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Geologic Map of Three Sisters Volcanic Cluster, Cascade Range, Oregon

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Pamphlet to accompany

Scientific Investigations Map 3186

Aerial view northward along glaciated summits of South Sister, Middle Sister, and North Sister volcanoes. Snow and ice-filled South Sister crater (rim at 10,358 ft) was created between 30 and 22 ka, during most recent of several explosive summit eruptions; thin oxidized agglutinate that mantles current crater rim protects 150-m-thick pyroclastic sequence that helped fill much larger crater. Middle Sister (10,047 ft) is capped by thick stack of radially dipping, dark-gray, thin mafic lava flows; asymmetrically glaciated, its nearly intact west flank contrasts sharply with its steep east face. Blue lake (near far right edge) is impounded by sharp-crested Neoglacial moraine. North Sister (10,085 ft) is glacially ravaged stratocone that consists of hundreds of thin rubbly lava flows and intercalated falls that dip radially and steeply; remnants of two thick lava flows cap summit. Broad mafic shield beyond North Sister is Black Crater; distant peak on horizon is Mount Jefferson; and Mount Hood is in dim distance. *Photograph by John Scurlock, 2007.*

2012

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Introduction

The cluster of glaciated stratovolcanoes called the Three Sisters forms a spectacular 20-km-long reach along the crest of the Cascade Range in Oregon, 35 km west of Bend and 100 km east of Eugene (fig. 1). As observed by trailblazing volcanologist, Howel Williams (1944), "For magnificence of glacial scenery, for wealth of recent lavas, and for graphic examples of dissected volcanoes, no part of this range surpasses the area embracing the Sisters and McKenzie Pass." The area we have now mapped in detail consists exclusively of Quaternary volcanic rocks and derivative surficial deposits. Although most of the area has been modified by glaciation, the volcanoes are young enough that the landforms remain largely constructional. Locations of many of the geographic features mentioned in this report are shown in figures 1 and 2.

Scientific and journalistic interest in the Three Sisters volcanic cluster was aroused a few years ago when ongoing uplift centered about 5 km west of South Sister was identified, first recognized by satellite imagery (interferometric synthetic aperture radar, InSAR) in 2001 (Wicks and others, 2002). Subsequent geodetic measurements and continuing InSAR analysis confirmed 3 to 4 cm/yr uplift during the interval from 1997 to 2004; the uplift has been modelled as inflation thought to be caused by an intracrustal intrusion (Dzurisin and others, 2006, 2009), largely aseismic and plausibly involving mafic magma like that which was last erupted 11 km to the north about 1,500 years ago.

Twelve of the 145 eruptive units described below are postglacial, younger than the deglaciation that was underway by about 17 ka. The most recent eruptions were of rhyolite near South Sister, about 2,000 years ago, and of mafic magma near McKenzie Pass, about 1,500 years ago. Despite the recency of eruptive activity, no fumaroles or hot springs are recognized in the area. West of South Sister, however, several springs (some of which are geochemically anomalous) that have orifice temperatures in the range of 2° to 12°C are present (Evans and others, 2004).

The three eponymous stratocones, though contiguous and conventionally lumped sororally, could hardly display less family resemblance. North Sister is a monotonously mafic edifice at least as old as 120 ka; Middle Sister, an andesite-basalt-dacite cone built between 48 and 14 ka; and South Sister, a bimodal rhyolitic-intermediate edifice that was constructed between 50 ka and 2 ka. For each of the three, eruptive volume is likely to have been in the range of 15 to 25 km^3, but such estimates are fairly uncertain, owing to glacial erosion.

Physiography and Access

Nearly all of the map area lies within the Three Sisters Wilderness, which is roadless, is free of buildings and shelters, and is protected by the Deschutes and Willamette National Forests. Seasonal access on foot is nonetheless simple, as numerous trails (many maintained and others informal) crisscross the wilderness from trailheads near the McKenzie Pass Highway (Hwy 242) to the north (fig. 2), the Cascade Lakes Highway (Hwy 46) to the south, and several Forest Service roads to the east. Most trails are accessible from July through October, but for the rest of the year, owing to heavy snowfall, few people (other than cross-country skiers) enter the wilderness. Average annual precipitation on the crest of the Cascade Range, measured at Santiam Pass (elevation 4,817 ft [1,468 m], about 28 km north of North Sister), is 217 cm (85.3 in), and average snowfall is 1,145 cm (451 in) [Western Regional Climate Center (http://www.wrcc.dri.edu/index.html)]. Only 8 percent of the average annual precipitation (and very little snow) falls there in the July-to-September quarter of the year. Precipitation falls off sharply east of the crest, to annual averages of about 34 cm at Sisters and 30 cm at Bend (fig. 1). Like the Sierra Nevada of California, the Three Sisters is a "gentle wilderness:" its summer climate is usually moderate, and its relief, distances, and wildlife hazards are modest, yet it remains spectacular and largely unspoiled.

The three principal volcanoes are similar in elevation: North Sister, 10,085 ft (3,074 m); Middle Sister, 10,047 ft (3,062 m); and South Sister, 10,358 ft (3,157 m). Their surrounding lava-flow aprons descend southward to about 5,440 ft (1,658 m) near Sparks Lake, northeastward to below 4,400 ft (1,340 m) at Trout Creek Swamp and along Whychus Creek (on topographic maps, shown as "Squaw Creek"), and westward to about 5,000 ft (1,525 m) near Indian Holes and as low as 3,500 ft (1,065 m) at Linton Lake. To its southeast and northwest, however, lavas of South Sister were buttressed by older edifices and, thus, bank as high as 7,000 ft (2,135 m) against Broken Top and up to 6,100 ft (1,860 m) against The Husband. Middle Sister, although lowest of the three main summits, nevertheless has the greatest relief of about 6,550 ft (2,000 m) because its western apron extends all the way down to Linton Lake.

The glacial ice that formerly mantled virtually the entire mapped area has diminished to 16 small glaciers, largely confined to cirques on the Three Sisters edifices, as shown on 1997 USGS topographic maps, which are based on aerial photographs taken as recently as 1982. Of the seven named glaciers on South Sister, however, Skinner and Carver Glaciers have since shrunk into stagnant snowfields, as has Irving Glacier on Middle Sister. Thayer and Villard Glaciers on North Sister and Renfrew Glacier on Middle Sister are small and close to extinction. As the climate changes, more and more rubble is exposed at the expense of ice.

Previous Work

The first geological overview of the Three Sisters region was presented in a book by Hodge (1925), which (although volcanologically wanting) remains worth reading for its historical, geographic, and natural history contributions. A volcanological reconnaissance by Williams (1944), which was based on only six weeks fieldwork, nicely established the main outlines of the Three Sisters and of several peripheral mafic volcanoes. Lacking chemical data, however, Williams called all the rhyolite lavas "dacite" (although he speculated that some would eventually be proven rhyolitic), and he also reckoned the ages of all the glaciated edifices to be far greater than now established

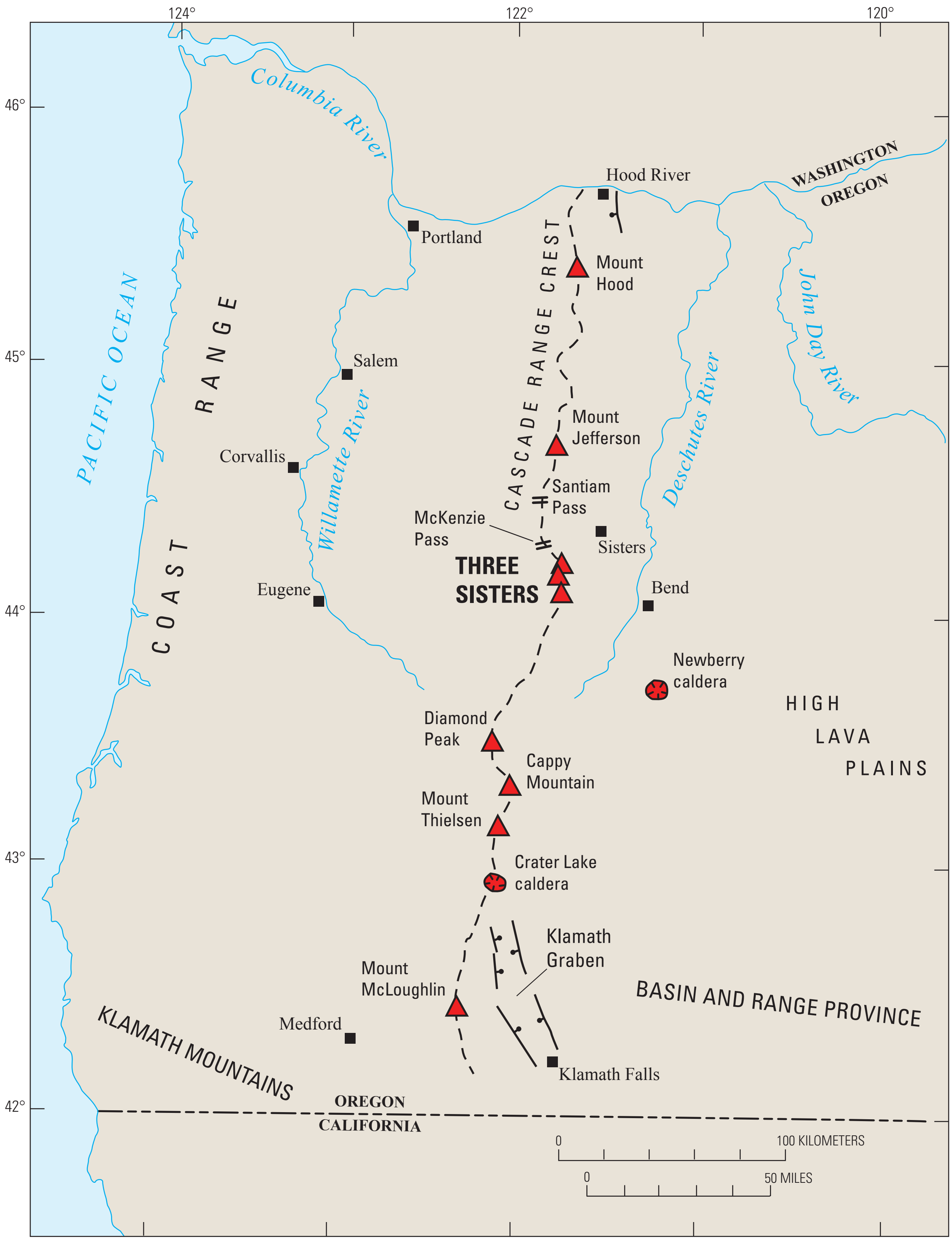


Figure 1. Regional location map of western Oregon, showing principal physiographic provinces, selected rivers and cities, and major Quaternary volcanic edifices of Cascade Range, including Three Sisters volcanic cluster. Solid black lines indicate main faults; ball and bar indicates downthrown side of normal faults. Dashed line through Three Sisters and nearby mountains and passes shows trace of Cascade Range crest, which is main drainage divide and approximate axis of Quaternary volcanic chain.

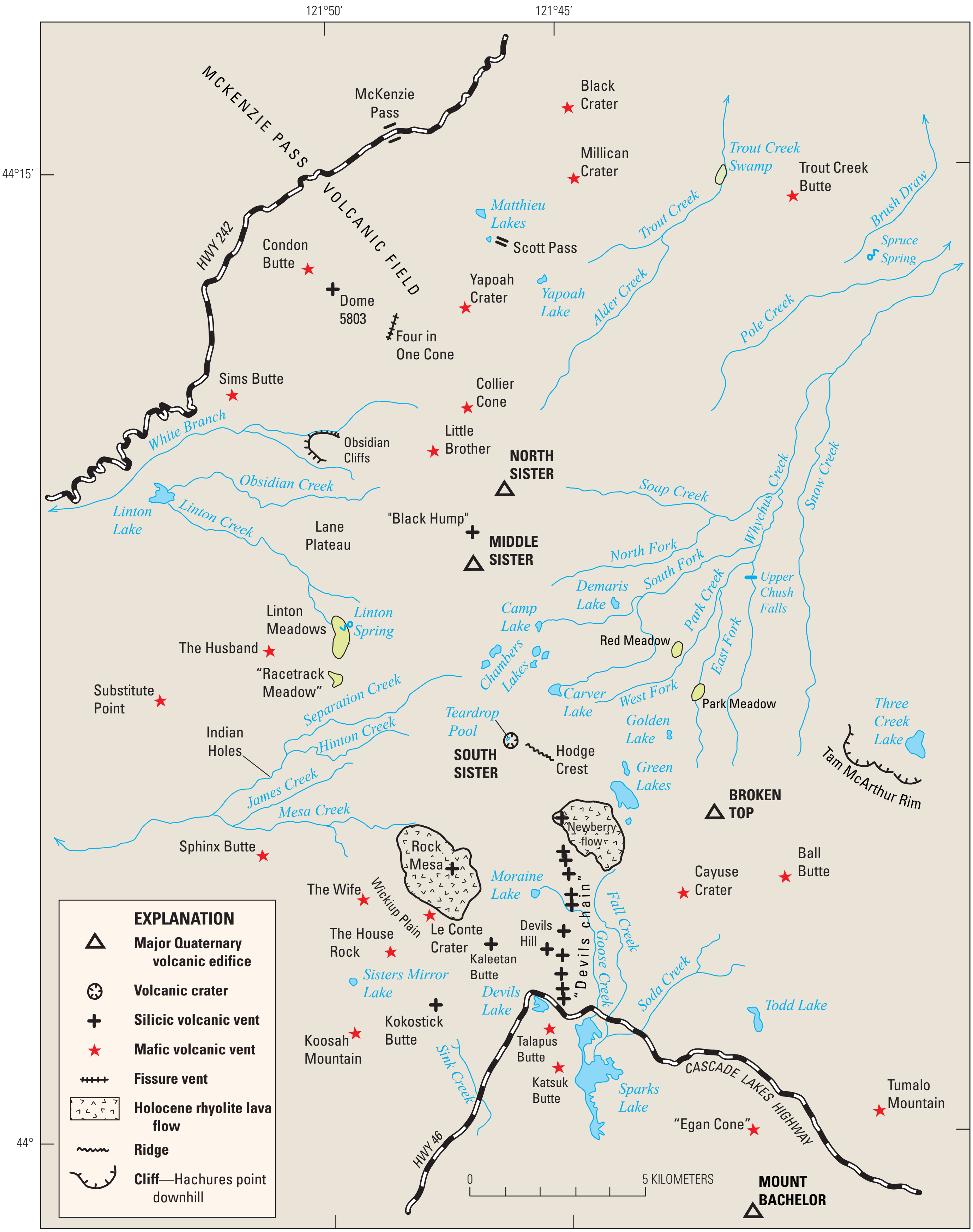


Figure 2. Map of Three Sisters region, showing locations of many geographic features mentioned in text.

by modern geochronology. Progressively more complete reconnaissance mapping and compilations subsequently were produced by Taylor and others (1987) and Sherrod and others (2004). Williams (1957) also published a reconnaissance geologic map of the entire Cascade Range of central Oregon from Crater Lake to Mount Jefferson (fig. 1). More detailed geologic maps of two quadrangles that overlap the eastern part of our study area were published by Taylor (1978, 1987). The most detailed geologic investigations here were by Scott (1987), on late Holocene rhyolites peripheral to South Sister, and a map by Scott and Gardner (1992) that covers the southeast flank of South Sister and the entire Mount Bachelor chain farther south. A geochemical study of mafic lavas in the region that includes the Three Sisters was published by Hughes and Taylor (1986) and Hughes (1990). Topical thesis studies emphasizing chemistry and petrography of particular areas were completed by Wozniak (1982), Clark (1983), Hill (1991), Webster (1992), Schick (1994), Gardner (1994), and Schmidt (2005). Mercer and Johnston (2008) and Schmidt and Grunder (2009) investigated the eruptive history and petrology of North Sister. A summary of the Sisters reach of the Quaternary Cascade arc—a 90-km-long subsegment centered on, but extending well north and south of, our Three Sisters map area—was included in an arc-wide overview by Hildreth (2007).

Methods

We spent about one month each summer from 2000 to 2009 mapping the volcanic field on foot, generally late in the season when snowmelt was most advanced. About 200 days were devoted to productive fieldwork, excluding stormy days, rest days, and travel to and from our California office. Because most of the area is glaciated and till strewn, aerial photographs were of only minor utility, and our detailed mapping was done directly on USGS 1:24,000-scale topographic quadrangle maps (South Sister, North Sister, Linton Lake, Trout Creek Butte, and Broken Top). A hand-held GPS device commonly was useful in the woods. Our goal was to study in detail the Three Sisters and the eruptive products of contemporaneous vents on their aprons. Accordingly, no effort was made to complete the quadrangles nor to undertake detailed mapping of the older (mostly middle Pleistocene) mafic centers that surround the Three Sisters cluster. The Three Sisters map area is bordered on its northwest side by the postglacial McKenzie Pass volcanic field (Taylor, 1968; Sherrod and others, 2004), which extends 25 km farther northwestward; we chose to show its southernmost component (lava flows from Collier Cone) and its easternmost component (the eastern lava flow from Yapoah Crater) as convenient margins for the Three Sisters map area.

One or several thin sections for each of the 145 volcanic units mapped were examined microscopically, and the observations are summarized in the unit descriptions. Most samples were analyzed chemically, as described and listed in table 1.

For a large fraction of the 130-odd pre-Holocene units herein defined, radioisotopic ages were determined in the U.S. Geological Survey geochronology laboratory in Menlo Park, California (supervised by A.T. Calvert). Most samples in this study were dated using $^{40}Ar/^{39}Ar$ incremental-heating techniques, following methods described in Calvert and Lanphere (2006) and Hildreth and others (2007), and the results are listed in table 2. Samples were irradiated at the U.S. Geological Survey reactor in Denver, Colorado, using 27.87-Ma Taylor Creek sanidine as a neutron-flux monitor. In table 2, weighted-mean plateau ages, isotope-correlation (isochron) ages, and total-gas ages are reported, and our interpreted eruption ages are highlighted in bold font. Plateau ages generally are interpreted as the most reliable if the $^{40}Ar/^{36}Ar$ intercept is within analytical error of atmospheric argon ($^{40}Ar/^{36}Ar = 295.5$). Isochron ages are interpreted as the most reliable if the $^{40}Ar/^{36}Ar$ intercept is outside analytical error of atmospheric argon. Total-gas ages are interpreted as the most reliable on fine-textured samples that show evidence for significant ^{39}Ar recoil. In several cases, we tested ^{39}Ar-recoil effects by conducting K-Ar analyses on the same rocks (table 3), following methods described in Hildreth and Lanphere (1994). Results from K-Ar determinations were concordant with the $^{40}Ar/^{39}Ar$ results, and, in one sample (TS-94, unit rkb), K-Ar analysis yielded a reliable age that we were unable to obtain with $^{40}Ar/^{39}Ar$ methods.

Geologic Setting

For a convergent-margin volcanic belt, the density of Quaternary volcanoes in the Cascade Range of Oregon (commonly called the Oregon Cascades) is extraordinary (about 1,050 vents). The only comparably extensive areas that have such dense concentrations of Quaternary-arc volcanoes are in southern Washington, northern California, Michoacán (Mexico), and a few short reaches of the Chilean Andes (Hildreth, 2007).

No well-defined volcanic front exists in Oregon (Hildreth, 2007). The crest of the Cascade Range, site of the Three Sisters, lies about 270 km east of the submarine deformation front that marks the site of a sediment-filled trench. The crust beneath the Cascade crest in Oregon is thought to be about 44 km thick (Leaver and others, 1984; Mooney and Weaver, 1989). The subducting slab beneath Oregon is virtually aseismic, and, because tomographic models for its dip and depth beneath the Oregon arc and forearc vary widely (Michaelson and Weaver, 1986; Rasmussen and Humphreys, 1988; Harris and others, 1991; Bostock and others, 2002; McCrory and others, 2004), its configuration remains uncertain.

Intra-Arc Extension

The plate-convergence rate at the latitude of the central Oregon Cascades is only about 3.5 cm/yr, increasing slightly northward (McCaffrey and others, 2007). The azimuth at which the Juan de Fuca plate underthrusts the Oregon plate margin is about N. 45° E., oblique to the north-trending plate boundary.

In addition to the basal traction that probably is contributed by the oblique plate convergence, tectonic deformation of Cascadia and adjacent areas is driven fundamentally by the dextral shear between the Pacific and North American plates (Atwater, 1970) and by the extension promoted by buoyant mantle beneath the western Basin and Range Province (Jones and others, 1996). Opposite the Cascade arc, most of the relative motion between the two megaplates is accommodated by spreading on the Juan de Fuca Ridge and subduction beneath Cascadia, but some 25 percent of the relative motion is distributed far inboard as block rotations and translations (Pezzopane and Weldon, 1993; Walcott, 1993; Wells and others, 1998; McCaffrey and others, 2007).

In response to the dextral shear couple, and in concert both with northwestward motion of the nearly rigid Sierra Nevada–Great Valley microplate (Dixon and others, 2000; Hammond and Thatcher, 2004) and with Basin and Range extension inboard (fig. 3), the Oregon forearc has undergone clockwise rotation since at least the middle Miocene (Wells and Heller, 1988; Wells, 1990; Wells and others, 1998). Along its trailing margin, rotation of the forearc block apparently contributes to the intra-arc and rear-arc east-west extension significant along the Oregon Cascades, from the Klamath Graben to the Columbia River (figs. 1, 3). On the decadal timescale of GPS measurements, however, intra-arc extension here is currently limited to about 1 mm/yr or less (McCaffrey and others, 2007). Oblique subduction of the Juan de Fuca plate probably also contributes by basal traction to northward motion of the Cascadia forearc. Northwestward translation of the Sierra Nevada–Great Valley microplate involves a broad dextral inboard shear zone (Walker Lane) that extends from southern Nevada to northeastern California, where the northwest-trending strike-slip belt merges diffusely into the array of north-striking normal faults that reach northward through the Klamath Graben, Mount Mazama, and the Cascade Range of central Oregon (fig. 3). The transition from predominantly dextral shear in California to block rotation in Oregon lies between the Lassen and Shasta segments of the arc, coinciding with the transition offshore from a strike-slip to a subducting plate boundary (fig. 3).

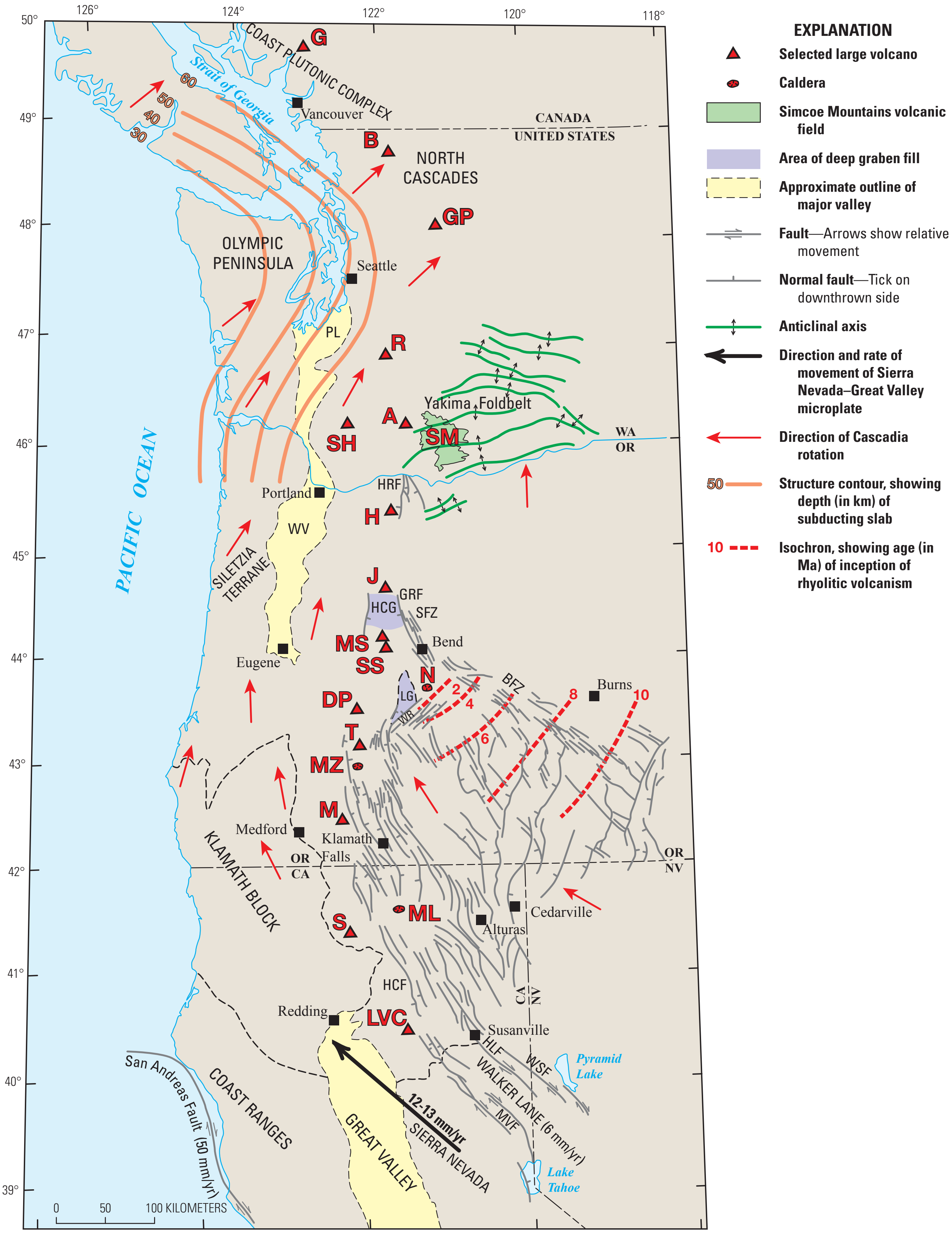
Farther north, the Brothers Fault Zone (fig. 3), a belt of weaker northwest-trending dextral shear, provides a diffuse northern margin for the Basin and Range extended region (Lawrence, 1976). The Brothers Fault Zone likewise terminates diffusely against the Cascade arc, first stepping left (west) to form the northwest-trending Sisters (Tumalo) Fault Zone, which, in turn, merges with the north-striking High Cascades Graben (fig. 3; see also Taylor, 1981, 1990; Smith and Taylor, 1983; Smith and others, 1987; Sherrod and others, 2004). Elements of this intra-arc belt of modest east-west extension, structurally active at least since 5 Ma, may or may not be continuous along the Cascade Range axis from Green Ridge (44.5° N.) northward through the Mount Jefferson reach to join the Hood River Fault (fig. 3) near the Columbia River (Walker and MacLeod, 1991; Conrey and others, 1997, 2002), where discernible extension apparently peters out.

