0-95 m thick

Deposits of Goat Rocks eruptive period --

- gp Pyroclastic fan deposits derived from Goat Rocks dome (Quaternary) -- Poorly sorted, reversely graded, light to medium gray dacite (appears to darken up-fan) block, lapilli, and ash layers 1-3 m thick, commonly separated by gray lithic ash beds 2-30 cm thick. Blocks are sub-rounded, generally ranging up to 3 m in diameter (rarely up to 20 m), commonly displaying prismatic jointing. Lithology: mildly vuggy dacite with 2-3 percent phenocrysts (1-1.5 mm in diameter), plagioclase > hornblende = hypersthene, in seriate, granular, fine-grained groundmass. Contains notably abundant medium- to coarse-grained gabbro inclusions. On upper surface of unit many roots of trees and shrubs remained after the 1980 eruption, indicating relatively little erosion by the blast and avalanche. Blocks exposed on the upper surface are abraded, striated, and broken by the passage of the 1980 debris avalanche. Unit was probably largely deposited as pyroclastic flows (dome-collapse block and ash-flows) and minor talus shed from Goat Rocks dome (destroyed in the 1980 debris avalanche). Forms the surface west of Step Creek. This surface is locally covered by scattered pumice blocks (not mapped) of unit f. Unconformably overlies lavas and breccias of the Castle Creek eruptive period. In northwest part of the map area this contact contains a thin interbedded sequence consisting of: (described from top to bottom)
- 25 cm Tephra set X of Kalama eruptive period
 - 10 cm Tephra set W of Kalama eruptive period
 - 35 cm Lahar composed of mixed andesite and rhyodacite clasts (rhyodacite derived from rocks of Sugar Bowl eruptive period)
 - 25 cm Mafic tephra of Castle Creek eruptive period
- Unit formed during the 1840s and 1850s AD. 0-35 m thick

- t Tephra layer T (Quaternary) -- Pumice and lithic lapilli tephra. Mantle-bedded, multiple-layer tephra is clast supported (with about 10 percent ash-size fraction), reversely graded, and loosely consolidated; a typical section contains:
- upper 2 m: lapilli tuff with scattered pumice blocks up to 30 cm in diameter.
 - 20 cm thick lithic concentration in the tephra.
 - 60 cm thick lapilli tephra.
 - bottom 10 cm of ash and lapilli.

Divisions between layers are gradational. Lapilli and small blocks range from 0.5-10 cm in diameter with a few outsized pumice clasts. Pumice is white, angular; heavy mineral separates include hornblende > hypersthene >> augite. Many large pumice clasts have pink oxidized interiors. Lithic clasts are angular and consist of andesite, basalt, and dacite (including summit-dome dacite: light gray sugary groundmass; phenocryst-poor low-silica dacite with about 0.5 percent hornblende needles up to 7 mm long; fractures commonly have a pink to red-brown patina). Overlies lahar unit (kl) of the Kalama(?) eruptive period and underlies pyroclastic fan deposits (gp) of the Goat Rocks eruptive period. Unit formed in 1800 AD (Yamaguchi, 1983). 0 - 8 m thick

Deposits of Kalama(?) eruptive period --

- kl Lahar and fluvial deposits (Quaternary) -- Variably colored dark to light gray fragmental deposits. Crudely stratified unit of alternately clast- and sandy matrix-supported textures. Clasts range widely in size (up to 2.5 m in diameter) and lithology (including summit-dome dacite); equant and subangular to subrounded. Occurs as remnants of sedimentary fill in paleovalleys incised into lavas of the Castle Creek eruptive period; surrounding Loowit Creek. Unconformably overlain by tephra layer T of the Goat Rocks eruptive period. 0 - 30 m thick

Deposits of Kalama eruptive period --

- ka Andesite breccia (Quaternary) -- Black to dark gray, poorly sorted breccia with clasts up to 60 cm in diameter. Lithology ranges from porphyritic (plagioclase >> hypersthene phenocrysts) to aphyric, glassy varieties. Difficult to distinguish from unit cab. Overlies the Sugar Bowl rhyodacite dome (sb) and deposits of the Castle Creek eruptive period (cb, cab) in eastern part of map area. Overlies 20 cm thick, white pumice lapilli tephra (probably tephra set W of the Kalama eruptive period; with mafic crystals of hypersthene > hornblende) in west fork of Step Creek. 0-50 m thick