Although the Juan de Fuca plate subducts northeastward beneath the North American plate, the maximum principal horizontal-stress direction in the upper plate is margin parallel, not in the convergence direction (Spence, 1989; Zoback, 1992). Presumably owing to the combination of oblique convergence and the northward push of the Sierra Nevada–Great Valley microplate through the Klamath Block (fig. 3), the direction of compression is north-south in Washington and Oregon and as far south as Mount Shasta, within the arc, forearc, and parts of the rear arc such as the Yakima Foldbelt. This stress orientation is reflected in north-south vent alignments from Mount Shasta to Mount Adams, but nowhere in the Cascade Range are vent alignments more conspicuous than here in the reach containing the Three Sisters, where lines of mafic volcanoes (and even a chain of Holocene rhyolite vents) form north-striking arrays (Bacon, 1985; Hughes and Taylor, 1986; Scott, 1987; Scott and Gardner, 1992). Without specific evidence, however, such vent alignments should not be assumed to have been supplied contemporaneously by a common dike system or to reflect a fissure-fed eruption. Many such alignments include varied magmas that erupted thousands of years apart, and parallelism of the dikes that presumably underlie them results from the enduring stress field, not necessarily from a common magma reservoir.

Differential extension and block rotation of the lithosphere may well play a more important role than subduction geometry in controlling segmentation of the volcanic belt, in defining its several distinguishable reaches in Oregon, and in promoting its exceptional width in California and southern Washington (Hildreth, 2007). The Cascade arc has been a well-defined, continuous belt since the Eocene, but dextral shear, block rotations, and Basin and Range extension were not imposed on the arc until the middle Miocene. Had none of these external tectonic processes been superimposed on the Cascade Range, a Cascade arc would, nonetheless, still exist today, owing to the slab-derived contribution to mantle-wedge melt production. In all likelihood, however, there would be no rear-arc center at Newberry Volcano, none of the H_2O-poor, low-K, high-alumina olivine tholeiite so abundant in central Oregon, and no true rhyolite in the Three Sisters reach of the arc.

Cross-Oregon Crustal-Melting Anomaly

The Three Sisters lie at the leading end of a crustal-melting anomaly that has propagated across Oregon (fig. 3) since the middle Miocene (MacLeod and others, 1975; Jordan and others, 2004). The anomaly manifested in the eruption of numerous units of true rhyolite (72–77% SiO_2), which is rare elsewhere along the Cascade arc (although common at rear-arc centers and in the extensional continental interior). Initiation of rhyolitic volcanism started in southeastern Oregon, advancing across Harney Basin by 9 Ma and Fort Rock Valley by 5 Ma. After this the rate of westward propagation slowed markedly (Jordan and others, 2004), approaching the later site of Newberry Volcano in the early Quaternary. Several middle and late Pleistocene rhyolites subsequently erupted near Newberry Volcano and in the Tumalo volcanic field (east of Broken Top; Hildreth, 2007), followed by rhyolites still farther northwest that range in age from 50 ka to 2 ka at Middle Sister and South Sister (fig. 4). Progression of the Oregon melting anomaly is sometimes said to mirror the comparable northeastward propagation of rhyolite initiation along the Snake River Plain as far as Yellowstone over the same time interval (Christiansen and McKee, 1978; Christiansen and others, 2002; Jordan and others, 2004), but the volume of



EXPLANATION
Selected large volcano
Caldera
Simcoe Mountains volcanic field
Area of deep graben fill
Approximate outline of major valley
Fault—Arrows show relative movement
Normal fault—Tick on downthrown side
Anticlinal axis
Direction and rate of movement of Sierra Nevada–Great Valley microplate
Direction of Cascadia rotation
Structure contour, showing depth (in km) of subducting slab
Isochron, showing age (in Ma) of inception of rhyolitic volcanism
PACIFIC OCEAN
Strait of Georgia
COAST PLUTONIC COMPLEX
Vancouver
CANADA
UNITED STATES
NORTH CASCADES
OLYMPIC PENINSULA
Seattle
Yakima Foldbelt
WA
OR
Portland
SILETZIA TERRANE
Eugene
Bend
Burns
Medford
Klamath Falls
OR
CA
OR
NV
KLAMATH BLOCK
Cedarville
Alturas
Redding
Susanville
CA
NV
Pyramid Lake
Lake Tahoe
COAST RANGES
GREAT VALLEY
SIERRA NEVADA
WALKER LANE (6 mm/yr)
12-13 mm/yr
San Andreas Fault (50 mm/yr)
0 50 100 KILOMETERS
G
B
GP
R
A
SH
SM
H
J
MS
SS
N
DP
T
MZ
M
ML
S
LVC
PL
WV
HRF
HCG
GRF
SFZ
LG
BFZ
HCF
HLF
WSF
MVF

rhyolite erupted along the Oregon trend is only about 1 percent of that along the Snake River Plain. Along both trends, eruption of considerable amounts of basalt and some rhyolite continued long after passage of the rhyolite-initiating front.

Because true rhyolites are so rare elsewhere within the Quaternary Cascade arc, as opposed to the rhyodacites (68–72% SiO_2) so abundant at Mount Jefferson and Crater Lake, it is likely that the rhyolite-generating crustal-melting anomaly beneath the Tumalo and Three Sisters areas is principally attributable to whatever combination of mantle flow and decompression has been responsible for the 16-m.y.-long westward propagation of intracrustal melting and rhyolitic volcanism across the High Lava Plains. Now that the leading edge has penetrated the Cascade arc, rhyolite production may recently be enhanced in the Sisters reach by the presence of preheated arc crust.

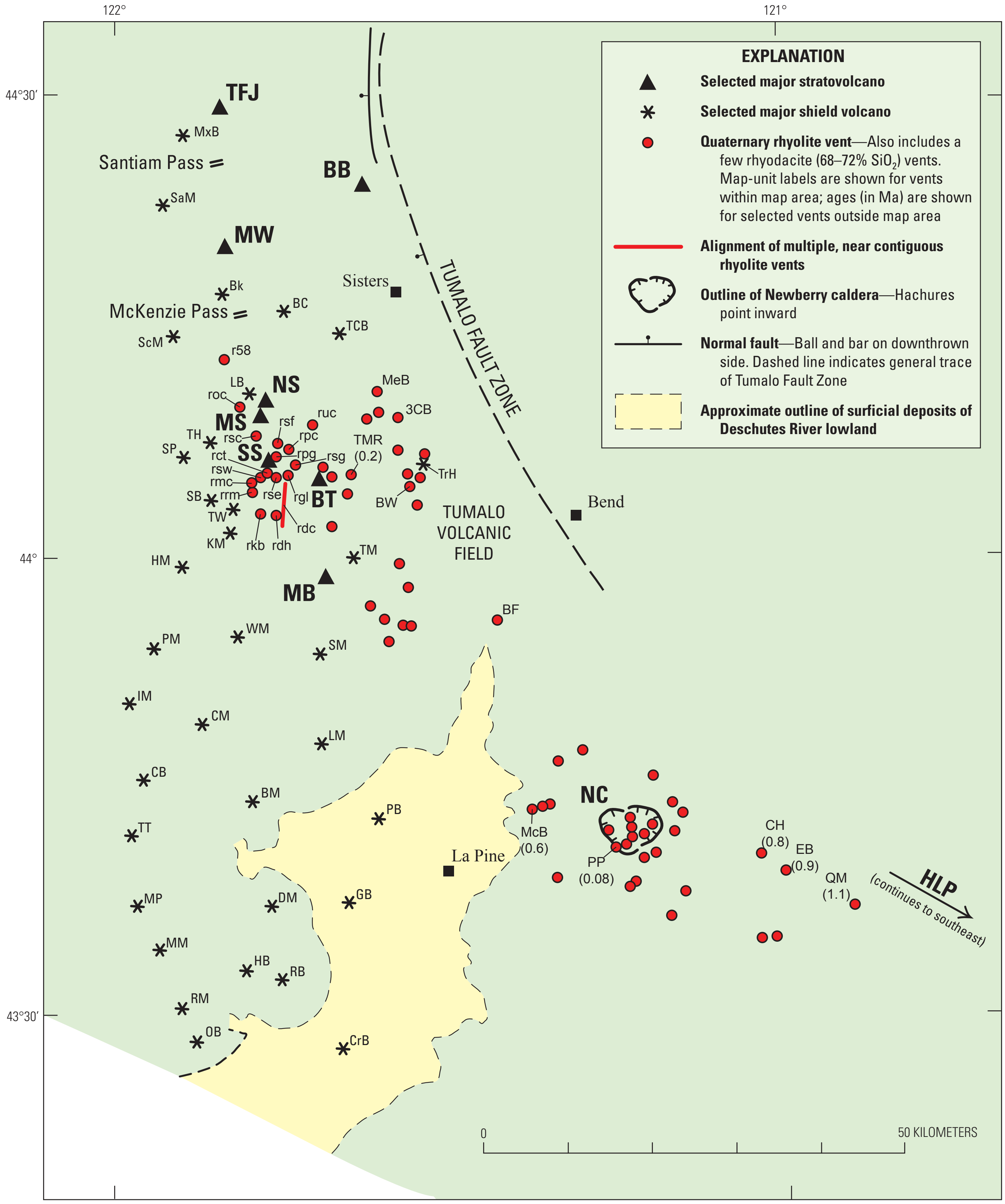
Local Basement Rocks

Although crystalline basement rocks of Mesozoic and greater age underlie the northern and southern parts of the Cascade arc, from near Mount Rainier southward 500 km to the Oregon-California border, basement rocks are wholly concealed (in the so-called “Columbia Embayment”) beneath Cascade-arc rocks of Eocene to Holocene age. A large window of basement rocks 20 km southeast of Mount Rainier (Miller, 1989) has age and lithologic affinities to the thrust sheets and mélange belts of both the Klamath Mountains and the Northwest Cascades. Consisting of tectonic slices and accretionary mélange of submarine-fan deposits, hemipelagic seafloor deposits, pillowed MORB greenstones, and tonalitic and mafic metaigneous K-poor arc rocks, all of Mesozoic age, the assemblage may represent the thick crust concealed beneath much of the “embayment.” Although it has been speculated that Mesozoic or Tertiary seafloor may underlie the “embayment,” a thick stack of varied accretionary rocks, which were thrust or underplated inboard and translated dextrally northward along the Mesozoic continental margin, is more consonant with the 44-km-thick sub-arc crust and with the absence of any along-arc discontinuity in the seismic-velocity structure along a refraction profile up the axis of the Oregon Cascades (Leaver and others, 1984).

Older rocks that are exposed adjacent to the Quaternary volcanic belt in central Oregon include the following three suites:

Suite 1—Cascade-arc assemblages of late Eocene to late Miocene age form a 70-km-wide terrain that crops out from the Willamette Valley to the western margin of the Quaternary volcanic belt and dips gently eastward beneath it. The maturely dissected terrain consists of varied sequences of tuffs, lavas, and lahar deposits, roughly 5 km thick, that are deeply eroded and regionally affected by low-grade alteration, although only modestly deformed (Peck and others, 1964; Sherrod and Smith, 2000). Pyroclastic and derivative sedimentary rocks dominate over lavas in the lower three-quarters of the pile, but andesitic

Figure 3. Tectonic setting of Quaternary Cascade arc. For complete Quaternary vent distribution and offshore plate system, see Hildreth (2007). Abbreviations for volcanoes, calderas, and volcanic fields: A, Mount Adams; B, Mount Baker; DP, Diamond Peak; G, Mount Garibaldi; GP, Glacier Peak; H, Mount Hood; J, Mount Jefferson; LVC, Lassen volcanic center; M, Mount McLoughlin; ML, Medicine Lake volcano; MS, Middle Sister; MZ, Mount Mazama (Crater Lake); N, Newberry Volcano; R, Mount Rainier; S, Mount Shasta; SH, Mount St. Helens; SM, Simcoe Mountains; SS, South Sister; T, Mount Thielsen. Abbreviations for faults, as well as for geomorphic and geographic features: BFZ, Brothers Fault Zone; GRF, Green Ridge Fault; HCF, Hat Creek Fault; HCG, High Cascades Graben; HLF, Honey Lake Fault; HRF, Hood River Fault; LG, La Pine Graben; MVF, Mohawk Valley Fault; PL, Puget Lowland; SFZ, Sisters (Tumalo) Fault Zone; WR, Walker Rim; WSF, Warm Springs Fault; WV, Willamette Valley. Worth noting are the following features: (1) Extensional region has expanded westward since late Miocene to overlap subduction-induced magmatic arc in California and Oregon. (2) Plate-boundary shear traction principally drives northwestward translation of rigid Sierra Nevada–Great Valley microplate, accounting for about 25 percent of relative motion between Pacific plate and stable North America plate (Dixon and others, 2000), most of which takes place along San Andreas Fault. Dextral shear (6 mm/yr) on Walker Lane (belt of rheologically weak lithosphere) accounts for about half of microplate translation and diffusely merges northwest into region of intra-arc normal faulting. (3) Microplate compression through Klamath Block helps (along with oblique plate convergence) to drive northward translation and clockwise rotation of Oregon forearc, contributing to intra-arc extension along its trailing edge. Oregon forearc block dominantly consists of 30-km-thick accreted oceanic crust of Siletzia terrane; its northward motion compresses accretionary Washington forearc against Canadian batholithic buttress (Wells and others, 1998). North Cascades and Coast Plutonic Complex predominantly consist of crystalline basement terranes of Mesozoic and older metamorphic and plutonic rocks. Directions of Cascadia rotation generalized from hundreds of GPS sites referenced to stable North America (McCaffrey and others, 2007). (4) Seaward-concave plate margin promotes slab arch, axis of which plunges toward 48° N.; slab depth inferred from seismicity and tomography by Crosson and Owens (1987). (5) Proximal forearc depression, 50 to 100 km seaward of active arc, is occupied by Strait of Georgia, Puget Lowland, and Willamette Valley and may reflect densification of slab at eclogite transition; its absence south of Eugene may reflect upper-plate deformation by northward-translating Klamath Block. (6) Formation of Yakima Foldbelt, which principally deforms lavas of the Columbia River Basalt Group, began about 15 Ma during their main eruptive interval and continues today; Mount Adams, Mount Hood, and Simcoe Mountains volcanic field overlie Yakima folds. (7) In central Oregon, isochrons depict westward progression of inception of rhyolitic volcanism across High Lava Plains (MacLeod and others, 1975; Jordan and others, 2004); in the Quaternary, eruptions of true rhyolite (rare elsewhere in Cascade arc) have further advanced through Newberry Volcano and as far northwest as South and Middle Sisters (see fig. 4).



122°
121°
44°30′
44°
43°30′
EXPLANATION
Selected major stratovolcano
Selected major shield volcano
Quaternary rhyolite vent—Also includes a few rhyodacite (68–72% SiO_2) vents. Map-unit labels are shown for vents within map area; ages (in Ma) are shown for selected vents outside map area
Alignment of multiple, near contiguous rhyolite vents
Outline of Newberry caldera—Hachures point inward
Normal fault—Ball and bar on downthrown side. Dashed line indicates general trace of Tumalo Fault Zone
Approximate outline of surficial deposits of Deschutes River lowland
TFJ
MxB
Santiam Pass
BB
SaM
MW
Sisters
TUMALO FAULT ZONE
Bk
BC
McKenzie Pass
TCB
ScM
r58
MeB
LB
NS
roc
3CB
MS
ruc
rsf
TH
rsc
rpc
TMR
(0.2)
SP
SS
rpg
rct
rsg
TrH
rsw
rmc
BT
SB
rrm
rse
rgl
BW
Bend
TW
TUMALO
VOLCANIC
FIELD
rdc
KM
rkb
rdh
TM
HM
MB
BF
WM
PM
SM
IM
CM
LM
CB
BM
NC
PB
McB
(0.6)
TT
La Pine
PP
(0.08)
CH
(0.8)
EB
(0.9)
QM
(1.1)
HLP
(continues to southeast)
MP
DM
GB
MM
HB
RB
RM
OB
CrB
0
50 KILOMETERS

(and lesser amounts of basaltic and silicic) lavas dominate in the top kilometer or so. The western Cascade-arc suite is weakly folded here (characterized by dips typically 5° to 15°), although it is affected by somewhat stronger folding and faulting farther north. Many plugs and a few modest granitoid plutons have been unroofed locally.

Suite 2—Rear-arc volcanic rocks and derivative sedimentary rocks, also of late Eocene to early Miocene age, that are generally attributed to the John Day Formation crop out only to the east of the Quaternary volcanic belt but probably also extend beneath it, presumably interlayered there with rocks of suite 1. The volcanic rocks are predominantly ignimbrites, ash-fall deposits, and lava flows and domes, mostly of rhyolitic composition, accompanied by varied tuffaceous sedimentary rocks and subordinate amounts of mafic alkalic lavas. In western exposures, however, ash-fall and tuffaceous sedimentary deposits of andesite-dacite composition were proposed by Robinson and others (1984) to represent the interfingering of distal-arc facies of suite 1. The John Day Formation assemblage (suite 2) likewise is faulted, tilted, or weakly folded but not strongly deformed (Peck, 1964; Smith and others, 1998; Sherrod and others, 2004).

Suite 3—Virtually undeformed and unaltered arc volcanic rocks, mostly 7.5 to 3 Ma, crop out directly beneath both sides of the Quaternary volcanic belt and interfinger eastward with fluvial sedimentary deposits that filled the Deschutes Basin just east of the arc. Dominant within the range are lava flows (mafic through silicic) and, in the basin to the east, ignimbrites and fluvial sediments. Ignimbrites were common before 5 Ma but not thereafter (Smith, 1987; Smith and others, 1987). Suite 3 is cut and partly contained by a Pliocene graben just north of our map area (Smith and Taylor, 1983). Numerous scoria cones and small shields interfinger with and overlie the sedimentary basin deposits as far as 50 km east of the present Cascade Range crest (Sherrod and others, 2004), suggesting that the vent belt was at least as wide in the Pliocene as during the Quaternary. Basaltic andesites dominate this suite, but eruptive products range from basalt to rhyodacite.

The Quaternary Volcanoes

The Sisters reach of the Cascade arc, which extends about 40 km north and south of the Three Sisters, contains at least 466 Quaternary volcanoes (Sherrod and Smith, 2000; Hildreth, 2007). Most are monogenetic, but scores of mafic shields and several stratocones are also present. At the latitude of the Three Sisters, the vent belt is about 35 km wide, extending about 12 km west and 22 km east of the Cascade crest. In addition, at least 450 separate vents are present on the great rear-arc Newberry Volcano edifice, adjacent to the east. Along the arc itself (fig. 1), the nearest substantial evolved (nonmafic) centers are Mount Jefferson (60 km north) and Cappy Mountain (90 km south). Large mafic edifices, however, are especially common along this reach of the arc (fig. 4); these include Mount Washington, Three Fingered Jack, and Black Butte to the north and Mount Bachelor and many more to the south (Williams, 1957; Sherrod and Smith, 2000; Hildreth, 2007).

The Mafic Periphery

As emphasized throughout a century of geologic investigations in the Three Sisters region, a central area of more evolved (andesitic to rhyolitic) and relatively young volcanic rocks, focussed on and around South Sister and Middle Sister, is almost completely surrounded by mafic eruptive centers (figs. 2, 4; see also Hodge, 1925; Williams, 1944; Taylor, 1990). Most of the peripheral mafic centers are middle and late Pleistocene, older than the evolved central complex (largely 50 ka and younger), although the distributed mafic volcanic fields around McKenzie Pass to the north and Mount Bachelor to the southeast are both younger.

One of the oldest mafic volcanoes in the near periphery is The Wife (~375 ka), a large glaciated shield centered 6 km southwest of South Sister. Proceeding clockwise around the periphery (fig. 2), The Wife is adjoined by the deeply incised

Figure 4. Rhyolite vents of Three Sisters and rear-arc Newberry caldera (NC) region. Vent locations are from MacLeod and others (1995), Sherrod and Smith (2000), Sherrod and others (2004), and this study. All vents are Quaternary; thus, they extend the northwestward rhyolite-inception age progression across High Lava Plains (HLP; see fig. 3). Rhyolites are as old as 1.1 to 0.8 Ma just east of Newberry caldera, and they are middle Miocene to Pliocene on High Lava Plains farther southeast. Surficial deposits of Deschutes River lowland near La Pine may cover additional rhyolites. True rhyolites (72–77% SiO_2) are rare in Quaternary Cascade arc and are almost absent along arc everywhere north of Lassen segment (Hildreth, 2007), except within Three Sisters volcanic cluster. Rhyolites on Newberry Volcano edifice, within Three Sisters cluster, and in between are all of middle or late Pleistocene or Holocene age. Trend of Cascade arc here is north-south, as depicted by belt of selected major shield volcanoes and stratovolcanoes. Abbreviations for shield volcanoes and stratovolcanoes: BB, Black Butte; BC, Black Crater; Bk, Belknap Crater; BM, Browns Mountain; BT, Broken Top; CB, Charlton Butte; CrB, Crescent Butte; CM, Cultus Mountain; DM, Davis Mountain; GB, Gilchrist Butte; HB, Hamner Butte; HM, Horse Mountain; IM, Irish Mountain; KM, Koosah Mountain; LB, Little Brother; LM, Lookout Mountain; MB, Mount Bachelor; MxB, Maxwell Butte; MM, Maklaks Mountain; MP, Maiden Peak; MS, Middle Sister; MW, Mount Washington; NS, North Sister; OB, Odell Butte; PB, Pringle Butte; PM, Packsaddle Mountain; RB, Ringo Butte; RM, Royce Mountain; SB, Sphinx Butte; SaM, Sand Mountain; ScM, Scott Mountain; SM, Sheridan Mountain; SP, Substitute Point; SS, South Sister; TCB, Trout Creek Butte; TFJ, Three Fingered Jack; TH, The Husband; TrH, Triangle Hill; TM, Tumalo Mountain; TT, The Twins; TW, The Wife; WM, Williamson Mountain. Abbreviations for rhyolites outside map area: 3CB, Three Creek Butte; BF, Benham Falls; BW, Bearwallow Butte; CH, China Hat; EB, East Butte; McB, McKay Butte; MeB, Melvin Butte; PP, Paulina Peak; QM, Quartz Mountain; TMR, Tam McArthur Rim.

Sphinx Butte shield (~280 ka), just north of which lies the large multivent shield called The Husband (150 ka or older), centered 6 to 7 km west of South and Middle Sisters. The northwest and northeast sectors of the mafic periphery are occupied, respectively, by the dissected Little Brother shield (~48 ka) and the towering ice-ravaged cone of long-lived North Sister (~120 to 45 ka). Just north of this pair spreads the postglacial McKenzie Pass volcanic field (fig. 2), marked by numerous mafic vents (mostly 4 ka to 1.5 ka; Sherrod and others, 2004). Trout Creek Butte, a large mafic shield and the oldest eruptive unit in the map area (~530 ka), lies 13 km northeast of Middle Sister, somewhat farther from the compositionally evolved focus than the younger mafic edifices mentioned. The eastern sector of the mafic periphery lacks a substantial edifice, but, instead, it is sprinkled with mafic scoria cones and silicic domes thought mostly to be of middle Pleistocene age (Taylor, 1987; Taylor and Ferns, 1995). To the southeast lies glacially gutted Broken Top (~300 to 150 ka), an extensive mafic shield surmounted by a modest stratocone, centered only 6 km from South Sister. To the south, the mafic peripheral ring is completed by several small shields and lava fans (fig. 2) that include The House Rock, Koosah Mountain, Le Conte Crater, and Talapus Butte, and Katsuk Butte (all late or latest Pleistocene), as well as several postglacial mafic vents on the apron of Mount Bachelor (Scott and Gardner, 1992).

Despite an abundance of silicic andesite, dacite, and rhyolite at Middle and South Sisters, such evolved products are nearly absent at most of the vents composing the mafic periphery just outlined. A striking exception is Broken Top and the upland of middle Pleistocene volcanic rocks (the Tumalo volcanic field) that extends east of it toward Newberry Volcano (fig. 4).

Broken Top and the Tumalo Volcanic Field

A highland area of numerous distributed silicic to mafic vents east of Broken Top was called the “silicic highland” by Taylor (1978, 1987), the “Tumalo volcanic center” by Hill and Taylor (1990), and the “Tumalo volcanic field” by Hildreth (2007). The 25-km-wide vent field includes andesitic and mafic scoria cones, as well as numerous rhyolitic and rhyodacitic lava flows and domes. The Tumalo volcanic field is thought to be the source of several rhyolitic to andesitic ignimbrites and plinian-fall deposits exposed near the towns of Tumalo and Bend (Taylor, 1981; Hill and Taylor, 1990; Mimura, 1992; Taylor and Ferns, 1994) that erupted between about 650 ka and about 200 ka (Sarna-Wojcicki and others, 1989; Gardner and others, 1992; Lanphere and others, 1999; Sherrod and others, 2004). Owing to extensive cover by younger mafic lavas and glacial deposits, neither its integrity as an eruptive center nor its western limit is well defined. Because silicic lavas near Todd Lake and Tam McArthur Rim (fig. 2), each adjoining the Broken Top edifice (Williams, 1944; Taylor, 1978), erupted during the same time interval as those of the Tumalo volcanic field (Hill, 1991), they could equally well be considered parts of an extensive middle Pleistocene silicic volcanic field. Of the four nearby stratovolcanoes, South, Middle, and North Sisters are wholly younger than the distributed Tumalo activity, but the eruptive lifetime of Broken Top overlapped with it.

Volumes of three extensive ignimbrites, patchily but widely preserved in the periphery of the highland, are poorly known but are likely to be in the range of 5 to 10 km^3 each. Because such volumes are near the usual threshold for caldera formation, the Tumalo volcanic field might or might not contain an unrecognized filled caldera that is obscured by products of younger eruptions. Following Hill and Taylor (1990), Sherrod and others (2004) suggested that a 5-km-wide buried source area may be centered on Triangle Hill (fig. 4), whereas Williams (1957) and Conrey and others (2002) suggested locations 5 to 8 km farther west (near Tam McArthur Rim) as possible sources for the youngest of them. Pinning down the source vents for the three Tumalo-field ignimbrites (the Desert Spring, Tumalo, and Shevlin Park Tuffs) remains one of the more challenging problems in Oregon Cascades volcanology.

Broken Top (9,175 ft; 2,796 m) was a modest volcano (eruptive volume, 7–10 km^3), active in the middle Pleistocene between about 300 and 150 ka but long extinct. Its mafic apron lavas bank against the dacitic Todd Lake volcanic pile (460±30 ka, according to Hill, 1991; see also Taylor, 1978); they also sandwich thick rhyodacite lavas at Tam McArthur Rim (213±9 ka; Hill, 1991) and near Upper Chush Falls (on topographic maps, shown as “Squaw Creek Falls”) (169±2 ka; table 2). Although the basal shield, stratocone, and intrusive core of Broken Top are dominantly of basaltic andesite composition (Webster, 1992), subordinate eruptive products range from andesite to rhyodacite. Internal structure of its ice-ravaged edifice (Taylor, 1978; Grubensky and others, 1998) is well exposed on cirque headwalls, on radial ridges, and in a large southeast-facing amphitheatre of complex but uncertain origin. Cayuse Crater (fig. 2) is an unrelated postglacial basaltic (50–52% SiO_2) complex of lava flows and scoria cones (unit bcc) that erupted about 11±1 ka on the southwest apron of the long-inactive Broken Top edifice.

North Sister

North Sister (10,085 ft; 3,074 m) is a glacially dissected stratocone of fairly uniform basaltic andesite (52.5–55.1% SiO_2; table 1; see also Taylor, 1987; Schmidt, 2005; Schmidt and Grunder, 2009), sufficiently eroded to expose hundreds of dikes and sills internally. Many dikes are zigzag or irregularly oriented within the pile of thin rubbly lava flows, but Schmidt and Grunder (2009) reported a long-term shift from edifice-influenced radial diking toward later dominance of north-south dikes controlled by the regional stressfield. Oldest and longest active volcano of the Three Sisters, its period of construction (about 120 ka to about 45 ka), nonetheless, appears to have entirely postdated that of Broken Top. Distal lavas from North Sister lie stratigraphically above the northwesternmost remnant of the Shevlin Park Tuff (unit spt), youngest ignimbrite of the Tumalo volcanic field. Although a few lavas at North Sister may be older still, the oldest reliably dated lava flow yielded an age of 119±6 ka (unit mns; table 2). Younger parts of the multistage edifice (which has a few severe internal unconformities) are as young as 46±6 ka, and the summit crag yields an age of 55±5 (all part of unit mns; table 2). It is remarkable that so mafic an edifice remained relatively monotonous compositionally during such an extended eruptive history (Schmidt, 2005; Mercer and Johnston, 2008). North Sister is part of the mafic periphery and is almost entirely older than eruptive products of the silicic focus represented by the edifices of South and Middle Sisters.

Also younger than North Sister is a late Pleistocene north-trending chain of mafic to intermediate scoria cones, lava flows, and fissure-fed agglutinates (Sherrod and others, 2004; Schmidt and Grunder, 2009), some components of which erupted through and then draped the (by then, severely eroded) North Sister edifice. Components of the chain are distributed for 11 km from the northwest ridge of North Sister northward past Matthieu Lakes to the shoulder of Black Crater. Another north-striking fissure vent, about 500 m long, unzipped down the south slope of the North Sister edifice. Although eruptive products of the several vents range in SiO_2 content from 53.2 to 58.7 percent, they hold in common higher FeO contents (8.1–9.5%) than central-vent products of the North Sister edifice (6.95–8.1%). Because the components are of varied composition and of several different eruptive ages (as old as 59±4 ka and as young as 20±5 ka; table 2), and because the vents are both fissural and point sourced, we prefer to call the chain the "Matthieu Lakes vent alignment." The alignment reflects the enduring influence of the region's extensional stress field, but its persistence sustains no inference of either contemporaneous magma storage or close magmatic affinity of the several batches erupted. The youngest eruptive units along the alignment (units mps and mpn) together form a high but narrow divide that extends from the base of North Sister to the northern edge of the map area. The slender north-trending ridge formed by these strips of mafic agglutinate and scoria are an expression of their fissural eruption but may also reflect glacial confinement, owing to eruption of some about 20 ka, during the Last Glacial Maximum.

South Sister

South Sister (10,358 ft; 3,157 m), once considered the youngest stratocone in the cluster (Wozniak, 1982; Clark, 1983), is largely contemporaneous with Middle Sister. During the interval from 50 to 30 ka, South Sister was a dominantly rhyolitic volcano, consisting of numerous and varied (aphyric to phenocryst-rich) rhyolite (72–74% SiO_2) lava flows and domes that crop out radially on the cone up to elevations as high as 8,560 ft, within 1,800 ft of the present summit. Around the base of the edifice, two large rhyolite domes (Kaleetan Butte and Devils Hill; units rkb and rdh) at the south toe of South Sister, as well as one near Green Lakes at the east toe (unit rgl) and a coulee along Whychus Creek northeast of the cone (unit rsf), erupted during this same time interval; all four have 74 percent SiO_2. Intermediate magmatism began with the radial outflow of several dacite and rhyodacite lavas in the interval from 38 to 32 ka, alternating with the rhyolite eruptions, followed by construction of a broad cone of andesitic (62–64% SiO_2) lavas, (62–64% SiO_2), and culminating at 27+3 ka in growth of a more steeply dipping summit cone of agglutinate-dominated andesite (56–60.5% SiO_2). Associated emplacement of a multiphase andesitic intrusive complex culminated in formation of a summit crater 700 m wide, one rim of which is exposed just inboard of Hodge Crest. Subsequent filling and overtopping of the large crater by a thick dacite lava flow (unit dlg) and more than 150 m of dacitic pyroclastic ejecta (unit des), followed by draping of the summit by a final thin sheet of mafic agglutinate (unit mtp; 54–56% SiO_2) that erupted from the much smaller present-day summit crater, together constitute a sequence that lasted until the latest Pleistocene.

After at least 15,000 years of inactivity, the South Sister locus underwent a compositional reversal, yielding two complex but separate rhyolitic eruptions at about 2.2 and 2.0 ka (Taylor, 1978; Scott, 1987). The first episode produced the 0.5-km^3 Rock Mesa coulee and subordinate tephra and satellite domelets (unit rrm; altogether about 0.53 km^3; all ~73.5% SiO_2) at the southwest toe of the South Sister edifice. The second episode produced the dike-fed, 5-km-long "Devils chain" of 16 vents (unit rdc) that cuts both the 35-ka Devils Hill dome (unit rdh) and the southeast flank of the South Sister edifice itself. North of a 3-km-long gap that bypasses the summit, another 1.2-km-long parallel chain of minor vents runs down the north slope of the edifice and may have been fed concurrently by the same dike system (Scott, 1987). All vents of the younger episode (altogether, about 0.32 km^3) produced rhyolite lava or tephra that contains 72.5 percent SiO_2, clearly distinguishable compositionally from rhyolite of the Rock Mesa episode. The northernmost vent of the "Devils chain" proper lies at 7,880 ft (2,400 m) elevation, well up the South Sister edifice and close to vents for several of the late Pleistocene rhyolites. That some 60 percent of the magma released during the younger episode issued from this uppermost vent (the Newberry flow) supports the likelihood that the rhyolitic magma reservoir lies under the South Sister edifice itself (Bacon, 1985; Scott, 1987).

Middle Sister

Middle Sister (10,047 ft; 3,062 m) is the youngest cone of the three, the present edifice having been built during the interval from 48 to 14 ka but mostly between 25 and 18 ka (table 2), thus overlapping in time with construction of South Sister. Glaciation (persistent from the late Pleistocene to the present) has already removed much of the east half of the cone, including most of the summit-vent complex, and has sharply steepened its east face. The young cone has issued a range of mafic, andesitic, and dacitic (52–65% SiO_2) lavas from its central-vent area, as well as dacites from six flank vents (three of them high on the edifice) and andesites from three more. The largest dacite flank vent, which fills the saddle between North Sister and Middle Sister, built a substantial pile (informally called "Prouty Point," "Black Hump," or "Step Sister") of at least five thick flows (64% SiO_2) that have been dated from 27 to 18 ka. Distal mafic lavas that erupted from an older buried edifice extend eastward from beneath the limit of lavas of the modern cone and yielded ages of 180 to 160 ka. A western apron of young andesite-dacite lavas (48–19 ka) that erupted at Middle Sister banks against glaciated mafic centers of middle Pleistocene age. Thus, there was an extended period (more than 100,000 yr long) that had little or no activity on the site prior to initiation of modern cone growth. Eruption of the rhyolite of Obsidian Cliffs (unit roc; 38±2 ka) at the northwest toe of the subsequent Middle Sister edifice was one of its earliest events.

Rhyolite Anomaly

True rhyolite (72–77% SiO_2) is rare along the Quaternary Cascade arc (Hildreth, 2007), except in the extensional Lassen segment, at the extensional rear-arc centers (Simcoe Mountains, Newberry, and Medicine Lake volcanic fields), and here in the Tumalo–Three Sisters region at the leading edge of the cross-Oregon age-progressive rhyolite trend discussed earlier. No fewer than 15 middle Pleistocene rhyolites (including the Tumalo Tuff, not mapped herein) are exposed in the greater Tumalo volcanic field (Hill, 1991; Sherrod and Smith, 2000) between Newberry Volcano and the Three Sisters (fig. 4). In this report, we describe 14 discrete eruptive units of true rhyolite (50 to 2 ka) at South Sister and the Obsidian Cliffs, a high-silica rhyolite coulee (unit roc; 38 ka) northwest of Middle Sister. The northwesternmost rhyolite (unit r58) crops out as glaciated Dome 5803, 4 km north of the Obsidian Cliffs (Hill, 1991; Sherrod and others, 2004). This remarkable clustering of Quaternary rhyolites contrasts with the presence of a single rhyolite dome in the Cascade Range of British Columbia, none at all along the arc proper in Washington or northern Oregon, and only one or two along the arc between the Three Sisters and the Lassen region (Hildreth, 2007).

Some rhyolitic (and rhyodacitic or dacitic) magmas can be produced by direct partial melting of crustal rocks, with or without subsequent crystal fractionation or mixing with mafic magmas that helped heat their source. In this sense, some silicic crustal melts can be at least as primitive (near-primary) as the basaltic melts that result from the conjunction of slab- and wedge-derived contributions and that undergo prolonged melt-matrix reaction during many tens of kilometers of ascent. There is broad agreement that silicic crustal melts provide persistent, varied, and substantial contributions to intermediate-composition arc magmas that range from basaltic andesite to dacite (Smith and Leeman, 1987, 1993; Hildreth and Moorbath, 1988; Bullen and Clynne, 1990; Hill, 1991; Green, 1994; Borg and Clynne, 1998; Conrey and others, 2001b), but the petrogenetic challenge has always been to identify silicic eruptive products that approach near-primary crustal melts and to infer their source materials. For the rhyolites at Three Sisters, Tumalo volcanic field, and Broken Top, Hill (1991) showed geochemically that none could have evolved by crystal fractionation from the broadly contemporaneous dacitic or rhyodacitic magmas. Instead, Hill proposed that the Three Sisters rhyolites resulted from 20 to 30 percent dehydration-melting of basaltic amphibolite and that the Broken Top–Tumalo (slightly more sodic) rhyolites originated by 30 to 50 percent melting of deep-crustal Cascadian tonalite. Both rhyolitic suites have $^{87}Sr/^{86}Sr$ ratios in the range of 0.7036 to 0.7037, favoring sources in Cenozoic Cascadian-arc crust. Because both suites also have relatively undepleted and flat heavy-rare-earth-element patterns, residual garnet appears to be excluded, suggesting that melt extraction took place in the middle crust rather than in the deepest arc crust, which is here as thick as 44 km.

As widely noted for "bimodal" extensional volcanic fields elsewhere, the elevated proportions of true rhyolite and true basalt in the Sisters reach (compared to the basaltic andesite to dacite suites that dominate adjacent reaches of the arc in Oregon) may reflect impingement on the Cascade arc by whatever combination of mantle flow and lithospheric extension has guided the progression of rhyolitic volcanism westward across the High Lava Plains and the Newberry Volcano region since the middle Miocene (MacLeod and others, 1975; Jordan and others, 2004).

Composition of Eruptive Products

Chemical data for 788 samples that represent all eruptive units defined herein are tabulated in table 1 and summarized in figures 5 and 6. Figure 5A shows the Three Sisters suite to be calc-alkalic, having an alkali-lime index of 59, as defined by Peacock (1931). Most samples are subalkaline, as defined by LeBas and others (1986), although some intermediate products of South Sister, Middle Sister, and Broken Top overlap marginally into the trachydacite field (fig. 5A). The suite straddles broadly the tholeiitic–calc-alkaline boundary (fig. 5B) defined by Miyashiro (1974), and it largely falls within the medium-Fe field defined by Arculus (2003), although many North Sister samples and a few other units plot in the low-Fe field (fig. 5B). Nearly all samples plot in the medium-K field (fig. 5C). Some of the South Sister silicic samples in the high-K field (fig. 5C) may have been K-enriched by alkali exchange during posteruptive vapor streaming or secular hydration; the four high-K samples from Middle Sister are pristine-looking summit dacites (unit dms). The two lowest-K basalts (fig. 5C) erupted from postglacial vents at the north end of the Mount Bachelor chain (units bes and bsl); the two other basalts that have less than 0.45% K_2O (unit bnf) are probably plagioclase accumulative (about 22% Al_2O_3) and stand out (at 51% SiO_2) on several panels in figure 6.

Chemical-variation diagrams (fig. 6) illustrate compositional features that highlight a variety of affinities and differences among the many volcanoes in the Three Sisters cluster, some of which are summarized below.

(1) North Sister basaltic andesites (unit mns) extend to higher contents of Al_2O_3 (18–20%) and to lower contents of Fe, Ti, and P than do most other mafic products of the volcanic field, including those of nearby Little Brother, Trout Creek Butte, the Matthieu Lakes vent alignment, and the thick summit-forming pile of Middle Sister (unit mms). Products of The Wife (unit mtw) and The House Rock (unit mhr), however, compositionally resemble those of North Sister. Previous studies have suggested that basaltic andesites of the central Oregon

Cascades can be assigned to two compositional types (or end members), one relatively richer and the other poorer in K, Fe, Ti, P, rare-earth elements, and high-field-strength trace elements; the abundant data of figure 6 illustrate that such rocks (52–57% SiO_2) in the Three Sisters cluster form a compositional continuum.

(2) Nothing that erupted from the three main stratocones (the Three Sisters) is primitive. MgO contents of 135 samples of North Sister basaltic andesite (table 1; see also Schmidt, 2005) range only from 6.5 to 4.0 percent; mafic products of Middle Sister have less than 6.0 percent MgO, and those of South Sister, less than 4.6 percent. Ni and Cr contents are correspondingly modest: North Sister has 20 to 150 ppm Ni and 40 to 150 ppm Cr; mafic products of Middle Sister have 25 to 80 ppm Ni and 45 to 105 ppm Cr; and the most mafic products of South Sister have only 12 to 30 ppm Ni and 10 to 65 ppm Cr (although its postglacial satellite cone, unit mlc, carries 100 to 130 ppm Ni and 150 to 205 ppm Cr).

(3) Twenty-five of the 788 samples plotted in figure 6 contain 7 to 9 percent MgO; they range in SiO_2 content from 49 to 52 percent, and all erupted from peripheral vents. The 25 samples represent 12 map units: bbr, bes, bsl, and btk, in the south near Sparks Lake; bjc and bsb, to the southwest of the Three Sisters; bwm, to the north; bac, bsq, and bss, to the northeast; bsc, to the east; and bcc, to the southeast. Most of the 25 have 115 to 160 ppm Ni and 140 to 290 ppm Cr (table 1); only two units are still richer in these compatible elements, bcc (440 ppm Cr) and bwm (as much as 213 ppm Ni and 355 ppm Cr).

(4) Considering all vents in the map area, no andesite (57–63% SiO_2) has more than 4 percent MgO (except unit aoc); dacites have less than 2 percent, and rhyolites, only 0.6 to 0.1 percent. Most silica-variation diagrams (fig. 6) converge from broad fields of varied mafic compositions into narrowly coherent arrays that extend from 61 to 70 percent SiO_2. This suggests routine mixing of the various fractionating mafic magmas to produce compositionally condensed parental lines of descent for the fractionating andesite-dacite arrays (which generally blend concurrently with silicic melts of crustal origin). Andesites and dacites of South Sister nonetheless tend to be slightly richer in Mg and poorer in Fe than most (but not all) of those from Middle Sister. The rarity of rocks having 70 to 72 percent SiO_2 (fig. 6) suggests a role for additional processes in generating the rhyolitic magmas, probably including large contributions of intracrustal partial melts (Hill, 1991) and extraction of silicic-melt batches directly from intermediate crystal mush (Hildreth, 2004).

(5) The Sr, Zr, and TiO_2 panels of figure 6 illustrate the wide ranges of large-ion-lithophile elements and high-field-strength trace elements among the varied mafic magmas that erupted in the volcanic field. Zr remains incompatible until the silicic-dacite range of the array, where zircon fractionation first becomes apparent and then dominates the Zr-depletion trend among rhyolites.

(6) Most of the 70 rhyolite samples analyzed range in SiO_2 content from 72 to 74.4 percent, and only unit roc (76.4–76.9% SiO_2) is a high-silica rhyolite. Rhyolites in the Three Sisters area are ordinary continental-margin arc rhyolites that have low TiO_2 (0.34–0.09%), low FeO* (2.2–1.0%), and moderate Al_2O_3 (14.6–13.0%) contents, each of which varies inversely with SiO_2 content (fig. 6). All are medium- to high-K and subalkaline, and all have low abundances but wide ranges of P_2O_5 (0.18–0.02%), MgO (0.65–0.11%), and CaO (1.96–0.86%) contents. Like most arc rhyolites, those of the Three Sisters are not as highly evolved in trace-element signature as intracontinental rhyolites of various distinctive types: Cl-rich peralkaline rhyolites; F-rich topaz-bearing rhyolites; high-temperature, Fe-rich anorogenic rhyolites; or allanite-monazite-bearing, light-rare-earth-element-depleted, subalkaline, high-silica rhyolites. Among true rhyolites of continental margins, when compared globally, those of the Three Sisters have moderate abundances (neither strikingly high nor low) of Sr (104–234 ppm), Ba (800–1,070 ppm), Zn (25–45 ppm), Ce (33–58 ppm), Y (13–22 ppm), and Zr (90–300 ppm). Their slightly low concentrations of Rb (58–80 ppm), Nb (8–13 ppm), and Th (3–8 ppm) are typical of mature arcs that lack mature continental basement (Macdonald and others, 1992).

Postglacial Eruptions

Postglacial mafic eruptions are more common in the Sisters reach than anywhere else in the Cascade Range (Hildreth, 2007). In the area of McKenzie and Santiam Passes (fig. 1), more than a dozen separate mafic eruptions are radiocarbon-bracketed between 4.5 and 1.2 ka (Sherrod and others, 2004), representing a 15-km^3, distributed mafic eruptive pulse in the late Holocene (Taylor, 1968). In the immediate periphery of the Three Sisters, several additional mafic vents, which include Sims Butte, Cayuse Crater, Le Conte Crater, the Mount Bachelor chain, the “Egan Cone” cluster, and the “Katsuk-Talapus chain” may all have erupted in the interval 17 to 8 ka, during deglaciation or in early postglacial time. Just north of North Sister, Yapoah Crater (54.5–57% SiO_2) produced a lava-flow fan about 2.5 ka; Four in One Cone (56–59% SiO_2), another such fan at about 1.9 ka; and Collier Cone, at about 1.5 ka, an apron as long as 13 km of lava flows that range in composition from 56 to 65 percent SiO_2 (Schick, 1994).

Mount Bachelor, a mafic shield volcano capped by a steep mafic summit cone, lies 15 km southeast of South Sister. It is

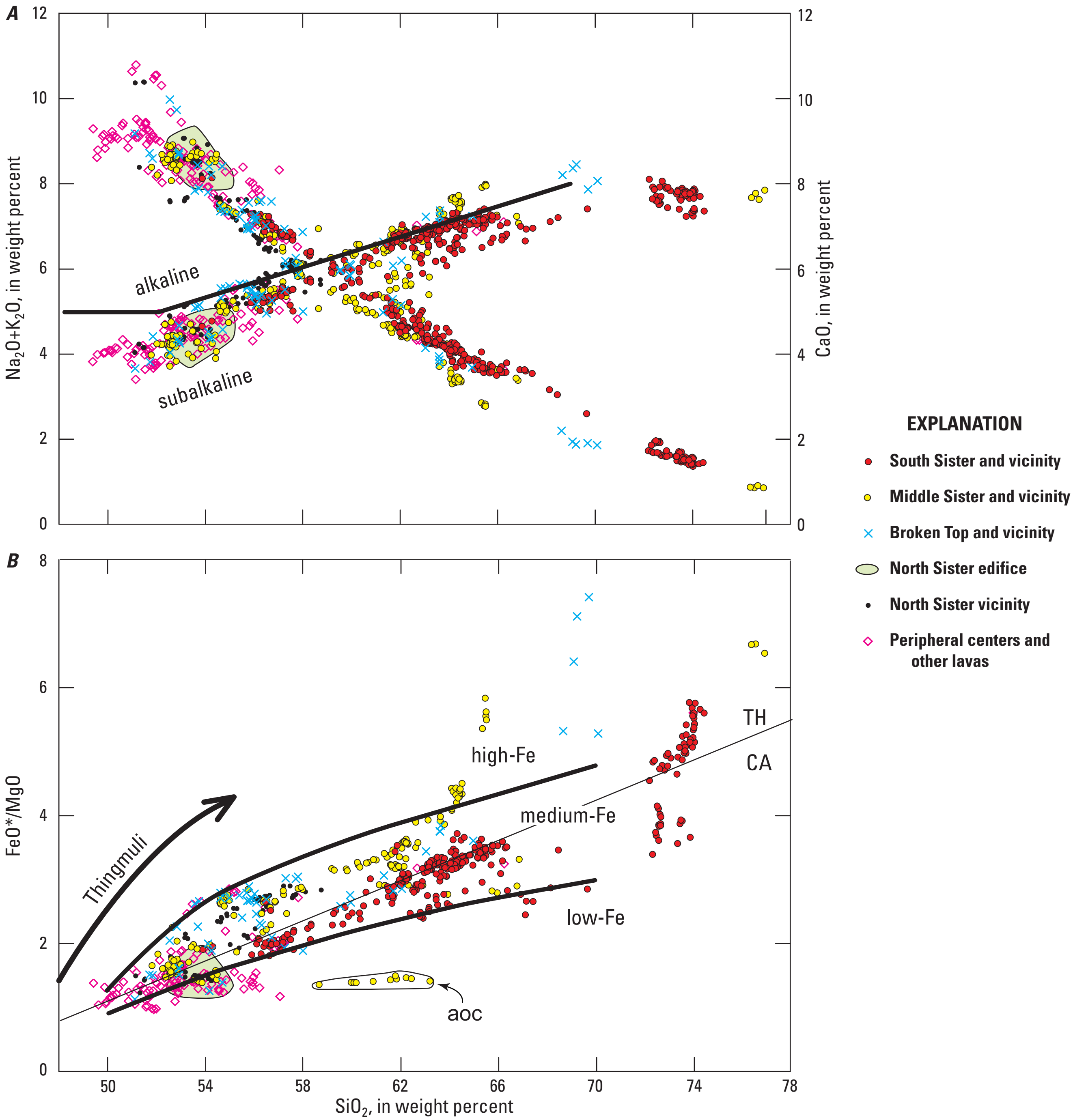


Figure 5. Chemical variation diagrams for more than 730 samples of Quaternary eruptive products of Three Sisters volcanic cluster, subdivided as in explanation. All data are tabulated by map unit in table 1. All data are normalized to 99.6 weight percent, volatile free (leaving 0.4% for trace oxides and halogens). *A*, Total alkalies (Na_2O+K_2O) and CaO versus SiO_2. Intersection of arrays gives alkali-lime index of 59, calc-alkalic suite as defined by Peacock (1931). Boundary between subalkaline and alkaline suites from LeBas and others (1986). *B*, FeO*/MgO versus SiO_2. FeO* is total Fe, calculated as FeO. TH/CA boundary separates tholeiitic and calc-alkaline suites, as defined by Miyashiro (1974). Strongly Fe-enriching Thingmuli trend from Carmichael (1964). High-, medium-, and low-Fe suite boundaries from Arculus (2003). Data for the andesite of Obsidian Creek (unit aoc) are labelled. *C*, K_2O versus SiO_2. High-, medium-, and low-K suite boundaries extended from Gill (1981). Figure 5 continued on next page.

the largest volcanic center along a 25-km-long chain of 50 vents that produced 40±5 km^3 of basalt and basaltic andesite (49–57% SiO_2) in a few major eruptive episodes during the interval from 17 to 8 ka (Scott and others, 1989; Scott and Gardner, 1992; Gardner, 1994). Most vents lie along a north-south alignment marked by numerous scoria cones, but most of the magma

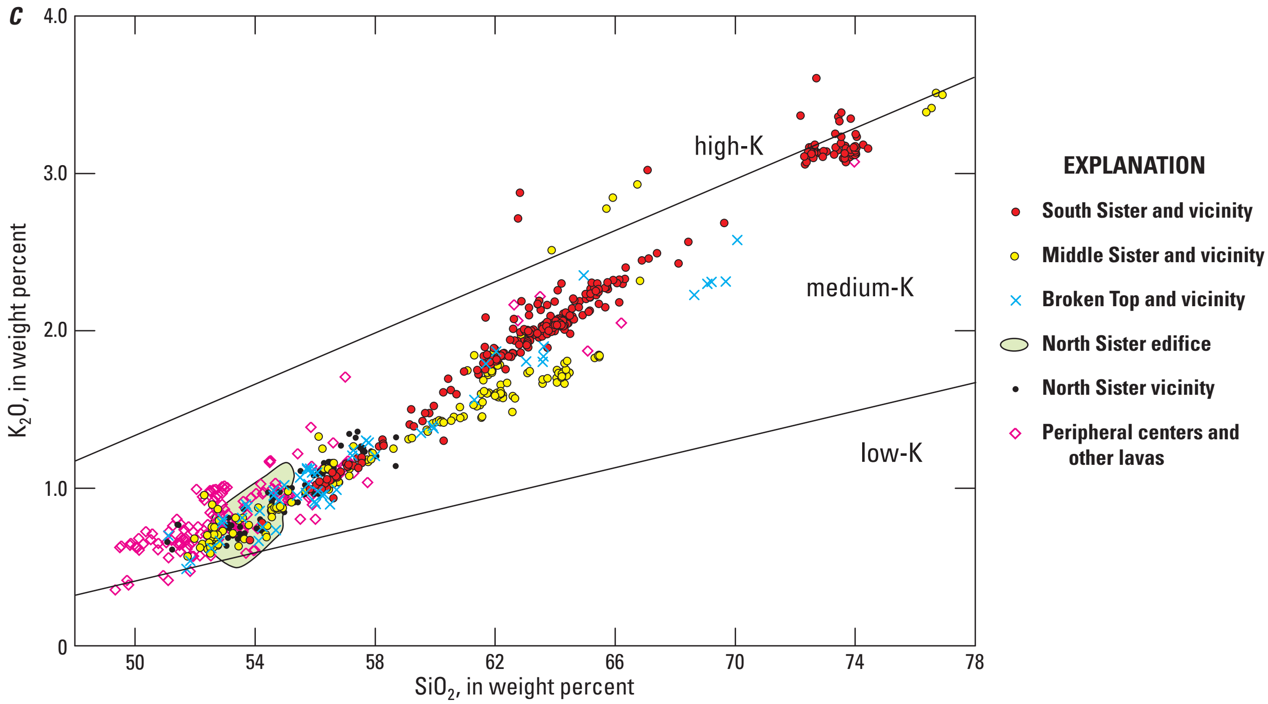


Figure 5.—Continued

issued effusively to build shields and lava fields. Five main eruptive episodes have been defined (stratigraphically and paleomagnetically) and related to late-glacial features, suggesting that most of the material erupted between 15 and 12 ka and that as much as 25 km^3 of it may have erupted in less than 1,500 years.