Dome of Sugar Bowl eruptive period --

sb Sugar Bowl dome (Quaternary) -- Medium-gray, massive, blocky rhyodacite. Mildly frothy porphyritic rhyodacite with 10-15 percent phenocrysts (0.5-1.5 mm in diameter), plagioclase > hypersthene > hornblende in very fine-grained microcrystalline groundmass. 50 m thick

Deposits of the Castle Creek eruptive period --

cb Basalt and basaltic andesite (Quaternary) -- Basalt and basaltic andesite lava and breccia; rare low-silica andesite. Form tabular lava flows, 1-7 m thick, of medium to dark-gray, mildly vesicular pahoehoe and aa with common red-brown scoriaceous, brecciated bases and tops. Lithology: seriate texture with fine-grained pilotaxitic groundmass and 1-15 percent phenocrysts (0.5-2.0 mm in diameter) of plagioclase > olivine ± augite. Phenocryst-poor varieties contain olivine only as groundmass phase. Unconformably overlies andesitic lavas and breccias of the Castle Creek eruptive period. Basaltic breccias largely overlies basaltic lavas, locally grade into dense lava, and are probably autoclastic basaltic flow breccias, subordinate lahars, and talus. 0-60 m thick

cbd Basalt dikes (Quaternary) -- Black to dark-brown, anastomosing, tabular to lensoidal dikes, locally columnar jointed. Lithology: 10-15 percent phenocrysts (0.5-1.5 mm in diameter), plagioclase > olivine, in a fine-grained pilotaxitic groundmass. Locally, mildly vesicular. Local, irregular red-brown and yellow alteration envelopes (baked zones) up to 4 m thick developed in host rocks adjacent to dikes. Intrude Kid dome (pkd) and Northeast dome (pned) of the Pine Creek eruptive period as well as andesite dikes (cad) of the Castle Creek eruptive period. Dikes are 0-3 m thick

cab Andesite breccias (Quaternary) -- Black to dark gray, tabular to lensoidal, fragmental beds, 2-10 m thick; common lenticular ashy interbeds. Beds are massive to normally graded, clast supported or supported in about 10-15 percent ash and lapilli matrix. Clasts are subangular to subrounded, dense or vesicular, glassy, monolithologic, range from 10 cm to 1 m in diameter, and are rarely prismatically jointed. Overlies and interfingers with andesite lavas (ca) and is unconformably overlain by basalt lavas (cb); upper contact locally marked by section of laminated intermediate or mafic ash up to 2 m thick. Breccias locally grade into dense lava interiors and are probably autoclastic andesitic flow breccias and, possibly, subordinate lahars. 0 - 95 m thick

- ca Andesite lava and minor flow-breccias (Quaternary) -- Medium to dark gray flows 7-15 m thick, with red-brown autobrecciated flow tops and bases; flow interiors dense with common platy fracturing. Lithology: porphyritic with fine-grained trachytic or pilotaxitic groundmass containing 5-20 percent phenocrysts of plagioclase > augite ± hypersthene, rare olivine; an atypical vesicular, plagioclase-phenocryst-rich variety occurs locally at base of unit, possibly correlative with unit cba. Overlies dacite domes and fragmental units of the Pine Creek eruptive period. Interfingers with and overlain by unit cab. In the lowermost Loowit Creek exposure a charred log in the basal part of the lowest andesite lava yielded an age of 1940 ± 90 ¹⁴C years B.P. (sample W6221). This lava overlies the following section:

Castle Creek eruptive period	10 cm	Laminated mafic ash
	15 cm	Plagioclase phyric andesite lahar
-----	2.5 m	Interlayered dacite and andesite tephras
Pine Creek eruptive period	60 cm	Laminated lithic dacite lapilli flowage deposit. Carbonized leaf and bark debris from the basal part of deposit yielded an age of 2840 ± 90 ¹⁴ C years B.P. (sample W6222).
	6 cm	Pink dacite ash

Section overlies diamicts (poa).

0-50 m thick

- cad Andesite dikes (Quaternary) -- Black, mildly vesicular tabular dikes. Dikes have thin chilled margins. Lithology: porphyritic texture with fine-grained hyalopilitic groundmass. About 5 percent phenocrysts (1-3 mm in diameter) of plagioclase > augite > hypersthene. Intrude Kid dome (pkd) and intruded by basalt dikes (cbd) of the Castle Creek eruptive period. Dikes are 1-4 m thick
- cba Basaltic andesite cinder, agglutinated spatter, and lava (Quaternary) -- Red to black scoriaceous to dense lapilli, block, and lava deposit. Lithology: 5-10 percent phenocrysts (0.5-3 mm in diameter) plagioclase > augite > olivine, in a very fine-grained, mafic rich felted matrix. Eroded cinder cone in southwest part of map area. Overlies Kid dome (pkd). 0-30 m thick

Deposits of Pine Creek eruptive period --

- pya Younger debris avalanche deposit (Quaternary) -- Variegated light gray and pastel yellow, pink, and green, unconsolidated mixture of relatively fresh to strongly altered (hydrothermally?) lithic dacite blocks, lapilli, and ash. These lithic clasts are all porphyritic and include dacite with plagioclase > hornblende > hypersthene and minor dacite with plagioclase > hornblende > quartz. Deposit contains a few large, contorted, stratified masses of block and ash-flow deposits but is largely massive. Cut by numerous shallowly to moderately inclined shear surfaces. Basal part of deposit is zone 0-3 m thick that contains abundant uncharred and battered logs; logs are commonly surrounded by a soft, yellowish brown sandy to clayey deposit, that may be an intermixed paleosoil. Log in the lowermost part of unit yielded age of 2590 ± 120 ¹⁴C years B.P. (sample W6032). 0-65 m thick
- pp Pyroclastic flow deposits (Quaternary) -- Lithic, rarely pumiceous, dacite block and ash-flow deposits. Light-gray, tabular bedded flow units; each flow unit about 10 m thick; reversely (rarely normally) graded; poorly sorted with common light-pink oxidized flow tops. Subangular, dense to mildly frothy, monolithologic dacite clasts up to 2 m in diameter; some units have common prismatically jointed blocks. Blocks are supported in matrix of coarse lithic ash and lapilli. Lithology: porphyritic dacites with plagioclase > hypersthene > hornblende. Lithic clasts in upper 1.5 m of unit locally display intense internal shattering where overlain by unit pya. Unconformably overlies dacite domes of the Pine Creek eruptive period and the older (poa) of two Pine Creek-age debris avalanche deposits. 0-35 m thick
- poa Older debris avalanche deposit (Quaternary) -- Variegated light gray and pastel yellow, pink, and green, unconsolidated mixture of relatively fresh and strongly altered (hydrothermally?) lithic dacite blocks, lapilli, and ash. Clasts are all porphyritic and include dacite with plagioclase > hypersthene > hornblende, dacite with plagioclase > hornblende > quartz > biotite, and dacite with plagioclase > hornblende > cummingtonite. The deposit contains a few large stratified masses of block and ash-flow deposits but is largely massive. Numerous shallowly to moderately inclined shear surfaces cut the section; many of these display cataclastic shear texture. Uppermost part of unit in lower Step Creek Canyon is an atypical red-brown contorted dacite breccia layer that displays a hummocky top where unconformably overlain by pyroclastic flow deposits (pp) of the Pine Creek eruptive period. Locally, may include undisturbed pyroclastic flow deposits (pp) of Pine Creek-age. 0-40 m thick, base not exposed