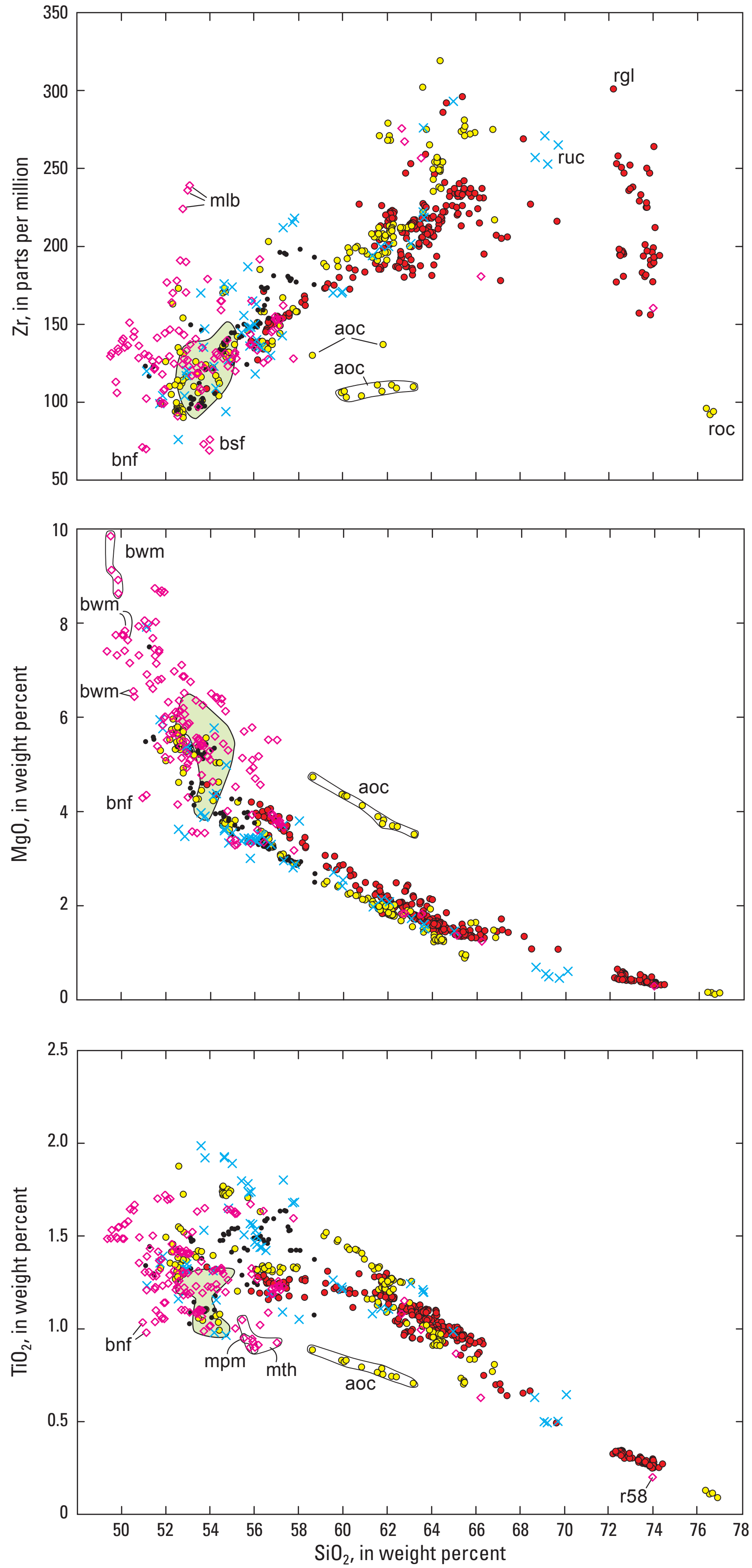
Comparably large effusion rates for basalt and basaltic andesite marked the late Holocene just north of the Three Sisters, in the McKenzie Pass volcanic field (fig. 2), where the 6 to 9 km^3, multivent Belknap shield was constructed in less than 1,500 years (Taylor, 1965, 1968). Only slightly older than Belknap, a nearby chain of scoria cones that includes Nash Crater and Sand Mountain produced 2 to 3 km^3 of Holocene mafic lavas and ejecta in about 1,000 years (Taylor, 1968; Sherrod and others, 2004).

From the Three Sisters proper, no postglacial mafic eruptions, nor any of andesite or dacite, have occurred. The only postglacial eruptions within the central volcanic focus were the late Holocene rhyolite episodes at Rock Mesa and the "Devils chain," both described in detail by Scott (1987). The stark contrast between the relative inactivity within the focal region (just two rhyolitic leaks in postglacial time) and the repeatedly voluminous postglacial mafic activity in adjacent areas both north and south plausibly attests to Holocene growth of substantial silicic-magma reservoirs that intercept ascending batches of mafic magma beneath South Sister and Middle Sister (Bacon, 1985; Scott, 1987).

Volcanic Hazards

Hazards associated with potential eruptions and slope failures in the Three Sisters region, as well as annual probabilities of several kinds of events, were summarized by Scott and others (2001). The abundance of small mafic volcanoes, many of them postglacial, just north and south of the Three Sisters cluster is strongly suggestive of the style most likely for the next eruption: local scoria accumulation, ash fall as far as ten kilometers or more away from the vent, and slow-moving lava flows that might close a road or descend along a valley floor.

Because summit vents of the stratovolcanoes have been inactive throughout the Holocene, revival of activity high on the main cones is unexpected. Such a revival might represent either a new episode of intermediate-magma ascent from great depth or the reactivation of a shallow rhyolitic reservoir. The two important rhyolitic eruptive episodes on the apron of South Sister about 2,000 years ago were comparable in extent and volume to 10 other rhyolite eruptions that took place on the slopes of Middle Sister and South Sister in the late Pleistocene (50–25 ka). For these 10, the tephra record has been removed or concealed, but Scott's (1987) investigation of the two late Holocene eruptive episodes gave an indication of what might be anticipated in the event of another rhyolitic eruption from the reservoir that potentially still underlies South Sister. The multivent, dike-fed eruptions of Rock Mesa and the "Devils chain" both opened explosively, depositing extensive blankets of subplinian tephra fallout, as well as thin pyroclastic flows and surges that extended about 1 km from their vents. The 10-cm isopach for pumiceous fallout from the Rock Mesa episode extends 17 km east and 13 km south; that for the "Devils chain" extends 11 km east and 6 km south. Ash layers about 1 cm thick are preserved locally as far as 20 km from the vents, and a trace of fine ash is detectable as far east as 30 km, almost to Bend (figs. 1, 4). The threat of ash clouds to the engines of aircraft is well known, and even millimeters of ash fall can foul machinery, vehicles, water supplies, and the respiration of most living things.



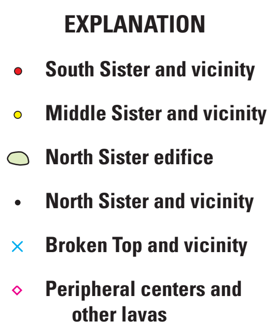


Figure 6. Plots showing Zr, MgO, TiO_2, Sr, FeO*, and Al_2O_3 versus SiO_2 contents for eruptive products of Three Sisters volcanic cluster. FeO* is total Fe, calculated as FeO. Data are divided into five volcanic groups, as in Correlation of Map Units and List of Map Units, as well as one additional grouping for North Sister edifice alone. All data are tabulated by map unit in table 1. Selected extreme or deviant units are identified by map-unit label. For example, the andesite of Obsidian Creek (unit aoc) stands out on several panels as low-Ti, high-Mg suite that is chemically collinear with North Sister and several mafic peripheral centers. All or most samples that have more than 19.5% Al_2O_3 are plagioclase rich and are probably accumulative.

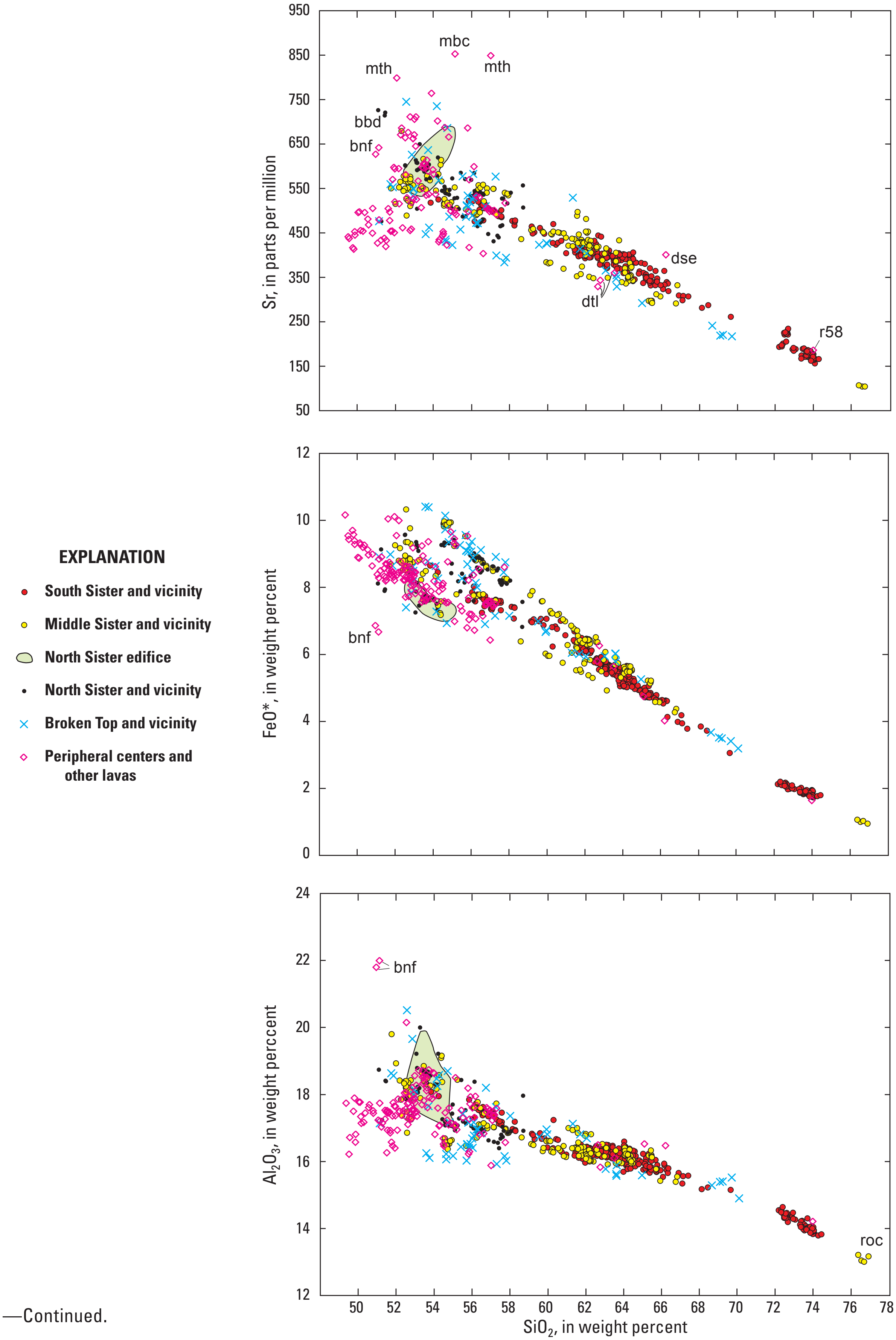


Figure 6. —Continued.

The only large Quaternary pyroclastic-flow deposits nearby are the three middling ignimbrites mentioned above, thought to have erupted in the Tumalo volcanic field in the middle Pleistocene (at roughly 650, 400, and 200 ka). No evidence exists for any such extensively devastating eruption during growth of the Three Sisters.

Lahars, which can result from eruptions that melt snow and ice, from breaching of moraine-dammed lakes, or from voluminous avalanches from steep edifices into stream valleys, have the capacity, if large enough, to be destructive far downstream (as discussed extensively for this area by Scott and others, 2001). Within our map area, stream valleys susceptible to such devastation include the many forks of Whychus Creek (which drains toward the town of Sisters), as well as White Branch and forks of Separation and Linton Creeks (all of which drain to the McKenzie River). Lakes susceptible to rapid breakout include moraine-dammed Carver Lake (O'Connor and others, 2001) and lava-dammed Sparks, Linton, and the Green Lakes, which would require influx of a major debris load to overtop their outlets.

Acknowledgments

We are grateful to Dave Tucker, George Cagwin, and Dean Miller for field assistance; to Ed Taylor for decades of field mapping and generous transfer of unpublished information; to Willie Scott for cogent field and logistical advice; to Julie Donnelly-Nolan for helpful project oversight and for encouraging us to undertake it in the first place; to Mariek Schmidt for her study of North Sister; and to James Saburomaru and Dean Miller for essential laboratory work. Helpful reviews of the map and manuscript were provided by Scott and by L.J. Patrick Muffler.

Introduction to Description of Map Units

The geologic map of the Three Sisters volcanic cluster represents part of a late Quaternary volcanic field within which scores of eruptions have taken place over the last 50,000 years, some as recently as about 1,500 years ago. No rocks of early Pleistocene (or older) age crop out within the map area, although volcanic and derivative sedimentary rocks of Miocene and Pliocene age are widespread to the east and west and are certainly buried beneath the younger volcanic field. Of the 145 volcanic map units described below, only 22 are certainly older than late Pleistocene (older than 126 ka), and 12 are postglacial (younger than about 15 ka). The oldest unit identified yielded an age of 532±7 ka, and the second oldest, 374±6 ka. Compositionally, 10 percent of the units are true basalt; 36 percent, basaltic andesite; 20 percent, andesite; 21.5 percent, dacite; and only 12.5 percent, rhyodacite or rhyolite.

Volcanic-rock nomenclature, which is kept simple here, is based principally on SiO_2 contents. Basalt has 47–52% SiO_2; basaltic andesite, 52–57%; andesite, 57–63%; dacite, 63–68%; rhyodacite, 68–72%; and rhyolite, more than 72%. For reasons of convenience or uncertainty, we sometimes use the terms "mafic" to lump basalt with basaltic andesite, "intermediate" for andesite-dacite, and "silicic" to cover the range of rhyodacite and rhyolite. In unit descriptions, we sometimes state the number of samples analyzed; for example, "n=10" indicates that ten samples were analyzed from that unit.

In unit descriptions, we abbreviate names of some common volcanic phenocrysts as follows: clinopyroxene, cpx; orthopyroxene, opx; plagioclase feldspar, plag. Phenocrysts are defined here as 0.5 mm and larger; microphenocrysts (mph), 0.1 to 0.4 mm; and microlites, smaller still. The modifier "phenocryst-rich" means that a rock has 12% or more crystals larger than 0.4 mm; "phenocryst-poor" signifies 5% or less; "aphyric" means what it says—none. Rocks containing 6 to 12% phenocrysts we typically characterize as moderately porphyritic or of moderate phenocryst content. Because crystal sizes vary widely for each species within most thin sections (and more so within most map units), we give estimates of combined abundance of phenocrysts and microphenocrysts for each species in each unit, followed parenthetically by the size range measured in thin section for each, from microphenocrysts (>0.1 mm) to the largest crystal observed: for example, 7–10% plag (mph to 4 mm); 2–3% pyroxenes (mph to 1.5 mm); and sparse oxide mph. No systematic attempt was made here to estimate separately the proportions of opx and cpx nor to estimate quantitatively the proportions of oxide microphenocrysts present (titanomagnetite, ilmenite, and their oxyexsolved daughters, which are rarely larger than 0.3 mm and seldom more abundant than 0.1–0.3%).

Most of the 145 volcanic map units described herein are newly defined, although equivalents of several were described by Taylor (1978, 1987), Scott (1987), and Scott and Gardner (1992). Each is an eruptive unit derived from a single vent or fissure. Some are simple flow units, but many are shields, cones, or stacks of several lava flows that have chemical and mineralogical coherence. Each unit has been delineated by field mapping on foot, its integrity having been confirmed, challenged, or revised by chemical and microscopic work in the laboratory. Definition of a few units required iterative acquisition of field and lab data over a period of years, providing a firm basis for subdividing, lumping, or correlating slightly heterogeneous sequences of lavas. Most units have narrow compositional ranges, but some show zoning or heterogeneity spanning ranges of a few percent SiO_2.

SiO_2 contents reported in the volcanic unit descriptions are based on major-element analyses (table 1) normalized on an anhydrous basis, as determined by x-ray fluorescence methods, in either the U.S. Geological Survey laboratory at Lakewood, Colorado (supervised by J.E. Taggart), or in the Washington State University GeoAnalytical Laboratory (supervised by J.A. Wolff).

Ages are estimated for all units, on the basis of their mutual stratigraphic positions and their relations to glacial deposits and erosion, as well as numerous new $^{40}Ar/^{39}Ar$ age determinations (table 2), and a few new K-Ar ages (table 3). All units mapped are Quaternary. Boundaries between early, middle, and late Pleistocene are widely agreed to be about 780 ka and about 126 ka (Gradstein and others, 2004). The formally defined boundary between the Pleistocene and Holocene is not very useful here, even if modified to 11.7 ka (Walker and others, 2009); accordingly, we refer to some units as postglacial or "latest Pleistocene" if they erupted subsequent to the widespread recession of glacial ice that took place in the Oregon Cascade Range during the interval from 18 to 15 ka. The radioisotopic age determinations were made in the U.S. Geological Survey geochronology laboratory at Menlo Park, California (supervised by Calvert), following methods described in Calvert and Lanphere (2006) and Hildreth and others (2007).

Locations of most geographic features cited in the text are shown in figures 1 and 2. Elevations are given in feet (1 ft = 0.3048 m; 1 m = 3.2808 ft) because the 1:24,000-scale topographic maps upon which the geologic map is based are available in feet only. All other measurements are metric. Grid references to site locations mentioned in the text are given to the nearest 100 m using the Universal Transverse Mercator (UTM) grid (1927 North American datum, zone 10), which is shown on U.S. Geological Survey topographic maps of the area. The first three digits are easting, and the second three are northing: for example, the summit of Middle Sister is approximated as 973/889 (97.3 km east, 88.9 km north). Occasionally, a fourth digit is added for precision to 10 m. At the end of each unit description, the name of the U.S. Geological Survey 7.5' quadrangle(s) in which the unit crops out is indicated in brackets, using the following abbreviations: BT, Broken Top; LL, Linton Lake; NS, North Sister; SS, South Sister; and TCB, Trout Creek Butte.

DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS

i **Glacial ice (late Holocene)**—Present-day (2009) glaciers. Because all are currently shrinking, contacts with ice-cored moraines are actively shifting and, thus, are only approximate. Area and volume estimates (as of 1981) for all 16 glaciers on Three Sisters, including measured ice-radar thicknesses for six of them, were given by Driedger and Kennard (1986) [NS, SS]

p **Pumice deposits (late Holocene)**—Pumice-fall deposits, local proximal pyroclastic-flow deposits, and reworked secondary deposits resulting from eruptions of units rrm and rdc. Shown only where thick enough to obscure underlying rock units sufficiently to prevent inference of their extent. See units rrm and rdc for discussion of regional extent of tephra fall, as mapped by Scott (1987) [BT, SS]

pdf **Pumiceous debris-flow deposits (late Holocene)**—Local tongues of rhyolitic pumice and ash, a few meters thick, that overlie parts of southwestern lava-flow lobe of Newberry flow (unit rdc), as discussed by Scott (1987). Deposits were remobilized (over snow?) from syneruptive pumice-fall deposits that accompanied extended extrusion of compound flow [BT, SS]

al **Alluvium (Holocene)**—Unconsolidated, water-transported mud, sand, gravel, and coarser debris deposited in or adjacent to present-day (2009) streams, lakes, and swamps. Includes a few pond and lake deposits and debris-flow levees along streams. Many small deposits have been omitted, particularly along narrow streambeds. Includes some debris-flow deposits that resulted from lake breakouts related to failure of moraine dams, as mapped by O'Connor and others (2001) [BT, LL, NS, SS, TCB]

g **Glacial deposits, undivided (Holocene and late Pleistocene)**—Till and minor amounts of associated glacial-outwash gravels. Till makes up many well-formed moraines, as well as extensive or patchy deposits that form irregular topography; consists of poorly sorted, boulder-rich, gravelly, silty sand. Moraine crests of four age groups are indicated by different styles of lines: Little Ice Age (late Neoglacial); early Neoglacial (about 5 to 2.5 ka); latest Pleistocene readvance (roughly equivalent to Younger Dryas of Europe, about 13 to 12 ka); and late Pleistocene (roughly 25 to 17 ka, including Last Glacial Maximum). Age assignments, in part, follow O'Connor and others (2001) and Marcott and others (2009). Little Ice Age moraines high on Three Sisters edifices are steep and sharp crested, and they commonly rise more than 100 m above adjacent terrain; they were deposited during last few centuries (1500–1900 C.E.) and remain barren. Early Neoglacial moraines were largely buried or removed by Little Ice Age advance, but a few surviving remnants are mapped below Prouty, Hayden, and Diller Glaciers. Modest readvance of latest Pleistocene glaciers, as documented elsewhere in Oregon Cascade Range by Scott (1977), left moraines typically 1 to 3 km downslope from Neoglacial moraines. Constructional moraines of late Pleistocene age are well represented in northeastern part of our map but generally lie outside map area elsewhere. No still-older glacial deposits have been confirmed here, with exception of single exposure at 6,060 ft elevation along North Fork Whychus Creek (UTM grid 018/889), where window of till is overlain by unit adl (24±1 ka) [BT, NS, SS, TCB]

s **Surficial deposits, undivided (Holocene and late Pleistocene)**—Generally a combination of glacial, fluvial, pond, and reworked pumice-fall deposits or accumulations of till, talus, protalus, or other colluvium. Widely omitted; mapped where contacts of underlying units are badly obscured. Large area between Devils Hill and Goose Creek consists of poorly exposed Pleistocene moraines mantled by late Holocene rhyolitic-pumice deposits many meters thick but variably reworked [BT, LL, NS, SS, TCB]

av **Debris-avalanche deposit (Holocene or latest Pleistocene)**—Mapped only at east edge of map area as swath more than 7 km long and 1 to 2 km wide, extending from south of Park Meadow to near Upper Chush Falls (on topographic maps, shown as "Squaw Creek Falls"). Abundant hummocks and crags are 10 to 50 m across, 1 to 8 m high, and internally shattered or disrupted; they consist of phenocryst-poor and phenocryst-rich andesite (57–58% SiO_2) lavas, stratified scoria, and tack-welded to dense agglutinate, mostly oxidized brick red. Avalanche descended East Fork Park Creek, evidently derived from failure of north slope of Broken Top edifice, possibly during deglaciation; it then crossed what is now Park Meadow, deposited blocks of agglutinate as big as 4 m as high as 60 m up west wall above modern meadow surface, and continued at least 6 km farther downvalley. Exposures of nonlithified diamict deposit are more than 10 m thick along Park Creek gorge just north of Park Meadow and more than 15 m along East Fork Park Creek gorge south of meadow; hummocks rise additional 1 to 6 m above general deposit surface. Craggy block of red blobby agglutinate beside trail on west side of Park Meadow (UTM grid 0355/8525) is 5 m high, 4 m thick, and 8 to 10 m long, rising sharply above 20-m-wide apron of its own disintegrating rubble; within this agglutinate, a homogenized layer, 5 to 40 cm thick, of platy gray andesite (58% SiO_2) lava stands vertical, showing that whole block has rotated about 90°. Such fragile blocks and numerous hummocks have not been overrun by ice, and it is unlikely that they were transported far on glacier surface after first coming to rest. If avalanche overran stagnant and wasting valley glacier at close of Pleistocene glaciation, it might help account for excess elevation and better preservation of megablocks and hummocks on valley walls but generally smaller blocks and more subdued hummocks protruding from thick avalanche deposit along lowland axial meadows. Overlies late Pleistocene glacial deposits and units awf, drm, mpm, and ruc [BT, TCB]

ls **Landslide deposit (Holocene or latest Pleistocene)**—Mapped only as single complex slump deposit from steep west side of Katsuk Butte (unit btk), probably deposited soon after deglaciation, as discussed by Scott and Gardner (1992). Includes rotated megablocks and chaotic rubble. Overlain by unit mlc [SS]