- pbd Breach dome (Quaternary) -- Medium-gray to pink strongly-shattered dome. Lithology: vuggy, porphyritic dacite with fine-grained granular groundmass containing 20-30 percent phenocrysts (0.5-2 mm in diameter) of plagioclase > hornblende = hypersthene. 175 m thick
- pkd Kid dome (Quaternary) -- Light-gray dacite. Strongly shattered. Erodes to badland topography. Lithology: porphyritic dacite with fine-grained granular groundmass containing about 20 percent phenocrysts (0.5-4 mm in diameter) of plagioclase > hornblende > hypersthene (hypersthene displays unusually high birefringence, up to second order blue in thin section). Unconformably overlain by the Breach dome (pbd), pyroclastic flow deposits (pp) of the Pine Creek eruptive period, and andesite lavas and cinder deposits (ca, cba) of the Castle Creek eruptive period. Intruded by Castle Creek-age andesite and basalt dikes (cad, cbd). 175 m thick, base not exposed
- pned Northeast dome (Quaternary) -- Light-gray dacite. Strongly shattered. Erodes to badland topography. Similar in outcrop appearance and lithology to Kid dome (pkd) and is, perhaps, correlative with it. Unconformably overlain by andesite breccias (cab) of the Castle Creek eruptive period and intruded by Castle Creek-age basalt dikes (cbd). 100 m thick, base not exposed

Domes of Smith Creek(?) eruptive period --

- sad Archybacter dome (Quaternary) -- Medium-gray dacite. Strongly shattered. Lithology: porphyritic texture with fine-grained granular groundmass containing 20 percent phenocrysts (0.5-2 mm in diameter) of plagioclase > hornblende; minor cummingtonite identified in a heavy mineral separate. Overlain by basalt lavas and andesitic breccias (cb, cab) of the Castle Creek eruptive period, as well as pyroclastic flow deposits (pp) of the Pine Creek eruptive period. 50 m thick, base not exposed
- sld Loowit dome (Quaternary) -- Light gray, highly fractured dacite. Lithology: porphyritic texture with a fine-grained granular groundmass containing 40 percent phenocrysts (0.5-2.0 mm in diameter) of plagioclase >> hornblende = altered cummingtonite(?), with trace of biotite. Fractures are mostly randomly oriented. In lower exposures, one major fracture set is sub-horizontal and wavy in form. Exposed along Loowit Creek, at and below Loowit Falls. Overlain by basalt lavas (cb) of the Castle Creek eruptive period. 115 m thick, base not exposed

Nomenclature Conventions for the above Unit Descriptions

Hyphenated compositional adjectives indicate a greater abundance of the latter part of the adjective; eg "lithic-pumiceous ash" is ash that is more pumiceous than lithic.

Non-hyphenated compositional adjectives are arranged in decreasing order of abundance; eg "block, lapilli, and ash deposits" are deposits with blocks making up the largest volume.

Mineral abundances are indicated by the symbols: ">", meaning "greater than", ">>", meaning "much greater than", "=", meaning "in about the same abundance as", and "±" meaning "may or may not include."

"B.P." indicates "before present".

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Table 3. Chemical Analyses

Analyses by S. Pribble, J. Taggart, A. Bartel, D. Siems;
U.S. Geological Survey

	87-1	87-3	87-6	87-9	87-10	87-16	87-18	87-19	87-20
SI02	66.20	63.00	63.50	57.80	64.60	63.30	52.90	59.00	57.40
TI02	0.52	0.67	0.67	1.70	0.60	0.65	1.48	1.18	1.26
AL203	17.30	17.60	17.80	16.40	17.40	17.60	18.10	18.00	18.30
FE203	3.79	5.11	4.78	9.56	4.54	4.98	9.29	7.38	7.98
FEO	nd	nd	nd	nd	nd	nd	nd	nd	nd
MNO	0.05	0.07	0.07	0.14	0.07	0.08	0.13	0.10	0.11
MGO	1.36	2.25	2.03	2.56	1.90	1.98	5.66	2.79	3.49
CAO	4.45	5.36	5.22	6.34	5.00	5.11	8.32	6.11	6.71
NA2O	4.69	4.53	4.49	4.46	4.48	4.56	3.96	4.52	4.35
K2O	1.37	1.29	1.28	1.27	1.27	1.29	0.96	1.33	1.16
H2O+	nd	nd	nd	nd	nd	nd	nd	nd	nd
H2O-	nd	nd	nd	nd	nd	nd	nd	nd	nd
P2O5	0.16	0.15	0.18	0.29	0.17	0.18	0.29	0.25	0.24
TOTAL	99.89	100.03	100.02	100.52	100.03	99.73	101.09	100.66	101.00