VOLCANIC ROCKS

[Listed alphabetically by 3-letter map-unit label]

abt **Andesite and dacite of Broken Top (middle Pleistocene)**—Varied apron of glaciated andesitic and dacitic (59.5–68.6% SiO_2) lava flows on southwest slope of Broken Top volcano, shown only west and southwest of Cayuse Crater. Interstratified with more mafic lavas (see unit mbt) that make up much of Broken Top edifice (which we reconnoitered only as limit to our mapped area). Includes varied andesite flows containing 5–25% plag (1–3 mm), cpx, opx, and olivine, as well as at least three dacite flows that contain 1–10% plag and sparse pyroxenes. Underlain and overlain by mafic lava flows from Broken Top (unit mbt) and overlain by lavas and ejecta from Cayuse Crater (unit bcc). Eruptive ages probably mostly 300 to 150 ka; dacite lava at 5,820 ft elevation on west bank of Fall Creek yielded $^{40}Ar/^{39}Ar$ age of 178±1 ka [BT]

acc **Andesite of Collier Cone (Holocene)**—Andesitic scoria cone (stippled on map), 160 m high and 700 m in diameter, centered 2.5 km northwest of summit of North Sister, and western lava-flow apron that divides into northwestern tongue that extends 4 km from vent and narrow western tongue that extends 13 km. Both tongues have several levees and remain coarsely blocky, scoriaceous, and little eroded. Flow sequence was subdivided into five distinguishable subunits (not shown separately here) by Schick (1994); first four range in SiO_2 content from 55 to 61%, whereas fifth is small proximal flow only 500 m long that has 65% SiO_2. Compositional range was attributed by Schick to crystal fractionation, to mixing with plutonic xenoliths (69–74% SiO_2) found partially melted and disaggregating in all subunits, and to entrainment of olivine and plag cumulates. Short fountain-fed lava flow (57.5% SiO_2) just north of cone is compositionally similar to andesitic parts of main apron. Crystal contents highly varied: 5–25% plag (<1–8 mm); 1–5% olivine (<1–4 mm); trace mph of cpx and Fe-Ti oxides. Younger than all volcanic units nearby. Little Ice Age till banks against south slope of scoria cone. ^{14}C age: about 1,500 calibrated yr B.P. (Taylor, 1968, 1981; Sherrod and others, 2004) [LL, NS]

acp **Andesite of Pole Creek scoria cone (late or middle Pleistocene)**—Andesitic (56.4, 57.7% SiO_2) scoria cone (stippled on map) on south bank of Pole Creek (south of Trout Creek Butte) and lava-flow apron 2 km farther east, just outside limit of late Pleistocene moraine deposits. Lava apron is scoriaceous, rubbly, and widely oxidized on its surface, massive and block jointed on streambank scarps, and virtually aphyric. Scoria cone covers area of 400 by 600 m and has about 110 m of relief; it mainly consists of loose oxidized scoria lapilli and bombs, but ejecta on steep north slope are widely agglutinated. Nearly aphyric scoriae contain only trace amounts of plag phenocrysts (rarely as big as 0.5–2 mm) and rare olivine and cpx mph. Groundmass has scattered plag-lath mph, seriate to microlites. Cone is not glacially eroded but is located right along distal limit of late Pleistocene ice advance, its southern and eastern margins abutted by outer edges of moraine deposits. West toe of cone is wrapped by younger lava flows of unit bss. Lava-flow apron overlies units mwh (195±5 ka) and bwl and extends unknown distance beyond east edge of map area. Cone is directly overlain by cream to buff pumice-fall deposit as thick as 60 cm, of unknown source; its pumice lapilli have 67.3% SiO_2, contain trace amounts of plag and cpx (<1% phenocrysts), and are predominantly 2–3 cm but as coarse as 8 cm; its largest lithic fragments are 2–3 mm. Undated [TCB]

adh **Andesite dome of Lewis Glacier headwall (late Pleistocene)**—Andesitic (62.6% SiO_2) lava dome and major apron of derivative talus that together make up two-thirds of steep wall above northeast edge of Lewis Glacier on South Sister. Most of glaciated dome remnant is blocky and strongly fractured glassy lava that envelops 25-m-thick, massive, more coherent interior. Total thickness is now about 100 m, but unit must have stood at least 40 m higher to have shed nearly 50-m-thick talus apron exposed on its east flank. Talus is monolithologic, matrix poor, and clast supported, consisting of subangular to subrounded glassy clasts, mostly 5 to 50 cm across and finely vesicular; uncommon blocks are prismatically jointed, suggesting that part of talus could be proximal lags of block-and-ash flows from dome. Best outcrops (through surficial scree) are block-rich ledges, typically about 3 m thick, that dip 30° to 35° southeast. Vague layering in deposit reflects crude size segregation, having somewhat larger matrix fractions in horizons that contain fewer large clasts; a few laterally persistent, matrix richer intervals and at least five coarse ledges indicate several emplacement pulses. Subordinate sandy to gravelly matrix is made up of material comminuted from accompanying monolithologic blocks. Dome and talus are cut by three or four dikes (unit ahi), same dikes that also cut subjacent unit alh. Phenocrysts: 10% plag (mph to 2 mm); 1% pyroxenes (mph to 0.5 mm), commonly in clots with plag. Northwest side of unit is truncated (together with underlying stack of andesite lava flows of unit alh) by northwest-facing wall of a paleocrater. Thick lava of unit dlg (25.3±1.4 ka, 22.3±1.6 ka) and fragmental unit dbl later filled paleocrater, banking against and overlying dacite dome of unit. Thick talus from dome directly underlies unit aeg (here, 27±2 ka; 28.5±2.1 ka, nearby). Undated [SS]

adl **Andesite of Demaris Lake (late Pleistocene)**—Andesite (61.1–62.9% SiO_2) lava, one or more flows that make up much of interfluve between North and South Forks of Whychus Creek. Proximal lava bench about 100 m thick, centered on Demaris Lake, lies 5 km from South Sister summit and 4 km from Middle Sister summit. Source vent is uncertain, as it is covered by younger lavas, but windows along North Fork Whychus Creek (through unit mcl), as far as 1.3 km northwest of Demaris Lake and as high as 6,620 ft elevation, favor source at or near Middle Sister. Everywhere glaciated and widely till mantled, unit extends 5 km northeastward from Demaris Lake, cropping out extensively north of South Fork Whychus Creek canyon. Locally vitrophyric, including many ice-contact exposures that have chunky or slender subhorizontal columns; however, glacial and fluvial erosion has widely exposed block-jointed to slabby or platy, variably devitrified interior facies. Phenocrysts: 15–20% plag (mph to as big as 4 mm); 3% pyroxenes (mph to 1 mm, rarely to 2 mm); sparse oxide mph; and common oxide-pyroxene-plag clots. Overlies units bwy, mdl (181±21 ka), mws (175±3 ka), msf (166±16 ka), mns (here, 119±6 ka), mnf (48±10 ka), and drm (29±1 ka), as well as undated till at 6,060 ft elevation along North Fork Whychus Creek. Overlain by unit mcl (16±10 ka, 23±16 ka) and by till of last Pleistocene glaciation. $^{40}Ar/^{39}Ar$ age: 24±1 ka [TCB]

aef **Andesite tephra fall at base of east face of Middle Sister (late Pleistocene)**—Stratified proximal ejecta at base of headwall of Hayden and Diller Glaciers, representing stratigraphically lowest internal exposures of Middle Sister edifice. Two sequences of similar bedded ejecta (not mapped separately) are separated by smoothly bevelled unconformity; base of lower 15-m-thick sequence is concealed by ice; upper sequence, about 30 m thick, is overlain by stack of ochre-weathering lava flows (unit mhd) that forms middle part of east face of Middle Sister. Both sequences dip 15° to 20° west beneath Middle Sister. Layers are mostly 5 to 20 cm thick, defined by fluctuations in sizes of coarse clasts in poorly sorted matrix that consists of very coarse ash and small lapilli. Coarse clasts are dominantly 2 to 5 cm (as large as 15 cm), range in texture from massive to finely vesicular, and appear to be compositionally uniform andesite (62.6–63.1% SiO_2). Phenocrysts: 5% plag (mph to 2 mm); about 1% pyroxenes (mph to 1.5 mm); sparse oxide mph; also contains common crystal clots of plag, pyroxenes, and oxides. Base of unit not exposed. Overlain by lavas of unit mhd (37±9 ka), which is, in turn, directly overlain by unit mms, which makes up upper half of east face. Stratified ejecta are cut by several dikes, which may have fed both overlying units. Undated [NS]

aeg **Andesite of Eugene Glacier (late Pleistocene)**—Cone-forming, red and gray stacks of numerous thin andesitic (56.0–60.4% SiO_2; n=32) lava flows, agglutinate sheets, and intercalated scoria falls that make up much of upper cone of South Sister between elevations of 8,200 and 10,000 ft (but not its summit). Glacially eroded apron extends radially downslope to 8,200 to 8,400 ft elevation on Hodge Crest (to east) and around Clark Glacier (to south and southwest), to 7,700 ft elevation near Eugene and Lost Creek Glaciers (to northwest), and to 7,600 ft elevation north and east of Carver Lake (to northeast); remnants are as low as 6,700 ft elevation in upper Separation Creek (to northwest). Irregular upper limit of radially dipping stacks defines ragged rim of late Pleistocene crater that truncates unit; Hodge Crest, now isolated by headward erosion of cirques of Prouty and Lewis Glaciers, forms integral part of unit's slope. Paleocrater, which originally was about 700 m in diameter, has been wholly filled by units dlg and des. Where exposed on glacier headwalls, individual stacks consist of 4 to 15 massive gray layers, each layer typically being 1 to 5 m thick (rarely, 10 m) and representing a discrete fountain-fed eruptive pulse. Many such (rheomorphic) massive flow units grade up, down, and proximally into agglutinate and, further, into red fragmental interlayers (also 1–5 m thick) of mixed origin: partly scoriaceous fallout (tack welded to nonwelded; rarely unoxidized) and partly scoriaceous flow-top rubble. Dense zones are texturally varied, from partly glassy to devitrified and either massively homogenized or retaining streaky to blobby ghost-agglutinate texture. Where steeply dipping (20° to 35° radially) on upper slopes, most flows are thin (and, locally, even convolutely foliated). A few northern flows that reached break in slope lower on edifice ponded to 15 to 25 m, and some of these exhibit glassy to aphanitic, chunk-jointed features suggestive of ice contact; where incised, such thickened flows are commonly block jointed or slabby internally. On headwall of Lost Creek Glacier, stratified pile of brick-red scoria more than 100 m thick (stippled on map) is thought to be early phase of unit. Considerable ranges in phenocryst contents among numerous sheets that make up unit: 10–20% plag (mph to 3 mm); 1–5% cpx (mph to 1 mm, rarely to 2 mm); varied amounts of subordinate opx and olivine (each largely mph but as big as 1.5 mm); plag+pyroxene±olivine±oxide clots range from sparse to abundant, as do oxide mph; a few, to as many as half of, plag phenocrysts are sieved internally but overgrown by clear rims; a modest fraction of plag phenocrysts are broken. Overlies units alg, dcg, dgl, drm, dwl, rct, and rsw. Overlain by units awf, dcl, dlg, des, mtp, and rsc. $^{40}Ar/^{39}Ar$ ages: 27.0±3.2 ka (north planèze), 26.7±1.7 ka (Hodge Crest; south wall, Prouty Glacier), and 28.5±2.1 ka (north wall, Lewis Glacier) [BT, SS]

ahc **Andesite tephra fall of Hodge Crest (late Pleistocene)**—Variably stratified, coarse andesitic (61.6–61.9% SiO_2) proximal fallout that extends across 700 m of Prouty Glacier headwall

(South Sister). Unit is host to andesite intrusive complex of Hodge Crest (unit ahi) near southeast corner of headwall, where unit is thickest; although base there is covered by ice, fallout is more than 200 m thick. Lowest 60 m is unstratified to vaguely so, having layering that is subhorizontal to slightly outboard dipping. Upper part, which is coarser and well stratified, has layers and lenses (variably, centimeters to meters thick) that dip 10° to 20° inboard and that overlie unconformity that smoothly bevels outward-dipping strata below. Fallout thins northward to only 60 m at distance of 100 m from intrusive complex of unit ahi and remains well stratified throughout, having layers that dip 20° to 25° outboard in all but top 10 m or so, which dip inboard 10° to 20°. Unconformity defined by outboard- to inboard-dipping strata may mark transient rim of paleocrater subsequently filled by overlying lava of unit dlg. Fallout was baked beneath unit dlg and is oxidized to several meters below contact. In addition, intruding dikes of unit ahi promoted hydrothermal alteration of host fallout. Coarsest part of fallout is inboard dipping and contains subrounded to angular clasts as big as 30 cm, all dense or slightly vesicular and lithologically similar; some blocks are prismatically jointed or breadcrusted. Matrix is coarse ash, seriate to smaller clasts. Phenocrysts: 15–20% plag (0.5 to 3 mm); ~1% pyroxenes (mph to 0.5 mm), mostly in plag+pyroxene clots. Overlies unit dpg, which in turn rests on units rpg (33±1.5 ka) and aph′. Overlain by units aeg (27±3.2 ka, 28.5±2.1 ka, 26.7±1.7 ka) and dlg (25.3±1.4 ka, 22.3±1.6 ka). Intruded by unit ahi. Undated [SS]

ahi **Andesite intrusive complex of Hodge Crest (late Pleistocene)**—Family of dikes and irregular intrusions as thick as 20 m on both sides of saddle between Hodge Crest and South Sister summit; well exposed on headwall of Prouty Glacier and on slope northeast of Lewis Glacier. Dikes on Prouty Glacier headwall are chemically and lithologically varied. One dike that reaches rim has 60.5% SiO_2 and carries 10–20% plag (mph to 2 mm) and ~1% pyroxenes (mostly mph but also sparse crystals as long as 2 mm), as well as common pyroxene-plag clots and oxide mph; dike resembles lava of unit awf. Another dike at base of Prouty Glacier headwall has 62.0% SiO_2 and is lithologically similar to lava of unit aph. These dikes intrude gray fragmental strata of unit ahc on Prouty Glacier headwall. On slope northeast of Lewis Glacier, three or four dikes cut stack of four lava flows of unit alh and also thick overlying unit adh; one of these dikes has 56.6% SiO_2, resembles unit aeg, and carries 10–15% plag phenocrysts and ~1% olivine and pyroxene mph. Host rocks and some dikes are truncated by west-facing wall of large paleocrater, which also truncates overlying cone-forming stacks of unit aeg (27±3 ka) and was subsequently filled by units dbl, dlg (here, 25±1 ka), and des. Dikes are thought to have fed part of cone-forming unit aeg, and others may have fed lavas of units aph and awf (24±1 ka). Intrusive complex may thus represent events spread over interval a few thousand years long. Additional dikes (not sampled) that cut unit aeg on Lost Creek Glacier headwall (west of South Sister summit) also are truncated by paleocrater wall and probably represent same time interval. $^{40}Ar/^{39}Ar$ age: 23.3±6.3 ka, for thick dike that cuts ridgeline saddle at Hodge Crest [SS]

ahl **Andesite of headwaters of Linton Creek (late Pleistocene)**—Thick andesitic (57.1–57.9% SiO_2) lava flow, distinguished by consistently small phenocrysts; crops out for about 1 km between headwaters forks of Linton Creek at elevations of 6,550 to 6,900 ft at west toe of Middle Sister. Glacially eroded unit is as thick as 70 m; a few oxidized flow-breccia lenses appear to reflect internal shear rather than separate vent-derived flows. Most outcrops are flow foliated and at least partly glassy, although a few devitrified exposures are massive and block jointed or slabby. Widespread remnants of glassy chunk-jointed exterior of flow suggest ice contact. Separate exposure in small window about 1 km north (UTM grid 951/891) is largely devitrified, massive, and block jointed, and it is marked by pale- to dark-gray mottling also characteristic of main outcrops. Phenocrysts: 2–3% plag; 1–2% olivine; both plag and olivine largely mph, but a few of each as large as 0.5–1.3 mm; also contains sparse oxide mph and sparse plag-olivine-oxide clots. Overlies units alc (27±1 ka), dlc, and mhl. Overlain by unit mms and probably by unit dlp (21.4±2 ka). $^{40}Ar/^{39}Ar$ total-gas age: 21±3 ka (well bracketed by ages of enclosing units) [NS]

alc **Andesite of Linton Creek (late Pleistocene)**—West apron of distal andesite (61.6–63.0% SiO_2) lava flows that extends from toe of Middle Sister edifice (where concealed more proximally by major unit mms) for 7 km farther west-northwest, as far as Linton Lake. Medial thickness is at least 120 m; distal relief in cliffs above Linton Lake is about 450 m, but much of this owes to flow having draped stairstep topography of previously glaciated valley. Both brick-red flow-breccia zone along steep margin of unit adjacent to Lane Plateau and scoriaceous flow-breccia zone along Pacific Crest Trail at 6,400 ft elevation (UTM grid 943/880) suggest two flow units, but such breaks are not exposed elsewhere. Most exposures are glassy or partly so, and many have glassy chunk jointing or inclined and subhorizontal slender columns suggestive of ice contact. Devitrified internal exposures are common where deeply incised, and they are block jointed or slabby to platy (locally convolute). Sparse pale-gray, phenocryst-poor, relatively mafic enclaves are rarely larger than 1 cm. Highest exposure (at 6,880 ft) lies just 2 km west of Middle Sister summit, its presumed source. Phenocrysts: 10–20% plag (mph to 5 mm, mostly ~1 mm); 2–3% pyroxenes (mph to 1.5 mm), mostly in abundant clots with plag and oxides; sparse oxide mph. Overlies units mth, dlc, and mlb (~48 ka); banks against unit aoc (49±4 ka). Overlain by units dlp (21.4±1.9 ka), mms, mmt, and ahl (21±3 ka). $^{40}Ar/^{39}Ar$ ages: 26.8±1.2 ka (distal), 27.2±1 ka (proximal); same age as compositionally similar lavas of unit alg that erupted at South Sister [LL, NS]

alg **Andesite west of Lost Creek Glacier (late Pleistocene)**—West-northwest apron of fairly uniform phenocryst-rich andesite (61.5–63.5% SiO_2) lava flows from South Sister, cropping out from Neoglacial moraines of Lost Creek Glacier down to Separation and Hinton Creeks (from 7,800 to 6,400 ft elevation), 1 to 3 km from summit of South Sister. Stacks of flows are glacially eroded into stairstep benches. Flows are mostly 2 to 10 m thick upslope and commonly separated by oxidized flow breccia, whereas toward lowland extremity of unit, several flows thicken to as much as 15 to 20 m. Sets of several shingled flows are glacially scoured into radial ridges that diverge downslope. Massive vitrophyre zones are preserved locally, but glacial erosion has been severe enough in this sector that most exposures are devitrified and platy, slabby, or block jointed. Flow foliation, locally convolute or ramped, is common, especially on higher, steeper slopes. Phenocrysts: 10–15% plag (mph to 2 mm), some of larger ones sieved; 2–3% pyroxenes (mph to 1.5 mm); sparse olivine and oxide mph; most pyroxenes are in clots with plag and oxides. Base not exposed. Overlain by units aeg and dwl directly and by units mms and rsc peripherally; lavas of unit msc (21.4±5.5 ka) appear to bank against toe of unit's apron. $^{40}Ar/^{39}Ar$ age: 27.1±1.1 ka (essentially same age as compositionally similar lavas of unit alc that erupted from Middle Sister) [SS]

alh **Andesite of Lewis Glacier headwall (late Pleistocene)**—Stack of four andesitic (62.0–62.9% SiO_2) lava flows separated by oxidized flow breccias in steep wall above northeast edge of Lewis Glacier on South Sister. Massive zones stand out as 2- to 12-m-high ledges on steep slope. Massive interior of fourth flow thins eastward from 6 to 2 m, draping three underlying flows. Lowest flow is largely devitrified, platy, and oxidized pink, its base covered at glacier margin; second and third flows are dark gray or oxidized red-brown, mostly massive and partly glassy; and fourth flow is black, glassy, and vesicular. All four are cut by three or four dikes that are assigned to unit ahi. Phenocrysts: 10–15% plag (mph to 2 mm), somewhat less (~10%) in lowest flow; 1–2% pyroxenes (mph to 1 mm), commonly in clusters of mph or in clots with plag; more pyroxenes (2–3%) in lowest flow; also contains abundant oxide-pyroxene-plag clots. Overlain conformably by unit adh. At its west end, stack is truncated by wall of paleocrater that was filled by units dbl and dlg (25.3±1.4 ka, 22.3±1.6 ka), both of which bank against this unit. Glaciated stack of flows of unit alg (27±1 ka) over on north-west flank of South Sister is chemically and petrographically similar to lowest flow in stack here, which yielded a $^{40}Ar/^{39}Ar$ age of 30.4±1.3 ka [SS]

als **Andesite south of Lewis Glacier (late Pleistocene)**—Plagioclase-rich andesitic (62.4% SiO_2) lava flow at 8,600 ft elevation on South Sister that forms glaciated cliff and crags (UTM grid 990/823) beneath southeast edge of Little Ice Age moraine of Lewis Glacier; only 400 m from current ice front. Steep, bluff-forming lava is as thick as 60 m and exposes both dark-gray, partly glassy zones and pale-gray, devitrified platy zones. Lava is compositionally distinct from other nearby plagioclase-rich units (aeg, dmn, and dgl) but petrographically and chemically similar (not identical) to unit alg on west flank of South Sister edifice. Phenocrysts: 10–15% plag (mph to 3.5 mm); 1–2% pyroxenes (mph to 1 mm), mostly in clots with plag and oxides; free oxide mph are sparse. Overlies units dmn (here, 27.7±1.0 ka) and rct (24±5 ka, 30±8 ka). Undated [SS]

anh **Andesite agglutinate north of Hayden Glacier (late Pleistocene)**—Fissure-fed andesitic (57.9–58.0% SiO_2) scoria, spatter, and fountain-fed lava flow that drape lower south face of North Sister. Upper end of 500-m-long fissure lies at about 9,100 ft elevation; lower end at about 8,200 ft; and rheomorphic lava drapes additional 500 m south, then southeast, to glacially eroded terminus at 7,800 ft elevation. Eroded remnants along fissure are only 50 to 100 m wide, but lava tongue broadens downslope over terrain less steep to about 200 m. Agglutinate and scoria along fissure are brick red and tack welded to fairly dense but blobby; lava flow also is largely oxidized and has blobby exterior but becomes denser and more homogenized (though still streaky) distally. Terminal lobe is 25 m thick and contains patchy exposures of gray, massive interior; it probably ponded against ice and was subsequently overridden and surficially stripped by it. Phenocrysts: ~1% plag (mostly mph, but rare crystals 0.5–1.5 mm in plag-pyroxene-oxide clots); rare cpx (≤0.5 mm), largely in clots; sparse oxide mph. Unit erupted through and drapes far older stack of previously eroded thin lavas of North Sister (unit mns). Overlain by Middle Sister lavas of unit mms. $^{40}Ar/^{39}Ar$ age: 21.0±6.3 ka [NS]

aoc **Andesite of Obsidian Creek (late Pleistocene)**—Extensive apron of phenocryst-poor andesite (59.9–63.2% SiO_2) lava flows that extends just beyond Linton Lake, 7 km from northwest toe of Middle Sister, its presumed source vent. Its most proximal exposures, where buried by younger lavas of Middle Sister, lie 3 km from summit of that edifice. As thick as 120 m at medial exposures, glacially scoured unit ponded (possibly against ice) near its terminus, where it now has 285 m of relief (although true thickness is less, owing to steepness of paleovalley floor it buried). Massive to columnar, black glassy base is exposed near 4,900 ft elevation along Obsidian Creek, but most exposures have been glacially sculpted into ridges and benches of devitrified, nonvesicular, fine-grained andesite that ranges from block jointed to thinly platy. Most commonly pale gray and mottled on joint planes but locally dark gray where still partly glassy. In otherwise massive devitrified rock, pale-gray films commonly accentuate pervasive hairline cracks spaced 2 to 5 mm apart that represent flow foliation. At snout of flow northwest of Linton Lake, thick, glassy, chunk-jointed carapace is preserved. Phenocrysts: virtually aphyric, but locally contains rare plag (0.5–1.5 mm), commonly rounded; rarer olivine (≤0.5 mm), typically partly resorbed and has reaction rims. Overlies unit mlb (~48 ka). Overlain by units acc, alc, dlp, mmm, mms, mrg, and roc. $^{40}Ar/^{39}Ar$ ages: 49±4 ka (proximally), 44.6±1.8 ka (at distal snout). Eroded nose assigned to this unit, located about 500 m northwest of Montague Memorial Plaque (UTM grid 940/912), is lithologically identical but has only 58.6% SiO_2; apparently a discrete but related flow, it yielded $^{40}Ar/^{39}Ar$ age of 47.9±2.2 ka [LL, NS]

apc **Andesite of Park Creek (late Pleistocene)**—Phenocryst-rich andesite (61.0–61.6% SiO_2) lava flow exposed discontinuously through till along West Fork Park Creek, 0.7 km to 2 km downstream from Red Meadow. Glassy zones preserved only locally in severely glaciated lava; mostly devitrified, nonvesicular, and block jointed to platy. Strikingly platy along gorge near waterfall at 5,820 ft elevation. Phenocrysts: 10–15% plag (mph to 4 mm); 2–3% pyroxenes (mph to 1.5 mm), mainly in plag-pyroxene-oxide clots; sparse oxide mph. Overlies unit ruc (169±2 ka). Overlain by unit drm (29±1 ka). $^{40}Ar/^{39}Ar$ age: 31±9 ka [TCB]

aph **Andesite of Prouty Glacier headwall (late Pleistocene)**—Phenocryst-poor andesitic (61.4–61.6% SiO_2) lava flow that crops out as ledge at ice level for about 250 m along northwest base of Prouty Glacier headwall on South Sister. Most of 7-m-thick exposure is gray and partly glassy, weathered pink to buff on blocky joint surfaces; base is covered by glacier. At both ends of exposure, flow margins are enveloped in crudely stratified, oxidized tephra-fall deposit that has agglutinated lenses. Midway along ledge, exposure is conspicuous 12-m-wide hemispherical devitrified zone that has distinctively concentric platy jointing. Phenocrysts: ~1% plag (mph to 2 mm); sparse pyroxenes (mph to 0.5 mm); sparser Fe-Ti oxides; most pyroxenes in oxide-pyroxene-plag clots. Directly overlain by stratified sequence of agglutinate and breccia (unit aph′), which is, in turn, capped by unit rpg (33±2 ka). Undated. One isolated outcrop in ice, just below base of headwall and 300 m along strike southeast of section just described, is 4-m-thick andesitic (61.6% SiO_2) lava ledge, apparently also of this unit; lava is enveloped in ochre breccia that contains vesicular, black clasts of glassy lava (59.3% SiO_2) that probably is coarse proximal fallout more than 5 m thick, its base covered by ice; lithologies are similar to unit aph′ [SS]