	87-23	87-24	87-27	88-1	88-14	88-16	88-17	88-18
SI02	64.60	64.20	59.10	53.00	67.00	66.20	67.50	51.30
TI02	0.57	0.58	1.20	1.50	0.59	0.57	0.48	1.71
AL203	17.70	17.90	17.90	17.90	16.40	17.10	16.90	17.00
FE203	4.31	4.43	7.48	3.67	1.34	2.34	2.78	2.89
FEO	nd	nd	nd	5.57	2.77	1.59	0.53	6.76
MNO	0.07	0.07	0.10	0.13	0.06	0.05	0.04	0.13
MGO	1.80	1.94	2.89	5.54	1.42	0.80	0.45	6.37
CAO	5.08	5.22	6.13	8.28	3.95	4.64	3.89	8.68
NA2O	4.55	4.50	4.46	4.04	4.80	4.69	4.61	3.80
K2O	1.26	1.24	1.32	0.99	1.78	1.49	1.56	1.09
H2O+	nd	nd	nd	0.10	0.18	0.08	0.42	0.09
H2O-	nd	nd	nd	0.06	0.03	0.03	0.56	0.24
P2O5	0.16	0.16	0.25	0.29	0.17	0.18	0.15	0.37
TOTAL	100.10	100.24	100.83	101.07	100.49	99.76	99.87	100.43

Table 3, continued

	88-19	88-24	88-28	88-30	88-32	88-34	88-35	88-36	88-37	88-38
SI02	64.40	63.40	57.40	68.50	58.20	64.30	57.70	50.60	63.90	63.80
TI02	0.60	0.65	1.64	0.38	1.71	0.61	1.70	1.70	0.60	0.63
AL203	17.40	16.90	16.10	16.10	16.10	17.40	16.00	16.60	17.40	17.50
FE203	2.09	3.09	4.43	1.15	2.66	2.18	2.89	3.17	2.17	3.55
FEO	2.41	1.36	5.21	2.20	7.05	2.45	6.65	6.40	2.39	1.07
MNO	0.07	0.06	0.14	0.05	0.14	0.07	0.14	0.14	0.07	0.07
MGO	1.94	1.74	3.06	0.93	2.62	2.00	2.53	6.54	1.97	1.98
CAO	5.18	4.95	6.50	3.32	6.25	5.17	6.15	8.43	5.16	5.15
NA20	4.54	4.46	4.43	4.88	4.53	4.50	4.46	3.70	4.47	4.49
K20	1.25	1.28	1.20	1.85	1.31	1.25	1.35	1.09	1.24	1.26
H20+	0.03	0.44	0.05	0.21	0.05	0.05	0.55	0.72	0.19	0.22
H20-	0.04	1.00	0.05	0.03	0.04	0.04	0.10	0.71	0.06	0.07
P205	0.16	0.19	0.28	0.14	0.03	0.17	0.29	0.39	0.16	0.17
TOTAL	100.11	99.52	100.49	99.74	100.69	100.19	100.51	100.19	99.78	99.96

	88-44	88-45	88-46	88-47	88-48	88-51	88-52	88-53	88-54	88-55
SI02	57.10	57.20	55.90	64.90	64.00	64.20	66.30	65.30	64.60	64.10
TI02	1.25	1.27	1.30	0.63	0.57	0.61	0.52	0.51	0.56	0.62
AL203	18.00	18.10	18.10	16.60	17.50	17.30	16.60	16.90	16.80	17.30
FE203	3.00	2.68	2.43	2.78	1.85	2.01	2.55	2.32	2.41	2.00
FEO	4.88	5.31	5.79	1.65	2.52	2.59	1.16	1.44	1.62	2.62
MNO	0.11	0.11	0.11	0.06	0.06	0.07	0.06	0.05	0.07	0.07
MGO	3.46	3.48	3.92	1.59	1.83	2.05	1.45	1.51	1.64	2.02
CAO	6.68	6.69	7.12	4.80	5.06	5.13	4.09	4.29	4.83	5.16
NA20	4.37	4.42	4.31	4.43	4.55	4.49	4.50	4.44	4.29	4.51
K20	1.16	1.17	1.09	1.46	1.25	1.25	1.46	1.39	1.42	1.24
H20+	0.03	0.11	0.14	0.25	0.01	0.03	0.57	0.53	0.27	0.02
H20-	0.01	0.04	0.06	0.49	0.04	0.04	0.51	0.77	0.87	0.05
P205	0.24	0.25	0.25	0.17	0.16	0.16	0.16	0.15	0.15	0.16
TOTAL	100.29	100.83	100.52	99.81	99.40	99.93	99.93	99.60	99.53	99.87