aph′ **Andesite tephra fall near base of Prouty Glacier headwall (late Pleistocene)**—Stratified tephra-fall deposit about 5 m thick that contains thin lenses and layers of massive andesitic (59.3–63.7% SiO_2) agglutinate, atop ledge of unit aph along northwest base of Prouty Glacier headwall on South Sister. Massive intervals are black, glassy, and finely vesicular, and they grade into rubbly zones above and below. Coarse nonwelded intervals contain moderately vesicular, glassy juvenile clasts as big as 20 cm (similar in lithology to massive layers), as well as abundant dense, angular, nonjuvenile lithic fragments; subordinate ochre coarse-ash matrix mostly consists of comminuted juvenile material. Individual nonwelded layers range laterally in thickness from 20 cm to 2 m and in color from ochre to brick red. Phenocrysts: ~2% plag (mph to 1.5 mm, rare to 3 mm); sparse pyroxene (mph to 0.5 mm). Rests on unit aph and is overlain by units rpg (32.8±1.5 ka) and dpg. Undated [SS]

asn **Andesite south of Newberry flow (late Pleistocene)**—Glaciated plagioclase-rich andesite (61.7% SiO_2) lava flow exposed only locally beneath snout of late Holocene Newberry flow (unit rdc), 4 km southeast of South Sister summit. Deeply covered by proximal rdc ejecta, unit is exposed principally as glacially eroded bench of block-jointed massive lava at 6,400 ft elevation. Apparently also overlain by unit rse (34±1 ka), extensive ridge of rhyolitic lava that stands between unit and its presumed source, South Sister edifice. Phenocrysts: 7–10% plag (mph to 2 mm); 3% pyroxenes (mph to 0.7 mm); sparse Fe-Ti oxides; contains abundant oxide-pyroxene-plag clots. Base not exposed. Undated [BT]

asw **Andesite of southwest slope of Middle Sister (late Pleistocene)**—Small window (100 by 300 m) of phenocryst-poor andesite (61.5% SiO_2) lava flow near southwest toe of Middle Sister cone. First draped by extensive lava apron of unit mms and then jointly glaciated, exposure is, in part, devitrified, pale gray, and platy or block jointed and, in part, black, blocky, and glassy to aphanitic. Locally, unit exhibits ramped flow foliation, oxidized joint films, and scoriaceous crusts along shear planes. Phenocrysts: <1% plag (mph to 1.2 mm); sparse pyroxenes (mostly mph, but very rare crystals 0.5–1 mm); sparse oxide mph. Base not exposed. Overlain and largely concealed by unit mms. $^{40}Ar/^{39}Ar$ age: 25±4 ka [NS]

asy **Hornblende-bearing andesite southeast of Yapoah Crater (late Pleistocene)**—Block-jointed bench of glaciated phenocryst-rich andesitic (58.7% SiO_2) lava that protrudes eastward from east-facing cliff of unit mwa, about 1.5 km southeast of Yapoah Crater. Bench is only about 100 m long, 60 m wide, and 30 m high, but its scarp sheds coarse talus that covers its base downslope. Lithologically unique in local area, it is either plug or remnant of unit that is elsewhere wholly concealed. Phenocrysts: 7–10% plag (0.5–4 mm); 3–5% hornblende prisms (0.5–15 mm long), mostly opacitized; rare cpx mph (0.3–0.4 mm); common hornblende-plag clots and clusters of plag mph. Groundmass rich in plag mph, seriate to microlites. Apparently intrudes unit mwa (59±4 ka), but contact relations are obscured by surficial deposits. Undated [NS]

awa **Andesite west of upper Alder Creek (late Pleistocene)**—Phenocryst-poor andesitic (55–58% SiO_2) lava flows and subordinate agglutinate that form three separate cliffy exposures about 1 km west of upper Alder Creek. East-facing wall and buttress (UTM grid 984/936) that protrudes from it (1 km east of Collier Cone) are 40 to 90 m high and consist of three fountain-fed lava flows that are separated by thin sheets of red agglutinate at western exposures but merge eastward into single cliff that has vertical jointing and no surviving partings. Another prominent buttress, isolated by scree just east of that wall (UTM grid 987/933) is single lava flow more than 30 m thick that grades down into stratified, variably agglutinated, red scoria-fall deposit more than 25 m thick; lava is pale gray, block jointed to slabby, and flow foliated, and it dips about 20° northeast; fall deposit mostly consists of lapilli but also has bombs and dense blocks as big as 30 cm and numerous lenses of dense agglutinate. Third exposure, about 300 m northeast of first, is slender ridge (UTM grid 988/942), 600 m long, 100 m wide, and 50 m high, that trends N. 10° E. and consists of single ice-sculpted lava flow; lava is massive and block jointed, and its basal oxidized breccia rests on lava flow of unit mns (xenoliths of which, 1–5 cm across, are common in overlying unit). Phenocrysts: <1% plag (0.5–2.5 mm); rare cpx (0.5–1 mm); rare olivine mph. Overlies unit mns. Overlain by pyroclastic unit mps, which buried vent for this unit; these two phenocryst-poor units may have erupted successively from common fissure-vent system. Distinguished from unit mwa, which crops out along same wall just north, by its much lower phenocryst content, lower Al_2O_3 content (<17%), and higher FeO content (>8%). $^{40}Ar/^{39}Ar$ age: 25.2±2.2 ka, for lava of northeast ridge [NS] awc **Andesite west of Collier Glacier (late Pleistocene)**—Glaciated fan (2 km long, 1 km wide) of fairly uniform andesite (61.6–62.3% SiO_2; n=13) lava flows that extends north-northwest from Middle Sister along west side of Collier Glacier. Among numerous shingled flows, sequences of five are exposed locally along glacier-marginal cliffs. Till-strewn surface of unit is glacially eroded into radial ridges and stairstep benches cut on stack of flows 5 to 25 m thick, all dipping moderately northwest. Uppermost flow of unit adjacent to Collier Glacier is more than 70 m thick, probably ponded originally against ice. Glassy chunk-jointed zones, mostly at bases of flows, crop out widely, but most rock exposed is devitrified and block jointed or platy. Phenocrysts: 5–10% plag (mph to 2.5 mm); 1% pyroxenes (mph to 1.5 mm), many in common plag-pyroxene-oxide clots; sparse oxide mph. Overlies units dss (25±3 ka) and mlb (~48 ka), which here, in turn, overlies unit mns. Overlain by units mrg (20±6 ka), mms, and dbh (18±2 ka). $^{40}Ar/^{39}Ar$ ages: 21.9±1.7 ka, 24.5±1.5 ka [NS]

awf **Andesite of West Fork Park Creek (late Pleistocene)**—Glaciated set of andesite (59.2–60.7% SiO_2) lava flows from South Sister, east of Prouty Glacier, that descends 3 km eastward from Little Ice Age moraines to lowland apron north of Golden Lake. One thick flow banked against northwest ridge of Broken Top and was diverted southward to Green Lakes. Most exposures on apron are devitrified and block jointed to slabby or platy, but proximal outcrops through ice and till are at least partly glassy, as are sparse flow-base exposures, even on lower apron. Green Lakes lobe is largely glassy, perhaps reflecting contact with valley-filling ice. Phenocrysts: 15–20% plag (mph to 2.5 mm); 3% pyroxenes (mph to 1.5 mm); minor olivine (mph to 1.5 mm); sparse oxide mph; also contains common plag-pyroxene-oxide clots. Overlies units mpm and aeg (27±2 ka); banks against units mbt, rpc, and drm (29±1 ka). Compositionally similar to dike of unit ahi on rim above Prouty Glacier. $^{40}Ar/^{39}Ar$ age: 23.7±1.3 ka [BT, SS]

awm **Andesite west of Middle Sister (late Pleistocene)**—Fan of ruggedly glaciated, moderately porphyritic andesite (59.1–60.6% SiO_2) lava flows on west slope of Middle Sister (7,150 to 8,100 ft elevation), cropping out in seven or more separate windows through till, scree, and unit mms. Lithologically similar to nearby unit awr (just north), but slightly richer in Ti, Fe, Mn, Mg, and Ca and slightly poorer in K and P. Several outcrops each expose from one to six flows, most of which retain some vitrophyre facies, but thick flows are dominated by variably devitrified internal facies, ranging from block jointed to platy. Scoriaceous and oxidized flow-breccia zones crop out widely, separating massive zones of stacked flow units. Flow thicknesses vary widely, between 2 and 50 m. Phenocrysts: 7–10% plag (mph to 2.5 mm); 2% pyroxenes (mph to 2.2 mm), mostly in common plag-pyroxene-oxide clots; sparse oxide mph. Base not exposed. Overlain by units mms and mms′; cut by dikes of unit mms and intruded and overlain by unit dlp (21±2 ka). Undated [NS]

awr **Andesite west of Renfrew Glacier (late Pleistocene)**—Fan of several (compositionally similar) andesite (60.8–61.6% SiO_2) lava flows that forms northwest medial slope of Middle Sister at elevations between 6,900 and 7,900 ft. Stacks of as many as six moderately porphyritic flows are glacially eroded into several west-trending buttresses, overlapped and surrounded by till and derivative coarse alluvium. Lithologically similar to unit awm (just south) but slightly richer in K and P and slightly poorer in Ti, Fe, Mn, Mg, and Ca; likewise similar to unit awc (just north) but richer in Ti, Fe, and Mg and slightly poorer in Si, Na, and K. Some flows are only 2 to 5 m thick and largely vitrophyric, having oxidized flow-breccia zones separating them; most are 15 to 40 m thick, extensively devitrified, and block jointed to platy. Where flows are steep, flow foliation commonly is convolute. Phenocrysts: 5–7% plag (mph to 2.2 mm); 1–2% pyroxenes (mph to 1.2 mm); sparse oxide mph; also contains abundant plag-pyroxene-oxide clots. Base not exposed. Overlain by unit mrg (20±6 ka), (inferentially) by mms and dbh (18±2 ka), and extensively by glacial deposits (unit g). Undated [NS]

awy **Andesite of Whychus Creek (middle Pleistocene)**—Phenocryst-rich andesite (61.3–62.0% SiO_2) lava flow exposed along gorge floor of Whychus Creek from near confluence of its north and south forks downstream for 2 km; remnant also banked against west wall of valley about 1 km still farther downstream. As thick as 25 m along walls of gorge, where base is not exposed and outcrops are devitrified and slabby to platy. Exposure through thick till on hill east of gorge rim and 500 m northeast of confluence is block-jointed black vitrophyre. Where banked against west sidewall downstream, columnar basal vitrophyre forms 6-m-thick ledge overlain by about 20 m of platy devitrified andesite (mantled by till). Phenocrysts: 10–15% plag (mph to 4.5 mm); 2–3% pyroxenes (mph to 1.5 mm), mostly in common plag-pyroxene-oxide clots; sparse oxide mph. Base not exposed along river, but flow banks against unit mbw on west sidewall. Overlain by units bwy and mwh (195±5 ka). Source vent unknown; most likely Broken Top. $^{40}Ar/^{39}Ar$ age: 298.7±1.4 ka [TCB]

bac **Basalt of Alder Creek (late or middle Pleistocene)**—Nearly aphyric basaltic (51.2–53.1% SiO_2) lava that forms prominent ridge at 5,800 to 5,950 ft elevation on north wall of Alder Creek, 6 km northeast of North Sister summit. Steep narrow ridge, about 400 m long, is nose of former glacially sculpted cleaver that separated ice streams. Rock is more pervasively altered than any recognized in map area other than in near-vent regions affected by hydrothermal or fumarolic processes. Where least altered (or merely silicified), rock is dark gray to greenish gray, massive, aphanitic, and almost aphyric. Somewhat more altered domains have medium- to coarse-grained groundmass and are diktytaxitic or exhibit angular vesicles. Most widespread lithology has coarse groundmass and extensive porosity, is locally brick red interspersed with green and yellow patches, weathers tan to yellow brown, and disintegrates to grus. Phenocrysts: 2–3% olivine (mostly mph, but rarely 0.5–1.2 mm). Groundmass, which contains abundant tiny olivine, varies from finely felty, rich in plag microlites, to dense tangle of plag-lath mph that are seriate from 0.1 to 0.5 mm and include rare laths as long as 1.5 mm. Base not exposed. Overlain by units mey and mns. Unique exposure is stratigraphically oldest unit in its area. $^{40}Ar/^{39}Ar$ age: 128±7 ka [TCB]

bbd **Basalt of Brush Draw (late or middle Pleistocene)**—Moderately porphyritic basaltic (51.1–51.4% SiO_2) lava flow that crops out south and east of Brush Draw at southeast toe of Trout Creek Butte. Exposed only beyond glacial limit, its surface is scoriaceous to rubbly. Source unknown, as proximal extent is wholly covered by younger lavas. Phenocrysts: 10% plag (mph to 3.5 mm); ~1% olivine (0.2–1.5 mm); rare cpx (0.5–1 mm); some plag crystals are sieved, and some are composite. Base not exposed here, but flow extends well northeast of map area. Banks around base of unit mtb shield (532±7 ka). Overlain by unit bss. Undated [TCB]

bbr **Basalt of Sparks Lake boat ramp (early Holocene or latest Pleistocene)**—Sparsely to moderately porphyritic basaltic (50.8–51.5% SiO_2) lava flows at shoreline of large eastern embayment of Sparks Lake and extending 1 to 2 km east and south thereof. Source vents are north-south chain of three basaltic scoria cones (stippled on map) about 3 km east of lakeshore and surrounded by apron of younger lava flows from “Egan Cone” (unit mec). Northern cone is 600 m wide, having 115 m of relief on its west side, whereas middle and southern cones are 200 m wide and only about 30 m high. All three cones have small craters: middle crater contains pond, and southern crater is breached southward. All cones are dominantly lapilli and are widely oxidized, and each has scattered scoria bombs as big as 1 m. Lava-flow surfaces are rubbly to blocky, uneroded, and pervasively vesicular. Because unit is not extensively rifted like underlying lavas of units bsl and bes, more massive interior exposures are rare. Unit forms main peninsula near Sparks Lake boat ramp and most offshore islands. Phenocrysts: ~3–8% olivine (0.2–2 mm); sparse plag laths (≤1 mm, mostly mph); sparse to abundant plag-olivine clots and intergrowths are diagnostic of unit, as are olivine clusters; cpx-plag clots are very rare. Groundmass is rich in plag-lath mph, seriate to microlites. Overlies units bsl and bes. Overlain by unit mec and local remnants of Mazama ash (7.7 ka; not mapped separately). Equivalent to parts of units “mb4” and “mb4b” of Scott and Gardner (1992). Undated [BT]

bcc **Basalt of Cayuse Crater (early Holocene or latest Pleistocene)**—Postglacial basaltic (49.7–51.9% SiO_2) scoria cones (stippled on map) and lava-flow apron (49.7–51.9% SiO_2) on southwest slope of middle Pleistocene Broken Top edifice. Fissure-fed alignment, striking northwest, built three small mounds and one substantial breached cone (having 200 m of downslope relief) of loose scoria and variably agglutinated spatter, widely oxidized. Two thin fountain-fed lava flows extend about 1 km southwest from northwestern vents. Main leveed flow fan from large breached cone divides downslope into one tongue along Fall Creek and another that extends 4 km to Soda Creek and alluvial floodplain at Sparks Lake. Scoriaceous rubbly flow surfaces are marked by several blocky levees, some having 10 m of local relief. Phenocrysts: ~7% olivine (mph to 1.5 mm); plag absent or limited to mph laths in groundmass. Overlies several glaciated lavas from Broken Top volcano and banks against Todd Lake volcanic edifice. Overlain by remnants of Mazama ash (7.7 ka) and late

Holocene pumice-fall deposits of units rrm and rdc (not mapped separately). On nearby Broken Top edifice, scoria fall from Cayuse Crater overlies till thought to represent 13–12 ka [12.5–11 ka uncalibrated] glacial readvance of Scott and Gardner (1992); elsewhere, organic-rich sediment beneath fallout gave age of 9,520±100 ^{14}C yr B.P. (considered minimum age by Scott, 1987) [BT]

bes **Basalt east of Sparks Lake (early Holocene or latest Pleistocene)**—Phenocryst-poor basaltic (49.3–49.8% SiO_2, at 0.35–0.41% K_2O) lava flows just east of (but only locally along) east shore of south arm of Sparks Lake. Flow surfaces are rugged, scoriaceous, and rubbly, virtually uneroded. Like underlying unit bsl, flows are cut by several linear rifts 1 to 15 m wide and as deep as 5 m that expose prismatically jointed or block-jointed interior facies. Crude columns 0.3 to 1 m thick and 1 to 5 m long exposed on rift walls are widely marked by subhorizontal vugs, which are typically 3 to 20 cm long, 0.5 to 5 cm thick, and irregular in shape. Phenocrysts: almost aphyric, except for very rare plag megacrysts, which are typically shattered and as big as 9 mm, and 3–5% tiny olivine mph (0.1–0.3 mm). Groundmass contains conspicuous plag microlites. Overlies unit bsl. Overlain by units bbr and mec and by local remnants of Mazama ash (7.7 ka). Undated [BT]

bhs **Basalt south of The Husband (middle Pleistocene)**—Assemblage of thin to thick basaltic (51.1–53.0% SiO_2) lava flows that make up glacially eroded floor and walls of Indian Holes valley at south base of The Husband. Less silicic than most lavas of The Husband (unit mth: 52–57% SiO_2), these basalts may represent early stage of The Husband, overlain by its main (less mafic) apron lavas. Alternatively, they may have issued from unrelated vents that later were buried, or some may have erupted at Sphinx Butte. Mapping in this area is inadequate to identify location(s) of source vent(s). Knob 6760, 3 km north of Indian Holes, on southeast apron of The Husband, is glaciated flank vent for lavas of unit mth′; its $^{40}Ar/^{39}Ar$ age, 149±5 ka, provides minimum age for The Husband edifice itself (unit mth) and for subjacent lavas of this unit. Basalts of this unit are all phenocryst poor but include varieties that range from plagioclase free, having 3–5% olivine (mph to 1 mm), to flows that have as much as 2% plag and 3% olivine (each 0.5–1 mm), with or without clots of olivine-plag mph. All or most flows carry sparse oxide mph, as well as sparse plag xenocrysts, sieved and rounded. Felty holocrystalline groundmass is dominated by plag laths, which are seriate from mph to microlites. Base of basalt pile is exposed downstream to west but not within map area. Overlain by units msc, ddl, and mth. Undated [SS]

bjc **Basalt of James Creek (middle Pleistocene)**—Vent cone and apron of phenocryst-poor olivine-basalt (51.5–51.8% SiO_2) lavas that extends 2 km west along James Creek and 2 km south to Mesa Creek. Glaciated Knob 6482 has 120 m of relief and consists of lava flows, agglutinate, sparse loose scoria, and 30-m-high vertically jointed lava wall on its north side that appears to partially expose a plug. Benches of dacite lava (unit ddl; 32±2 ka) that banked against interior facies of knob indicate that basalt was glaciated at least once prior to dacite eruption. Ice-scoured apron lavas are mostly massive and widely till strewn, showing little preservation of vesicular facies. Phenocrysts: 3–5% olivine (mph to 1 mm), some in clusters and many carrying spinel inclusions; no truly phenocrystic plag, but felty holocrystalline groundmass contains plag, seriate from microlites to microphenocrystic laths, a few of which are as long as 0.5–0.7 mm; also contains rare plag xenocrysts (1–1.5 mm), sieved and rounded. Overlies unit dmc. Overlain by unit ddl. $^{40}Ar/^{39}Ar$ age: 148±4 ka [SS]

bnf **Basalt of North Fork Whychus Creek (middle Pleistocene)**—Four mutually isolated windows of phenocryst-rich basaltic (50.9–52.5% SiO_2) lava that crop out (progressively downstream) on floor of North Fork Whychus Creek, at 5,320 ft elevation, and on west rim of Whychus Creek valley, at 5,180 ft, 5,160 ft, and 5,000 ft elevations. Correlated, in part, on basis of unusually high Al_2O_3 contents (20.2–22.0%). At streambed location, flow forms massive ledge 10 m thick that supports cascade; sandwiched by units mws below and msp above, its outcrop pinches out laterally within 30 m. Middle two outcrops are glacially scoured ledges of massive, block-jointed to slabby basalt mantled with till, one of them overlain by unit msp. Downstream outcrop is lithologically similar ledge, more than 25 m thick, that overlies units mwh and mws and is overlain by thick till. Phenocrysts: 20–35% plag (mph to 4.5 mm), blocky or elongate; 0.5–2% olivine (0.5–3 mm); rare cpx (1–2 mm); many large olivine crystals are partly resorbed and unusually elongate; tiny plag, olivine, and oxide crystals of felty groundmass are not seriate with phenocrysts. Overlies units mwh (195±5 ka) and mws (175±3 ka). Overlain by unit msp, which is in turn overlain by lava flow of unit mns (which here gave $^{40}Ar/^{39}Ar$ age of 119±6 ka). Buried source vent could be far to west or southwest. Undated [TCB]

bsb **Basalt of Sphinx Butte (middle Pleistocene)**—Deeply eroded basaltic (51.3–52.7% SiO_2) edifice exposed on south wall of Mesa Creek (and possibly farther northwest at western limit of map area). Glacially eroded butte has 550 m of relief on its steep north face, which exposes massive plug (unit bsb′) 300 m wide and retains thick deposits of stratified scoria and agglutinate (stippled on map) adjacent to its summit. Along Mesa Creek, apron of lava flows, which are largely massive, slabby, block jointed, or chunk jointed, supports stairstep set of small waterfalls. Phenocrysts: 2–5% olivine (8–10% in plug rock, unit bsb′); no truly phenocrystic plag, but felty groundmass is rich in plag-lath mph, a few of which are as long as 0.7 mm; also contains sparse sieved plag xenocrysts as big as 1 mm and sparse oxide mph. Investigation of edifice only cursory; contact where unit banks against lavas of The Wife (unit mtw; 374±6 ka) was mapped by Wozniak (1982). Overlain by unit ddl (32±2 ka). $^{40}Ar/^{39}Ar$ age: 279±6 ka [SS]

bsl **Basalt southeast of Sparks Lake (early Holocene or latest Pleistocene)**—Phenocryst-poor basaltic (51.1% SiO_2, at 0.56% K_2O) lava flows exposed along east shore of south arm of Sparks Lake; lowest of four distinguishable sets of lava flows that make up extensive postglacial apron east of lake. Source vent unknown, apparently buried by younger mafic lavas. Flow surfaces are rugged, scoriaceous, and rubbly. Block-jointed or columnar interior is widely exposed where large cracks have opened near lakeshore flow margin, creating several rifts 1 to 5 m deep and 1 to 15 m wide. Phenocrysts: 3–5% olivine (0.5–2 mm); sparse plag (mostly mph, but rare crystals to 2 mm). Groundmass commonly finely diktytaxitic and rich in plag-lath mph. Base not exposed. Overlain by associated postglacial units bes and bbr and by local remnants of Mazama ash (7.7 ka). Equivalent to part of unit "mb4" of Scott and Gardner (1992) and Gardner (1994). Undated [BT]

bss **Basalt of Spruce Spring (late Pleistocene)**—Apron of thin basaltic (50.0–50.4% SiO_2, at 0.6–0.7% K_2O) lava flows just southeast of Trout Creek Butte that emerges from beneath distal limit of late Pleistocene moraines and extends 4 km farther east (between Pole Creek and Brush Draw) to terminus just beyond edge of map area. Unglaciated surface is scoriaceous, rubbly, and locally block jointed, especially on levees. Phenocrysts: 2–3% olivine (0.5–1 mm, very rarely to 4 mm); at least 5% olivine mph (0.2–0.4 mm); ~1% plag phenocrysts (0.5–2 mm), but ~30% plag mph in holocrystalline plag-lath groundmass. Coarse-grained groundmass has abundant plag mph and microlites, as well as diktytaxitic porosity that has scattered 1-mm-wide equant vesicles superimposed. Normal magnetic polarity (Taylor, 1987). Overlies units bbd, acp, and mwh (195±5 ka), wraps around scoria cone of unit acp, and banks against base of unit mtb shield (532±7 ka). Overlain and proximally concealed by late Pleistocene till (unit g); source vent probably far to west. Undated [TCB]

btk **Basalt and basaltic andesite of Talapus and Katsuk Buttes (latest Pleistocene)**—Compound edifice of basaltic (51.7–53.4% SiO_2) lavas, hyaloclastite, and scoria cones that form west wall of Sparks Lake. Elongate edifice, only 1.5 to 2.5 km wide, extends 6 km north-south and has 225 m of relief. Chain of vents near north end, probably dike fed, includes two substantial subaerial scoria cones (stippled on map). In its northern part, lower 140 m of edifice is interpreted as hyaloclastite tuff by Scott and Gardner (1992) that may have erupted through its own meltwater pond within latest Pleistocene recessional ice. Plateau above is capped by stacks of thin subaerial lava flows from several vents. Basal contact of subaerial deposits descends southward, almost to base of edifice at its south end (possibly reflecting southward slope of ice surface at time of eruption). Fragmental deposits are locally palagonitized. Slumps of more coherent rimrock lavas include rotated megablocks 10 to 200 m long (Scott and Gardner, 1992), as well as chaotic rubble. Large area of slumps west of Katsuk Butte was overrun by lava flows of unit mlc, itself of latest Pleistocene age, suggesting that slumping took place soon after deglaciation. Phenocrysts: ~5% olivine (0.2–2 mm, mostly 0.5–1 mm); abundant plag consists mostly of microphenocrystic laths (or clusters thereof), but some lavas contain sparse plag laths 0.5–1.2 mm long, and olivine-plag clots are common. Southwest edge of Katsuk Butte overlies unit dse, and stratified ejecta of Talapus Butte (stippled on map) overlie unit rdh (34.8±1.5 ka) on slope north of Devils Lake. Overlain by units mlc and rdc. Undated [BT, SS] bwl **Basalt of lower Whychus Creek (late or middle Pleistocene)**—Phenocryst-poor basaltic (50.8% SiO_2) lava flow exposed at 4,150 to 4,220 ft elevation on north wall of Whychus Creek near east edge of map area. Deeply eroded flow is block jointed but locally still scoriaceous and rubbly on its surface, which lies barely outside belt of moraine deposits. Source vent unknown, presumably far upstream. Downstream extent beyond map area not determined. Phenocrysts: sparse plag (0.5–2.5 mm), but abundant groundmass plag-lath mph, seriate to microlites; 5–7% olivine (mph to 1.3 mm), seriate to groundmass olivine. Overlies unit mwh (195±5 ka). Overlain by unit acp. Undated [TCB]