Table 3, continued

	88-56	88-57	88-58	88-60	89-3	89-4	89-5	89-6	89-7	89-14
SI02	64.60	63.80	68.30	58.80	53.80	51.40	60.70	57.10	59.80	61.20
TI02	0.61	0.60	0.40	1.13	1.38	1.79	1.22	1.64	1.25	1.07
AL203	17.40	17.30	16.10	17.60	18.00	16.80	16.60	15.90	16.70	16.70
FE203	3.03	3.85	1.47	2.47	2.87	3.38	2.60	3.12	2.37	2.28
FEO	1.45	0.60	1.99	4.97	5.83	6.58	5.04	7.08	5.37	4.67
MNO	0.07	0.07	0.05	0.10	0.12	0.14	0.11	0.15	0.11	0.10
MGO	1.92	1.87	0.98	3.61	4.82	6.88	2.07	3.43	2.00	2.31
CAO	5.01	4.94	3.36	6.22	7.86	8.59	5.56	6.92	5.79	5.35
NA20	4.70	4.53	4.91	4.41	4.09	3.73	4.56	4.29	4.49	4.46
K20	1.34	1.34	1.83	1.21	1.00	0.99	1.40	1.12	1.36	1.48
H20+	0.08	0.05	0.21	0.10	0.06	0.05	0.04	0.10	0.17	0.15
H20-	0.05	0.03	0.10	0.07	0.02	0.05	0.04	0.03	0.03	0.02
P205	0.17	0.16	0.13	0.20	0.27	0.38	0.25	0.26	0.24	0.25
TOTAL	100.43	99.14	99.83	100.89	100.12	100.76	100.19	101.14	99.68	100.04

	89-23	89-26	F87-42*	F87-44*	F88-6*
SI02	60.30	61.80	64.10	52.80	56.00
TI02	1.10	1.03	0.59	1.48	1.29
AL203	17.00	17.00	17.40	18.40	18.50
FE203	2.11	2.35	4.41	9.13	8.12
FEO	5.01	4.41	nd	nd	nd
MNO	0.10	0.10	0.08	0.13	0.11
MGO	2.73	2.22	1.76	5.61	3.99
CAO	5.86	5.44	4.82	8.06	7.08
NA20	4.37	4.52	3.99	3.59	3.86
K20	1.45	1.49	1.30	0.99	1.06
H20+	0.13	0.10	0.95	0.95	nd
H20-	0.08	0.02	0.03	0.03	nd
P205	0.25	0.25	0.16	0.27	0.23
TOTAL	100.49	100.73	99.59	101.44	100.24

* Analyses courtesy of Fraser Goff, Los Alamos Laboratories

LIST OF ANALYZED SAMPLES Table 3, continued

Localities on Plate 1

#	Unit	Short Description
87-1	-sld	SMITH CREEK(?) -AGE DACITE OF LOOWIT DOME
87-3	-gp	GOAT ROCKS-AGE PYROCLASTIC FLOW CLAST
87-6	-d	JUNE 4-JULY 18, 1980 DEBRIS FLOW DEPOSIT
87-9	-ca	CASTLE CREEK-AGE PLAGIOCLASE PHYRIC ANDESITE LAVA
87-10	-pkd	PINE CREEK-AGE KID DOME DACITE
87-16	-t	GOAT ROCKS-AGE TEPHRA LAYER T; EAST OF MAP AREA
87-18	-cb	CASTLE CREEK-AGE BASALTIC ANDESITE LAVA
87-19	-ca	CASTLE CREEK-AGE ANDESITE LAVA
87-20	-ca	CASTLE CREEK-AGE ANDESITE LAVA
87-23	-poa	PINE CREEK-AGE OLDER DEBRIS AVALANCHE DEPOSIT DACITE CLAST
87-24	-pp	PINE CREEK-AGE PYROCLASTIC FLOW DACITE CLAST
87-27	-ca	CASTLE CREEK-AGE PLATY ANDESITE LAVA
88-1	-cb	CASTLE CREEK-AGE BASALTIC ANDESITE
88-14	-	SUGAR BOWL-AGE DACITE LAHAR
88-16	-poa	PINE CREEK-AGE OLDER DEBRIS AVALANCHE DEPOSIT DACITE CLAST
88-17	-poa	PINE CREEK-AGE OLDER DEBRIS AVALANCHE DEPOSIT DACITE CLAST
88-18	-cbd	CASTLE CREEK-AGE BASALT DIKE
88-19	-pned	PINE CREEK-AGE DACITE OF NORTHEAST DOME
88-24	-sad	SMITH CREEK(?) -AGE DACITE OF ARCHYBACTER DOME
88-28	-cb	CASTLE CREEK-AGE PLAGIOCLASE-PHYRIC BASALTIC ANDESITE
88-30	-sb	SUGAR BOWL-AGE RHYODACITE OF SUGAR BOWL DOME; EAST OF MAP AREA
88-32	-ca	CASTLE CREEK-AGE PLATY ANDESITE
88-34	-poa	PINE CREEK-AGE OLDER DEBRIS AVALANCHE DEPOSIT DACITE CLAST
88-35	-cad	CASTLE CREEK-AGE ANDESITE DIKE
88-36	-cbd	CASTLE CREEK-AGE BASALT DIKE
88-37	-pkd	PINE CREEK-AGE DACITE OF KID DOME
88-38	-pp	PINE CREEK-AGE DACITE PYROCLASTIC FLOW
88-44	-ca	CASTLE CREEK-AGE ANDESITE
88-45	-ca	CASTLE CREEK-AGE ANDESITE BRECCIA
88-46	-cb	CASTLE CREEK-AGE BASALTIC ANDESITE BRECCIA
88-47	-poa	PINE CREEK-AGE DACITE WITHIN SHEAR ZONE
88-48	-poa	PINE CREEK-AGE OLDER DEBRIS AVALANCHE DEPOSIT DACITE CLAST
88-51	-pp	PINE CREEK-AGE PYROCLASTIC FLOW DEPOSIT DACITE CLAST
88-52	-pya	PINE CREEK-AGE YOUNGER DEBRIS AVALANCHE DEPOSIT, GREEN DACITE CLAST
88-53	-poa	PINE CREEK-AGE OLDER DEBRIS AVALANCHE DEPOSIT, GREEN DACITE CLAST
88-54	-poa	PINE CREEK-AGE OLDER DEBRIS AVALANCHE DEPOSIT, GREEN DACITE CLAST
88-55	-poa	PINE CREEK-AGE OLDER DEBRIS AVALANCHE DEPOSIT, DACITE CLAST
88-56	-pbd	PINE CREEK-AGE DACITE OF BREACH DOME
88-57	-pbd	PINE CREEK-AGE DACITE OF BREACH DOME
88-58	-sb	SUGAR BOWL-AGE RHYODACITE OF SUGAR BOWL DOME
88-60	-ka	KALAMA-AGE ANDESITE BRECCIA
89-3	-cb	CASTLE CREEK-AGE BASALTIC ANDESITE BRECCIA
89-4	-cb	CASTLE CREEK-AGE PLATY BASALT
89-5	-ca	CASTLE CREEK-AGE PLATY ANDESITE
89-6	-cba	CASTLE CREEK-AGE BASALTIC ANDESITE AUTOBRECCIA LAVA
89-7	-ca	CASTLE CREEK-AGE ANDESITE BRECCIA
89-14	-cab	CASTLE CREEK-AGE ANDESITE BRECCIA
89-23	-cab	CASTLE CREEK-AGE ANDESITE BRECCIA, ATOP(?) UNIT pya
89-26	-cab	CASTLE CREEK-AGE ANDESITE BRECCIA
F87-42	sad	SMITH CREEK(?) -AGE DACITE OF ARCHYBACTER DOME
F87-44	-cb	CASTLE CREEK-AGE OLIVINE BASALTIC ANDESITE LAVA
F88-6	-cb	CASTLE CREEK-AGE BASALTIC ANDESITE LAVA