bwm **Basalt west of Millican Crater (late Pleistocene)**—Glaciated aprons of olivine-rich basaltic (48.6–50.6% SiO_2) lava flows that crop out widely on both sides of north-trending fissure-fed ridge of unit mpn, which probably conceals their vent. East apron slopes gently southeast for 2 km, overlapping west toe of Millican Crater edifice (unit mmc). West apron slopes northwest for more than 2 km, extending at least as far as Lava Camp Lake (1.2 km north of edge of map area). Most exposures are slightly vesicular but otherwise are massive and block jointed, forming numerous ledges (1–3 m high), knolls, and ice-scoured swells. Window through moraine just south of east apron exposes two ledge-forming lava flows for about 100 m (UTM grid 992/988). Another window, through unit myl about 1.5 km farther southeast, is block-jointed ledge only about 1 m high and 50 m across (UTM grid 010/981). Phenocrysts: moderate variations in plag and olivine abundances among lava flows; 3–10% olivine (mph to 1.5 mm, rarely 2.5 mm); 0–5% plag (0.5–2 mm, rarely as long as 3.5 mm), many subhedral; clots of olivine+plag mph and clusters of olivine mph are as big as 10 mm and generally are sparse but in some flows are abundant. Groundmass is rich in plag-lath mph and microlites. Overlies unit mmc. Overlain by units mpn, myc, myl, and (inferentially) mnt (20±5 ka). Undated [NS, TCB]

bwy **Basalt of Whychus Creek (middle Pleistocene)**—Two windows of phenocryst-poor basalt (51.1–51.8% SiO_2): one is at 5,120 to 5,160 ft elevation just downstream from Upper Chush Falls; other is 2 km north at about 4,800 ft on lowermost North Fork Whychus Creek. Although slightly different chemically, both are nearly aphyric and unlike any other rare basalts in this area. Exposures about 500 m downstream from Upper Chush Falls include 10-m-high ledge (slabby to block jointed), which supports a small waterfall at 5,140 ft elevation on Whychus Creek, and knife-edge point at nearby confluence of Park Creek. On North Fork Whychus Creek, coarsely block jointed rimrock ledge more than 15 m thick supports cascades; its basal flow breccia and massive lava flow drape andesite of unit awy and old till sandwiched between them on right-bank wall. Phenocrysts: almost none; holocrystalline groundmass microlites are seriate to ~3% olivine mph (0.2–0.4 mm) and <1% plag laths (0.2–0.7 mm long); most mph are in olivine-plag-oxide clots. Overlies units mbt and awy (299±1 ka). Overlain by units adl, drm, mwh (195±5 ka), and ruc (169±2 ka). Undated [TCB]

dbh **Dacite of "Black Hump" (late Pleistocene)**—Glaciated pile of effusive dacite (64.0–64.5% SiO_2) lava flows that erupted at vent in saddle between North Sister and Middle Sister. Compact ice-sculpted edifice, variously called "Black Hump" (Hodge, 1925), "Prouty Point," or "Step Sister," is about 1 km across, consists of at least five flow units, and has 325 m of relief, including several cliffy faces. In addition, two of these thick flows extend separately for about 1 km west and northwest of proximal pile as narrow arêtes. Another flow crops out atop medial cleaver in Collier Glacier. Individual flows range in thickness from 25 to 90 m. Lithologies vary from black vitrophyre, locally columnar, to pale-gray devitrified felsite, block jointed or slabby to platy, commonly having oxidized scoriaceous rubbly zones between flows. Phenocrysts: 7–10% plag (mph to 4 mm, rarely larger); 1–2% opx (mph to 2 mm, rarely to 3.5 mm); sparse oxide mph; contains common plag-pyroxene-oxide clots, which account for most pyroxene crystals. Overlies units awc (22±2 ka), dss (25±3 ka), and mms. Relations with unit dhr at col are obscured by scree. $^{40}Ar/^{39}Ar$ ages: 17.9±2.2 ka (for western lava flow), 23±7 ka (for base of pile north of Hayden Glacier) [NS]

dbl **Dacite breccia of Lewis Glacier headwall (late Pleistocene)**—Crudely stratified, pale-gray- to tan-weathering, fragmental dacite (62.6–62.8% SiO_2) deposit as thick as 50 m that banks against paleocrater wall above Lewis Glacier and directly underlies unit dlg. Clasts are monolithologic, glassy, dense or weakly vesicular, subangular to subrounded, and as big as 20 cm throughout most of section but as large as 1 m near top; matrix is seriate from ash to lapilli-sized clasts. Clasts are slightly less silicic than overlying lava flow of unit dlg and contain twice as many plag phenocrysts. Strata are subhorizontal to slightly inboard dipping in headwall exposures, but craggy remnants preserved outboard of wall (atop eroded rim of wall-forming unit adh dome) dip steeply outboard. Phenocrysts: 15% plag (mph to 3 mm); <1% pyroxenes (mostly mph), largely in clots with plag. Top 2 m of unit is baked brick red, contrasting starkly with black, glassy horizontal columns of overlying lava flow of unit dlg (25.3±1.4 ka, 22.3±1.6 ka). Undated [SS]

dcg **Dacite southwest of Clark Glacier (late Pleistocene)**—Southwest apron of South Sister edifice, consisting of many compositionally uniform dacite (63.0–63.5% SiO_2; n=26) lava flows. Stairstep stack of flows, each 15 to 100 m thick, forms glaciated 3 by 3 km surface that extends from Clark Glacier to toe of edifice at Hinton and Mesa Creeks. Lithologies vary from black vitrophyre, commonly chunk jointed or columnar, to devitrified and block jointed or slabby to platy. Flow foliation is commonly conspicuous and locally convolute in thickest flows. Scoriaceous rubbly oxidized zones are common between flows. High on apron, steep and thick eruptive masses have internal shear zones of oxidized breccia intimately alternating with vitrophyric and platy domains, perhaps reflecting influence of snow and ice. Phenocrysts: 10–20% plag (mph to 4 mm); 1–3% pyroxenes (mostly mph, but as big as 1 mm); sparse oxide mph; abundant plag-pyroxene-oxide clots; most pyroxene and half of plag crystals reside in clots. Overlies units bjc, ddl (32±2 ka), rmc (47±8 ka), and rsw (51±10 ka). Overlain by unit aeg (here, 27±2 ka) and also by units rct (24±5 ka, 30±8 ka) and rrm (~2.1 ka), which bank against it. $^{40}Ar/^{39}Ar$ age: 30.7±2.6 ka [SS]

dcl **Dacite of Chambers Lakes (late Pleistocene)**—Agglutinated tephra fallout and rheomorphic dacite (64.8–65.9% SiO_2; n=13) lava flows, widely exposed in saddle between Middle Sister and South Sister. Principal outcrop forms glacially eroded ridge about 1 km wide that separates two clusters of Chambers Lakes. Relief exposed exceeds 110 m, but true thickness is less if ridge-forming agglutinate drapes unexposed units. Deposit is crudely stratified or lensoid, eroded into ledges; variable dips as steep as 25° suggest buried paleotopography. Main lithology is orange and black streaky vitrophyre that grades from densely eutaxitic to tack welded and, locally, to loose pumice and scoriae (as big as 40 cm), which can be black, dark brown, or tan but mostly are oxidized orange. Fiamme vary from tiny wisps to as long as 50 cm and as thick as 15 cm. Lithic clasts include phenocryst-poor mafic lavas but are predominantly pyroxene andesite-dacite, mostly smaller than 10 cm but some as large as 50 cm. Source probably is glacially excavated bowl now occupied by largest lake, adjacent to which juvenile and lithic clasts are both largest. On ridgecrest, least viscous agglutinate sections spread southward and eastward as rheomorphic flows that range in texture from blobby to massive and virtually homogenized; they grade up and down into eutaxite. Where glacially beveled, such flows range internally from densely glassy to devitrified and platy. Phenocrysts: 3–7% plag, varying widely in clasts of similar composition; most plag ranges in size from mph to 2.5 mm, rarely 3–6 mm; 0.5–2% pyroxenes (mostly mph, but sparse grains 0.5–1.5 mm); common oxide mph; some but not most plag crystals are sieved internally; also common are plag-pyroxene-oxide clots, which account for most pyroxene crystals. Overlies unit aeg (27±3 ka), but base is rarely exposed. Overlain by units mcl, mms, and dig (14±3 ka), as well as pumice-fall remnants of unit rdc. $^{40}Ar/^{39}Ar$ age: 26±2 ka [NS, SS]

dcn **Dacite north of Carver Lake (late Pleistocene)**—Sequence of two or three glacially scoured dacite (66.9–67.4% SiO_2) lava flows exposed in windows through Neoglacial till between Carver Lake and Chambers Lakes; all dip northward from buried vent on South Sister edifice, summit of which lies only 2 km south. Lavas are vesicular and glassy or partly devitrified, as well as block jointed and having densely vitrophyric bases that locally are chunk jointed. Phenocrysts: ~10% plag (mph to 4 mm, rarely 6 mm); 1–2% pyroxenes (mph to 2 mm); sparse oxide mph. Base not exposed. Apparently (not certainly) overlain by unit aeg (here, 27±2 ka). Undated [SS]

ddl **Dacite of Dew Lake (late Pleistocene)**—Thick, glacially scoured, phenocryst-poor dacitic (64.1–64.4% SiO_2) lava flows that extend 4 km westward between Separation and Mesa Creeks from beneath southwest apron (unit dcg) of South Sister edifice. Flows tightly wrap vent knob of unit bjc, around which they divide into two tongues. Proximal area exposes as much as 50 m of local relief, and distal cliffs are as high as 80 m in both tongues. Lithology varies from massive black vitrophyre, commonly chunk jointed or columnar, to pale gray, devitrified, and slabby or platy. Phenocrysts: 2–3% plag (mph to 1.5 mm, rarely 3 mm); 0.5–1% pyroxenes (nearly all mph, but rarely as large as 0.8 mm); sparse oxide mph; also contains common plag-pyroxene-oxide clots. Overlies units mtw, bsb, bhs, and bjc. Overlain by units dcg (30.7±2.6 ka) and msc (21±6 ka). $^{40}Ar/^{39}Ar$ age: 32.3±1.8 ka [SS]

des **Dacite ejecta of South Sister summit (late Pleistocene)**—Stratified dacitic (62.8–64.2% SiO_2; n=14) fall and surge deposit, ultraproximal, largely phreatomagmatic, that makes up much of uppermost 120 to 150 m of summit cone of South Sister. Coarse fragmental deposit crops out best above Prouty Glacier headwall east and northeast of summit but also is exposed above Lewis Glacier headwall to southeast and on crater rim west of Teardrop Pool; it is overlain only by dacitic lava flows locally along north rim of summit (units dnt, dnt′) and by thin andesitic agglutinate (unit mtp, topmost eruptive unit that extensively drapes summit). Much of unit banks inside ragged rim of (locally breached) outer paleocrater wall that consists of unit aeg; it rests on intracrater lava dlg and fills paleocrater to unknown depth. Thickest exposed section, on steep slope above Prouty Glacier headwall consists conspicuously of four subunits (not mapped separately):

1. Lowest 10 m is coarsely lithic rich, unstratified to crudely stratified section, poor in juvenile clasts, that dips 10° to 25° outboard; its poorly exposed base rests on unit dlg. Lithic clasts, mostly 1–40 cm across, rarely as big as 100 cm, are angular fragments of underlying unit dlg, most of them hydrothermally altered. Subordinate juvenile dacite material is limited largely to lapilli and finer fractions.

2. Overlying subunit 1, about 30 m of section contrasts in being predominantly juvenile, lithic poor, and well stratified. Its basal 50 cm is sharply bounded, pale-gray interval dominated by juvenile dacite that is glassy, angular, slightly to moderately vesicular, and seriate from ash to 20 cm blocks; this layer banks against and drapes a 5-m-long block of prismatically jointed dacite that rests atop subunit 1 and may represent initiation of dome disruption that followed episode of vent excavation. Nearly all of this subunit consists of thin-bedded to laminated, lithic-poor strata, typically in coherent bedsets 10 to 30 cm thick, that also dip 10° to 25° outboard, like section beneath. Far more thinly stratified than other subunits, its layering is defined by coarse-to-fine alternations on subcentimeter scale. Most clasts are only 0.5 to 2 cm across, although sparse clasts are as big as 20 cm; all are glassy and angular, some are prismatically jointed, and vesicularity varies from fine to poor.

3. Middle 25 to 30 m is coarsest part of section, marked by three very coarse layers, each 4 to 10 m thick, separated by wavy-bedded intervals 1 to 3 m thick; strata dip 15° to 20° inboard and overlie unconformity that smoothly bevels underlying outward-dipping strata. Clasts are massive or poorly vesicular, glassy, angular, matrix-supported, and monolithologic crystal-rich dacite; many are 5 to 50 cm across, and some are prismatically jointed; matrix is crystal-rich coarse ash, seriate to small lapilli. Basal few meters of bedded middle section is disrupted by several small faults.

4. Upper 75 m is stratified only crudely and dips gently inboard, conformable with coarse middle part of section. As in subunit 3 beneath it, clasts are massive or poorly vesicular, glassy, angular, matrix supported, and monolithologic; most clasts are only 0.5 to 2 cm across, although scattered coarser (5 to 15 cm) clasts in lenses or vague horizons help define crude layering. Matrix consists of crystal-rich coarse ash, seriate to small lapilli. Within continuous 145-m-thick section of four subunits, no sedimentary intervals are observed that might represent prolonged breaks in eruption. Wavy and contorted beds and bomb sags are common. Accidental lithic fragments are sparse except in basal 10 m, where angular and altered dacite lithic fragments (0.5–40 cm across, some to 100 cm) are abundant, and all or most are derived from underlying unit dlg. Phenocrysts in juvenile clasts: 15–20% plag (mph to 3 mm); 2–3% pyroxenes (mph to 1 mm); sparse oxide mph; also contains common plag-pyroxene-oxide clots as big as 5 mm, which account for most pyroxene crystals. Overlies units aeg (here, 27±3 ka) and dlg (25.3±1.4 ka, 22.3±1.6 ka). Overlain by units mtp, dnt (23.5±1.1 ka), and dnt′. Undated [SS]

dgc **Dacite of Goose Creek (late Pleistocene)**—Glaciated dacite (64.8–65.3% SiO_2) lava flow that extends 3.5 km southward from southeast toe of South Sister to alluvial plain north of Sparks Lake. Maximum relief about 75 m proximally and medially, but only 35 m at distal terminus. Source vent buried by younger units. Ranges in lithology from black vitrophyre to devitrified, block jointed or slabby to platy. Locally preserved are glassy margins that have vertical, horizontal, and inclined slender columns, suggestive of ice contact. Normal magnetic polarity (Taylor, 1978). Phenocrysts: 5–7% plag (mph to 3 mm); 1–2% pyroxenes (mostly mph, rarely as big as 1 mm); sparse oxide mph; also contains common plag-pyroxene-oxide clots. Intruded and overlain by unit rdc; appears to underlie eroded ridge (UTM grid 004/786) of unit dml (33.6±1.2 ka). Overlies unit abt (178±1 ka, at Fall Creek). $^{40}Ar/^{39}Ar$ age: 31.6±2.0 ka [BT]

dgl **Dacite of Green Lakes (late Pleistocene)**—East-southeast apron of South Sister edifice, consisting of many phenocryst-rich dacite (62.9–64.2% SiO_2) lava flows. Glacially scoured unit forms most of edifice flank on north side of trough draining Lewis Glacier, extending from beneath Hodge Crest planèze (unit aeg) down to Green Lakes basin. Total elevation difference exposed within unit is 600 m, but greatest local relief (and, thus, maximum thickness exposed) is only 130 m (on scarp just west of Green Lakes). Consists of 12 or more flows that range in thickness from about 15 m to 60 to 80 m, thicker ones being strongly flow foliated. Flows range in lithology from dark-gray vitrophyre to devitrified, block jointed, or slabby to platy, weathering tan or pale gray. Phenocrysts: 5–10% plag (mph to 3 mm); 1–3% pyroxenes (0.2–1 mm); sparse oxide mph; also contains common plag-pyroxene-oxide clots, which account for most pyroxene crystals. Overlies unit rgl (32±1 ka). Overlain by units dmn (28±1 ka, 25±1 ka) and aeg (here, 27±2 ka). Undated [BT, SS]

dhr **Dacite of Hayden Glacier–Renfrew Glacier col (late Pleistocene)**—Single dacite (63.6–64.3% SiO_2) lava flow, 15 to 20 m thick, that drapes north ridge of Middle Sister cone from 9,600 ft elevation down to 9,200-ft-high saddle between Hayden and Renfrew Glaciers. Vent is presumed to have been slightly east on part of edifice since removed by Hayden Glacier. Surface of flow is extensively vesicular, oxidized pink, or laced with secondary minerals that lend outcrops an orange cast. Exposures of flow interior are flow foliated, partly glassy, massive or vesicular, block jointed, or locally devitrified and platy. Phenocrysts: ~10% plag (mph to 5 mm); ~2% pyroxenes (mph to 2 mm, rarely 3 mm); sparse oxide mph; also contains abundant plag-pyroxene-oxide clots. Rests unconformably directly on smoothly beveled stack of flows of unit mms. Relations with adjacent unit dbh obscured by scree that fills col. $^{40}Ar/^{39}Ar$ age: 19.1±1.7 ka [NS]

dig **Dacite of Irving Glacier (latest Pleistocene)**—Dacite (64.1–64.2% SiO_2) coulee from inconspicuous vent at 8,500 ft elevation on south slope of Middle Sister. Proximal to medial reach is leveed, unglaciated, and 150 to 400 m wide. Distally, it bifurcates around rhyolite lava dome of unit rsc; southwest arm ends 3 km from vent in 100-m-high, glacially modified cliff above Separation Creek; southeast arm ends 2 km from vent in 135-m-high cliff, where flow banked against ice that had ponded in basin now occupied by Chambers Lakes, as shown by glassy subhorizontal columns widely preserved on flow front. Latest Pleistocene ice encountered by both arms probably still flowed down to saddle from high on South Sister when south slope of Middle Sister was ice free. Thick vitrophyre zones form upper and lower parts of flows, whereas central parts of terminal cliffs include devitrified internal zones exposed by glacial erosion. Vent area is 50-m-wide depression enclosed by blocky sidewall levees 10 to 15 m high and upslope headwall consisting of stack of thin mafic lava flows of older unit mms, which was oxidized brownish orange by dacite eruption. Airborne ejecta are sparse; glassy angular blocks, some prismatically jointed, are strewn about depression, but most tumbled in from levees. Inner east wall of depression is tack-welded to densely agglutinated spatter. Levees adjacent to vent are capped by oxidized flow breccia and locally by agglutinate, but elsewhere levees are composed of black glassy blocks of unoxidized dacite, mostly massive but some having scoriaceous surfaces. Films of secondary minerals coat joints in near-vent dacite and, more conspicuously, in mafic rubble of headwall. Phenocrysts: 5–10% plag (mph to 3.5 mm, rarely to 8 mm); 1–2% pyroxenes (mph to 1.5 mm); sparse oxide mph; also contains common plag-pyroxene-oxide clots; limited thin-section data suggest greater abundance of plag and pyroxene mph in proximal levees than in distal lava lobes. Overlies units mms, rsc (25±1 ka), dcl (26±2 ka), and dsn (19±4 ka). $^{40}Ar/^{39}Ar$ age: 14.4±2.7 ka [NS, SS]

dkb **Dacite of Kokostick Butte (late Pleistocene)**—Phenocryst-rich dacite (62.5–63.1% SiO_2) coulee and chain of small satellite domes 2 to 5 km south of Rock Mesa. Coulee is 2 km long and 1 km wide, having maximum relief of 100 to 150 m at its southern flow front, from which springs emerge as source of Sink Creek. Chain of five satellite domelets extends 1.8 km south-southwest from main coulee, to which they are compositionally identical; domelets range in height from 30 to 90 m and in width from 130 to 300 m. Coulee and domelets are glacially scoured but have little till on top; all are widely glassy and retain extensive outcrops of slender exterior columns, which are commonly inclined or subhorizontal, suggestive of ice-contact effusion. Where most deeply eroded by ice, steep faces of coulee and two largest satellites expose partly devitrified, vertically jointed to slabby interiors. Phenocrysts: 15–20% plag (mph to 3 mm); 2–3% pyroxenes (mostly mph, but as big as 1 mm); sparse oxide mph; also contains abundant plag-pyroxene-oxide clots, which account for most pyroxene crystals. Southern domelets intrude and overlie apron of mafic lava flows (unit mkm) from Koosah Mountain. Mafic lava flows of postglacial unit mlc wrap coulee and two domelets. $^{40}Ar/^{39}Ar$ age of coulee: 27.3±2.6 ka [SS]

dlc **Dacite of Linton Creek (late Pleistocene)**—Window of glaciated dacite (66.8% SiO_2) lava that has 70 m of steep relief, exposed only in 100 by 300 m area at about 5,800 ft elevation in headwaters of middle fork of Linton Creek, just above Pacific Crest Trail (UTM grid 946/876). Glassy, finely vesicular, flow-foliated, chunk-jointed zone below is overlain by platy devitrified zone near top of exposure. Phenocrysts: 5–8% plag (mostly mph, but as long as 1.7 mm); ~1% pyroxenes (mph to 1.5 mm); sparse oxide mph; also contains common plag-pyroxene-oxide clots, which account for most pyroxene crystals. Base not exposed. Overlain by units ahl, alc (27±1 ka), mhl, and mms. Undated [NS]

dlg **Dacite of Lewis Glacier headwall (late Pleistocene)**—Thick dacite (63.5–63.8% SiO_2) lava flow near summit of South Sister that crops out as bold cliffs high on headwalls above Lewis and Prouty Glaciers. Convolutely foliated flow is 75 to 100 m thick and banks against ragged wall of paleocrater that consists of units aeg, ahc, adh, and alh, as exposed on both headwalls. Vitrophyre and partly devitrified upper zone overlie cliff-forming devitrified internal zones, block jointed or slabby, exposed above glaciers. Basal zones exposed in both headwalls exhibit subhorizontal columns as thin as 8 cm; vertical fractures cutting columns impart hackly appearance. Overlies fragmental deposit of unit dbl in Lewis Glacier headwall and another older fragmental deposit (unit ahc) in Prouty Glacier headwall; lava of this unit baked both underlying units. Overlain by 150-m-thick section of phenocryst richer fragmental dacite strata (unit des). Another glaciated dacite (63.7–64.4% SiO_2) lava flow as thick as 60 m, which crops out 2 km north of summit (and 600 m lower), is correlated chemically and petrographically and here also assigned to this unit. Flow is widely devitrified and platy, although locally glassy, block jointed, or brecciated; it weathers pale gray or tan, and its exposure extends about 1 km northward along west side of steep gulch draining into eastern cluster of Chambers Lakes. Base of flow is not exposed; flow is directly overlain by rhyolitic lava flow of late Holocene unit rdc and is apparently intruded by its feeder dike. Phenocrysts: 3–5% plag (mph to 2 mm); 1–2% pyroxenes (mostly mph, but including rare crystals 1–2.5 mm); sparse oxide mph; also contains common plag-pyroxene-oxide clots, which account for most pyroxene crystals. Overlies or banks against units aeg (here, 27±3 ka), adh, ahc, alh (30±1 ka), and dbl. Overlain by units des and rdc. $^{40}Ar/^{39}Ar$ ages: 25.3±1.4 ka, 22.3±1.6 ka [SS]

dlp **Dacite of Lane Plateau (late Pleistocene)**—Sandal-shaped dacite (64.2–65.3% SiO_2) coulee and glacially eroded remnant of narrow lava stream that fed it from vent at 7,800 ft elevation on west slope of Middle Sister. Coulee, 2 by 1 km in area and having 90 m of relief distally, forms steep-sided ice-scoured plateau that slopes gently westward between Linton and Obsidian Creeks. Remnant of feeding flow forms 800-m-long steep ridge about 150 m wide that has as much as 40 m of local relief; segments formerly connecting it to both vent and coulee have been eroded away. Extrusive vent mass, 2.2 km east of main coulee and 425 m higher in elevation, is unusual protrusion 150 m long and 20 to 50 m thick that stands as wall-like monument about 25 m high. Steep downhill face of wall is largely glassy and widely retains horizontal polygonal joints, including long slender radial and inclined columns at its upper edge, suggesting that extrusion took place into ice. Near-vertical joints crop out at base of wall where dacite welled out over (and baked) andesite lava of unit awm. Both coulee and feeder ridge are lithologically varied, widely exhibiting vitrophyric exterior facies (locally columnar) but slabby to platy devitrified interior facies where more deeply eroded. Phenocrysts: 5–7% plag (mph to 3 mm, rarely to 8 mm); 2–3% pyroxenes (mph to 1 mm, rarely to 2 mm); sparse oxide mph; also contains common plag-pyroxene-oxide clots;

limited thin-section data suggest that phenocryst abundance of near-vent lava is roughly half that of medial and distal lava. Overlies units aoc, alc (here, 27±1 ka), ahl (21±3 ka), and awm. Younger units mms and mms′ bank against uphill wall of vent mass. $^{40}Ar/^{39}Ar$ age: 21.4±1.9 ka [NS]

dmc **Dacite of Mesa Creek (middle Pleistocene)**—Poorly exposed window of glaciated dacite (65.1% SiO_2) lava that forms north slope of Mesa Creek, 0.5 to 1.5 km west of Rock Mesa. South-sloping surface has about 60 m of total relief; pink and gray exposures exhibit strong flow foliation, locally platy. Source vent, concealed by younger units, probably is buried beneath much younger South Sister edifice. Phenocrysts: ~7% plag (mph to 1.3 mm); ~2% pyroxenes (nearly all mph, rarely as long as 1 mm); sparse oxide mph; contains common plag-pyroxene-oxide clots. Base not exposed. Overlain by units mlc and bjc (148±4 ka). Undated [SS]

dml **Dacite southeast of Moraine Lake (late Pleistocene)**—Glaciated stack of phenocryst-rich dacite (64.0–65.7% SiO_2) lava flows north of Devils Hill that extends 2 km southeast from Moraine Lake to Goose Creek. One flow extends 1 km southwest, where its snout emerges from beneath younger coulee of unit dmw. Main pile south and east of Moraine Lake has as much as 140 m of relief and consists of at least four flows, all heavily mantled by proximal pumice-fall deposits of units rrm and rdc. Moraine Lake has no moraine; valley-crossing ridge above its south shore is spur of glaciated lava of this unit, thickly mantled by pumice and discontinuous subordinate veneer of glacial debris. Distal crags, severely ice sculpted at Goose Creek, have about 100 m of relief. External vitrophyre facies are widely preserved on stairstep ledges, whereas shelves and plateaus, more deeply scoured, tend to expose internal devitrified zones, commonly platy. On steep ledge banked against Devils Hill and on west-facing scarp south of Moraine Lake, slender glassy columns (commonly inclined or sub-horizontal) are widespread, suggesting ice-contact emplacement. Compositionally similar to underlying unit dwp and overlying unit dmw. Phenocrysts: 5–10% plag (mph to 3 mm); ~1% pyroxenes (nearly all mph, rarely as big as 0.8 mm); sparse oxide mph; also contains common plag-pyroxene-oxide clots, which account for most pyroxene crystals. Overlies unit dwp (34±3 ka); appears to overlie unit dgc (32±2 ka), but relation is uncertain. Banks against units rkb and rdh (35±2 ka). Underlies units dmn (28±1 ka), dmw, rse (34±1 ka), and rdc. $^{40}Ar/^{39}Ar$ age: 33.6±1.2 ka [BT, SS]

dmn **Dacite north of Moraine Lake (late Pleistocene)**—Glacially scoured dacite (65.1–66.3% SiO_2) lava flows on south slope of South Sister; exposed as high as 8,840 ft elevation at snout of Lewis Glacier, extending 3 km south, nearly to Moraine Lake, in two (compositionally identical) tongues, each a single flow. Thickness as much as 80 m, proximally, medially, and distally. Source vent probably central on South Sister, now covered by unit aeg and other younger units. Vitrophyre facies are patchily preserved and typically block jointed, but most exposures are devitrified (or partly so) and either block jointed or platy. Phenocrysts: 5–7% plag (mph to 3 mm); 1–2% pyroxenes (mostly mph, sparsely 0.5–1.5 mm); sparse oxide and olivine mph; clots of plag+pyroxenes+oxides are common, accounting for most pyroxene crystals. Overlies units dgl, dml (33.6±1.2 ka), dmw, and rse (34±1 ka). Overlain by units aeg (here, 27±2 ka), als, and rct (24±5 ka). $^{40}Ar/^{39}Ar$ ages: 27.7±1.0 ka (west tongue), 25.2±0.8 ka (east tongue) [SS]

dms **Dacite of Middle Sister summit (late Pleistocene)**—Glassy, phenocryst-poor dacite (63.9–66.7% SiO_2) lava flow that drapes upper southeast ridge of Middle Sister, extending from within 30 m (south) of true summit (10,047 ft elevation) downslope for about 350 m to 9,420 ft elevation. Small outlier 80 m farther down ridgecrest and another just north of summit suggest that much more was eroded away. Main remnant is 100 to 200 m wide across ridgeline and 10 to 20 m thick; its ragged southwest contact reflects instability of subjacent thin rubbly flows of unit mms on steep slope. Blocky surface is frost riven but was not overridden by glacial ice. Eroded mass of possible vent plug cuts unit mms below east rim in precipitous chute about 100 m southeast of true summit. Black glassy blocks are generally massive, rarely vesicular or partly devitrified. Greenish-black, finely vesicular, phenocryst-poor pumice lapilli sparsely scattered among blocks on ridgecrest are compositionally similar. Phenocrysts: 2–3% plag (mph to 1.5 mm); ~1% pyroxenes (nearly all mph, rarely as big as 1 mm); sparse oxide mph. Rests directly on unweathered surface of unit mms. Unit mss banks against northern remnant. Undated [NS] dmw **Dacite coulee west of Moraine Lake (late Pleistocene)**—Glacially scoured, steep-sided dacite (64.6–65.5% SiO_2) lava flow at south toe of South Sister. Flow emerges from beneath younger lavas on lower slope of edifice and extends 3 km southward where it banks against unit dml at north side of Kaleetan Butte. Flow is 0.5 to 1 km wide, about 60 m thick distally, and 90 to 120 m thick medially, adjacent to Moraine Lake. Phenocryst-rich dacite is widely flow foliated. Devitrified interior, block jointed to platy, is widely exposed, but vitrophyric margins (dense or locally vesicular) are also extensively preserved, including widespread chunk jointing and slender columns, inclined or subhorizontal, indicative of ice-contact emplacement. Rusty films common on joint surfaces. Phenocrysts: 10–15% plag (mph to 3 mm); 1–2% pyroxenes (mostly mph, but as large as 0.8 mm); also contains abundant plag-pyroxene-oxide clots, which account for nearly all oxide mph present. Proximal part of flow also has trace hornblende (mph to 1 mm long), all grains of which are marginally or fully opacitized. Overlies units dml (33.6±1.2 ka) and dwp (34±3 ka). Overlain by lithologically similar unit dmn (28±1 ka) and by unit rct (24±5 ka). Undated [SS]

dnt **Dacite north of Teardrop Pool (late Pleistocene)**—Block-jointed and fractured, glassy, phenocryst-rich dacite (62.7–63.1 % SiO_2) lavas that directly cap compositionally similar fragmental unit des for about 200 m along northwest rim of South Sister summit. Sandwiched between unit des and summit-mantling agglutinate unit mtp, total lava thickness is 8 to 10 m near rim. Outboard of rim, lavas extend about 100 m downslope in three overlapping fingerlike lobes that drape steep slope of fragmental unit des; blocky lobes are marked by joint-coating films of white and orange precipitates. Phenocrysts: 10% plag; 2–3% pyroxenes; also contains common plag-pyroxene clots. $^{40}Ar/^{39}Ar$ age: 23.5±1.1 ka [SS]

dnt′ **Silicic dacite north of Teardrop Pool (late Pleistocene)**—Massive glassy ledge of phenocryst-rich dacite (67.1% SiO_2) on north rim of South Sister summit; petrographically similar to, but far more silicic than, dacite lavas of unit dnt, only about 100 m west. Ledge is only 30 to 50 cm thick and crops out laterally for only about 15 m. Films of white and orange precipitates are present on smooth joints and on its upper surface. Phenocrysts: 7–10% plag (mph to 3 mm); 2–3% pyroxenes (mph to 0.7 mm); sparse oxide mph; also contains common plag-pyroxene-oxide clots. Sandwiched between top of unit des and summit agglutinate unit mtp, ledge is in same stratigraphic position as unit dnt but represents anomalously silicic effusion, presumably of small volume. No evidence is preserved in outcrop or thin section for welding or pyroclastic texture, but origin as rheomorphically homogenized agglutinate seems likely. Undated but presumed to be virtually contemporaneous with unit dnt [SS]

dpg **Dacite pumice fall of Prouty Glacier headwall (late Pleistocene)**—Dacite (64.6% SiO_2) scoria-fall deposit, pale gray to buff weathering, 5 to 20 m thick, exposed on steep headwall above Prouty Glacier. Crudely stratified in lower half, moderately so in upper half, having nearly horizontal layering. Unit consists predominantly of phenocryst-poor scoria lapilli, mostly 1 to 2 cm but as big as 20 cm, and it lacks fine-grained matrix. Pale-gray lithic ejecta as big as 10 cm, principally of intermediate lava, are common near base. Most small scoriae are buff, although some are dark brown or mixed; larger scoriae are dark brown or gray internally but typically retain buff exterior; all are glassy and finely to coarsely vesicular. Stratification in basal several meters at south end of exposure is accentuated by alignment of elongate (slightly flattened), large dark clasts. Phenocrysts: ~1% plag (mph to 1-mm-long laths); <1% pyroxenes (all mph); sparse oxide mph; sparse fine-grained clots of plag+pyroxenes+oxides. Rests directly upon lava of unit rpg (32.8±1.5 ka) and unit aph′. Overlain unconformably by tephra-fall deposit of unit ahc and by layered scoria, agglutinate, and fountain-fed lavas of cone-building andesite unit aeg (here, 27±3 ka). Undated but compositionally and petrographically similar to lava of unit ddl (32±2 ka) on opposite side of South Sister [SS]

drm **Dacite of Red Meadow (late Pleistocene)**—Extensive set of glacially scoured dacite (62.6–66.3% SiO_2; n=20) lava flows on northeast apron of South Sister. Emerging from beneath Neoglacial moraines of Prouty Glacier, ledgy stack of several 10- to 20-m-thick flows condenses medially to two thick flows, one of which continues 6 km northeast, forming broad divide between Whychus and Park Creeks. Where two flows are exposed locally (see internal contact near UTM grid 024/877), unit is as wide as 2 km medially, and surface is extensively mantled by Pleistocene till. Thickness is as great as 150 m medially and at least 60 m near distal terminus. Despite having been everywhere overrun by Pleistocene ice, unit widely retains vitrophyric external facies, including flow-margin carapace of slender black inclined columns facing Red Meadow, suggesting emplacement against valley glacier. In many patches, however, erosion has exposed devitrified internal facies, partly to fully devitrified and commonly slabby to platy. Phenocrysts: 10–15% plag (mph to 3 mm); 1–2% pyroxenes (mostly mph, but as large as 1.5 mm); sparse oxide mph; also contains abundant plag-pyroxene-oxide clots, which account for most pyroxene crystals. Nearly all plag is clean and unsieved; rare sieved plag crystal observed is apparent xenocryst attached to 1.5 mm olivine that has reaction rim. Overlies units apc (31±9 ka), rpc, rpg (32.8±1.5 ka), and bwy; wraps around snout of unit rsf coulee (36±2 ka). Overlain by units adl (24±1 ka), awf (24±1 ka), and, proximally, aeg (here, 27±3 ka). $^{40}Ar/^{39}Ar$ age: 28.7±0.8 ka [BT, SS, TCB]

dse **Dacite east of Sink Creek (late or middle Pleistocene)**—Phenocryst-poor dacite (66.2% SiO_2) lava flow forming 200-m-wide glaciated shelf that crops out for about 800 m beneath southwestern margin of Katsuk Butte. Ledge front has about 25 m of relief. Mantled by surficial deposits, unit is poorly exposed, consisting mostly of angular blocks of massive flow-foliated dacite. Phenocrysts: almost none; very rare plag (0.5–2 mm); very rare cpx mph prisms. Groundmass contains sparse quench needles of flow-aligned oxides and plag (mostly microlites, but rarely as big as 0.1 by 1 mm). Base not exposed. Overlain by unit btk. Postglacial lava flows of unit mlc bank against unit. Undated [SS]

dsn **Dacite north of Separation Creek (late Pleistocene)**—Glacially scoured flow of moderately porphyritic dacite (64.3–64.4% SiO_2) lava between headwaters forks of Separation and Linton Creeks. Forming barren plateau (0.5 by 1 km) of extraordinarily platy lava at about 6,850 ft elevation, flow has maximum exposed relief of about 40 m near its western limit. Source vent buried beneath younger units of Middle Sister edifice; composition is remarkably similar to that of overlying coulee of unit dig, which also erupted on Middle Sister. Thick flow is almost horizontal, having probably ponded at lowland toe of edifice. Massive vitrophyric lower zone is exposed along marginal drainages, but most of extensive outcrop is devitrified and platy, commonly splitting into plates only 0.5 to 1 cm thick. Phenocrysts: 2–5% plag (mph to 3 mm); <1% pyroxenes (nearly all mph, but rarely 0.5–1 mm); sparse oxide mph; also contains common plag-pyroxene-oxide clots, which account for most pyroxene crystals. Base not exposed. Overlain by units mms and dig (14±3 ka). $^{40}Ar/^{39}Ar$ age: 19±4 ka [NS, SS]

dss **Dacite of Sister Spring (late Pleistocene)**—Glacially scoured dacite (63.6–63.7% SiO_2) lava flow at northwest toe of Middle Sister edifice, directly overlying coulee of the rhyolite of Obsidian Cliffs (unit roc). Depressions on barren plateau surface contain several ponds, including “Arrowhead Lake.” Thickest exposure is northwest scarp, 60 to 80 m high, from base of which Sister Spring emerges. Most outcrops are devitrified and very platy, though patchy remnants of vitrophyre remain on plateau surface. Phenocrysts: 5% plag (mph to 2.5 mm); ~1% pyroxenes (mostly mph, rarely as big as 0.5 mm); sparse oxide mph; also contains common plag-pyroxene-oxide clots. Overlies unit mlb (~48 ka); also overlies unit roc (38±2 ka), draping several lithologic zones of rhyolite. Overlain by units awc (22±2 ka), mms, and mrg (20±6 ka). $^{40}Ar/^{39}Ar$ age: 25±3 ka [NS]

dsw **Dacite domes southwest of Middle Sister (late Pleistocene)**—Three small dacite (65.4–65.5% SiO_2) lava domes, identical in composition, low on southwest slope of Middle Sister. Two western domes, which are contiguous, are 500 m and 400 m in diameter, and each has about 90 m of maximum relief. Smaller dome, 500 m east, has only 50 m of relief and is 150 m wide. Line transecting three vents strikes N. 70° E., unlike any other such alignment in region. Although all were lightly scoured by ice, glassy carapace is widely preserved, varying from densely vitrophyric to micropumiceous. Outward-directed polygonal jointing and slender columns (locally horizontal) are retained in glassy exterior facies of all three domes, suggesting possibility of extrusion through ice. Limited exposures of devitrified, block-jointed to slabby felsite were found atop eastern and central domes. Phenocrysts: 7–10% plag (mph to 4.5 mm); ~1% pyroxenes (mostly mph, but sparsely 0.5–1.7 mm); sparse oxide mph; also contains common plag-pyroxene-oxide clots. Extruded through and onto Middle Sister apron of unit mms lavas. $^{40}Ar/^{39}Ar$ age: 17±15 ka [NS]

dtl **Dacite of Todd Lake (middle Pleistocene)**—Multiflow edifice of glaciated dacitic (62.6–65.0% SiO_2) lavas at southeastern margin of map area, between Sparks and Todd Lakes, at south toe of Broken Top volcano. Edifice is elongate northeast, is 3.5 km long, covers about 4 km^2, and has 475 m of relief on its southwest slope. Extensively till-mantled, eroded lavas flows are block jointed or slabby to platy. All or most flows are phenocryst rich. Phenocrysts: 7–10% plag (0.5–3 mm); 1–2% each of opx, cpx, and Fe-Ti oxides. Petrographic summary given by Taylor (1978), who also determined normal paleomagnetic polarity for several lava flows and described plug just north of summit. Overlies unit mbl. Holocene unit mec banks against west toe of edifice, and (according to Taylor, 1978) middle Pleistocene mafic and andesitic lavas from Broken Top bank against north toe. Whole-rock K-Ar age of 460±30 ka was given by Hill (1991) [BT]

dwl **Dacite west of Lost Creek Glacier (late Pleistocene)**—Stairstep pair of thick dacite (63.1, 64.6% SiO_2) lava flows that form steep glaciated buttresses on west slope of South Sister, 0.8 to 1.1 km west of upper Lost Creek Glacier. Lower flow forms dark-gray-weathering cliff, 40 m high, that has extensive exposures of flow-foliated devitrified lava that splits platy. Upper flow, more silicic, is as thick as 75 m and generally is glassier and irregularly jointed or block jointed, although devitrified slabby zones also are exposed. Both cliff-forming flows have low-relief benches on top. Phenocrysts: 10–15% plag (mph to 4 mm); 1–3% pyroxenes (mph to 1.5 mm); sparse oxide mph; both flows also contain abundant plag-pyroxene-oxide clots, which account for most pyroxene crystals; upper flow is rich in pale-gray, finely vesicular, fine-grained enclaves, mostly 1–2 cm, that contain mph of plag and pyroxene. Overlies unit alg (27±1 ka). Overlain by stack of numerous thin lavas of cone-building unit aeg (here, 27±3 ka). Undated [SS]

dwp **Dacite of Wickiup Plain (late Pleistocene)**—Glacially scoured dacite (64.0–64.5% SiO_2) lava flow beneath southeastern margin of Rock Mesa (unit rrm). Exposed in several windows through thick pumice-fall deposit of unit rrm. More than 50 m of relief is exposed distally; 35-m-high crag along flow margin at Wickiup Plain retains slender glassy columns, horizontal and inclined, that suggest ice-contact emplacement. Sparse scattered exposures along surface of largely pumice-buried flow are either vitrophyric and polygonally jointed or devitrified and slabby to platy. Flow continues south beneath unit rkb and crops out further at south toe of Kaleetan Butte, where it is likewise variously glassy or devitrified and locally oxidized. Phenocrysts: 10–15% plag (mph to 4.5 mm); 1–2% pyroxenes (mostly mph, rarely 0.5–1 mm); sparse oxide mph; also contains common plag-pyroxene-oxide clots. Base not exposed. Overlain by units rct (24±5 ka), rkb, rrm, dml (33.6±1.2 ka), and dmw, and its snout is wrapped by postglacial unit mlc. Like adjacent dacite lavas, flow probably vented well up on South Sister edifice; if so, it would also extend north beneath unit dcg (31±3 ka), but lowland trough between them is covered entirely by Rock Mesa pumice deposits (unit rrm). $^{40}Ar/^{39}Ar$ age: 34±3 ka [SS]

mbc **Basaltic andesite of Black Crater (late or middle Pleistocene)**—Large mafic (55–57% SiO_2) lava and scoria cone, situated mostly north of map area (fig. 2). Cone is 3 km in diameter, has 900 m of relief, and produced lava-flow apron that extends 4 to 5 km north and northeast of summit. Stratified proximal agglutinate, scoria, and fountain-fed lava flows dip radially away from central microdiorite plug. Lower slopes were glacially scoured, and two supposed “craters” on north and east are actually glacial cirques. Lavas exposed at north edge of map area are massive, less commonly vesicular, and glacially eroded into series of block-jointed or irregularly jointed ledges. Phenocrysts: 0.5–3% plag (0.5–1 mm); ~1% olivine (mph to 1 mm, rarely to 2.5 mm, locally in clusters); trace amounts of cpx. Overlain by unit mmc. Normal paleomagnetic polarity (Taylor, 1987). Undated [TCB]

mbl **Basaltic andesite of Bare Lake (middle Pleistocene)**—Sparsely to moderately porphyritic mafic (54.8–57.2% SiO_2) lava flows and ejecta exposed in two areas beneath south slopes of Todd Lake dacitic edifice (unit dtl). Western exposure forms steep glaciated nose that has 140 m of relief; eastern exposure has 250 m of relief, much of it cliff forming. Consists of several ledgy flows, block jointed or slabby to thinly platy; thickest flow, which forms 80-m-high southeast cliff above “Todd Creek,” has steep curviplanar joint sheets that disintegrate into slabby talus. Fissure vent, which is marked by stratified scoria and agglutinate, trends north for 400 m along ridgecrest northwest of Bare Lake. Roadcuts in western outcrop expose brick-red scoria-fall deposit, loose to variably agglutinated and 3 to 10 m thick, underlying lava ledge into which agglutinate grades; fallout consists mostly of lapilli but also includes bombs as big as 25 cm, suggesting likelihood of second vent (concealed) closer than fissure vent 2 km east. Phenocrysts: most flows have 1–2% plag (0.5–1 mm) and sparse olivine and cpx (each 0.1–0.4 mm); cliffy flow facing "Todd Creek" contains ~8% plag (1–4 mm), common 1 mm olivine, and sparse cpx. Lavas also carry abundant fine-grained inclusions, 0.5–6 cm across, that contain opx, cpx, and plag phenocrysts and, thus, may be dacitic xenoliths. Tiny glaciated nubbin beside highway 100 m southeast of "Todd Creek" (UTM grid 051/744) is outlier of phenocryst-poor cpx-olivine-plag lava that carries same inclusions. Lavas bank against dome of pyroxene-plag rhyodacite (unit rtl; 69.5% SiO_2) southwest of Todd Lake, according to Taylor (1978), who also reported that unit mbl has normal paleomagnetic polarity. Overlain by unit dtl (460±30 ka; Hill, 1991); Holocene unit mec banks against toes of both exposures. Undated [BT]

mbt **Basaltic andesite of Broken Top (middle Pleistocene)**—Catch-all assemblage of varied and undifferentiated mafic lava flows, all thought to have erupted at or near Broken Top volcano. Generally mapped only around fringes of Broken Top apron, essentially to define boundary of present map area. Broken Top volcano has not yet been studied in detail, but its apron lavas, crater walls, and central intrusion are predominantly basaltic andesite. Our reconnaissance and that of Taylor (1978) and Webster (1992) indicate that andesite, dacite, and rhyodacite are subordinate and that edifice was built between roughly 300 ka and 150 ka. Lavas lumped in this map unit range in texture from phenocryst poor to phenocryst rich and in composition from 52.5% to 57.8% SiO_2 (n=28); all contain plag (seldom bigger than 3 mm) in excess of olivine (mph to 1 mm, rarely to 2 mm) and typically subordinate cpx (0.5–1 mm); sparse oxide mph are present in some samples, but not all. Older than most contiguous units described herein except for a few intercalated Broken Top andesite-dacite lavas east of Fall Creek that are assigned to comparable catch-all andesitic unit abt [BT, TCB]

mbw **Basaltic andesite of Whychus Creek bridge (middle Pleistocene)**—Four limited exposures of phenocryst-rich mafic (52.9% SiO_2) lava flows, which crop out as windows through till in bed of Whychus Creek near bridge at 4,400 ft elevation on U.S. Forest Service Road 1514 and on noses of ridges just southwest and northeast of there. Glaciated ledges are block jointed and massive or sparsely vesicular. Phenocrysts: ~20% plag (mph to 4 mm); 3–5% olivine (mph to 2 mm); rare cpx. May have erupted at or near Broken Top. Base not exposed. Overlain by units awy (299±1 ka) and mwh (195±5 ka). Undated [TCB]

mcl **Basaltic andesite of Camp Lake (late Pleistocene)**—Apron of phenocryst-poor mafic (56.3–56.8% SiO_2) lava flows that extends from its glacially eroded vent complex at about 7,700 ft elevation on southeast flank of Middle Sister for 4 km eastward between North and South Forks, Whychus Creek. Vent area is ice-ravaged scoria-cone remnant (stippled on map) exposed in 600-m-wide window through lavas of unit mms. Scoria deposit is crudely stratified, mostly coarse ejecta but locally is well-bedded ash and lapilli. Bombs are as big as 1 m, and deformed spatter blobs are as long as 2 m and as thick as 30 cm. Deposit varies from loose to moderately agglutinated and is mostly brick red but locally black, and its exposed thickness is as great as 25 m; base is not exposed. Where capped by coeruptive lava flows or cut by dikes of unit mms or overlain by lavas of unit mms, scoria deposit is further oxidized and fused near contacts. Central lava mass, 60 by 100 m wide and 15 to 20 m thick, is massive, largely devitrified, and block jointed, except that its basal 2 to 3 m is platy. This platy jointing dips radially inward, as does bedding in subjacent scoria. If it is manifestation of plug, effusing lava must have flared radially outward, such that all its contacts dip moderately, and no steep contacts or steep flow foliation are exposed. Outflow lavas are eroded into stairstep benches, cliffs, and pond-filled hollows. Many exposures are 60 to 90 m thick, and distal cliff at South Fork Whychus Creek (UTM grid 022/882) is 120 m high; unit consists of several flows, individually 10 to 30 m thick. Black, glassy, chunk-jointed zones are exposed locally, but most outcrops are devitrified and block jointed to platy. Phenocrysts: 1–3% plag (mph to 1 mm); ≤1% olivine (mph, rarely 0.5–1 mm); very sparse oxide mph; many plag phenocrysts are in clusters, which less commonly also include olivine and oxide mph. Groundmass typically is rich in plag microlites, which are in some samples seriate to plag mph. Overlies units adl (24±1 ka), mdl, mnf, and msf; fills relief cut into unit dcl (26±2 ka) just northeast of largest of Chambers Lakes (UTM grid 983/868); banks against toe of unit rsf coulee (35.8±2 ka). Overlain by units mms′ and mms; cut by dikes of unit mms. $^{40}Ar/^{39}Ar$ ages: 16±10 ka, 23±16 ka [NS, TCB] mdl **Basaltic andesite north and south of Demaris Lake (middle Pleistocene)**—Glacially eroded, cpx-bearing mafic (53.0–53.6% SiO_2) lava flow exposed in two windows through younger lavas, each about 500 m away (to south and to north) from Demaris Lake. Compositionally similar but not identical, they may be different flows. Southern outcrop (53.0% SiO_2) is single flow more than 60 m thick, block jointed to slabby, that forms east-facing cliff. Northern outcrop, which is more subdued, has ice-scoured, block-jointed ribs of modest relief. Phenocrysts: 7–10% plag (mph to 2.5 mm); ~1% olivine (mph to 1.5 mm); sparse 1 mm cpx, found principally within three-phase clots; clusters of plag crystals also common. Base not exposed but probably lies atop nearby unit msf, which is here extensively till covered. Overlain by units mcl, adl, and rsf. $^{40}Ar/^{39}Ar$ age: 181±21 ka (southern window) [TCB]

mdw **Basaltic andesite west of Dutchman Flat (late or middle Pleistocene)**—Glaciated mafic (56.8% SiO_2) scoria cone, forming Hill 6485 at north edge of Mount Bachelor Ski Area carpark. Cone is 75 m high and 350 by 500 m wide, and it consists of stratified brick-red scoria and agglutinate, mantled with glacial deposits. Phenocrysts: common plag; sparse olivine. Wrapped on west by early Holocene lava flows of unit mec and on east by postglacial lavas of Mount Bachelor (Scott and Gardner, 1992). Undated [BT]

mec **Basaltic andesite and basalt of "Egan Cone" (early Holocene)**—Postglacial basaltic (50.7–52.2% SiO_2) scoria cone (stippled on map) at southeast edge of map area (at north toe of Mount Bachelor) and extensive apron of mafic (51.2–54.1% SiO_2) lava flows that extends 2 km north and 4.5 km west and northwest to Sparks Lake (which it helped to impound). Flows are rugged, scoriaceous, rubbly, commonly leveed, and little eroded. Breached scoria cone, which is 800 m wide and 200 m high, consists of brick-red scoria lapilli and bombs. Phenocrysts: almost none; common olivine and plag mph (0.1–0.5 mm); uncommon mph clusters of olivine or olivine+plag; rare plag megacrysts (as big as 6 mm and typically shattered). Groundmass rich in plag-lath mph (rarely as long as 0.7 mm), seriate to microlites; plag microlites appear to be increasingly abundant distally. Overlies unit bbr and postglacial lavas of Mount Bachelor; banks against units dtl, mbl, mdw, mts, and rtl. Primary scoria-fall deposit just east of "Egan Cone" is virtually unweathered where overlain directly by Mazama ash (7.7 ka), suggesting that unit is only slightly older (Scott and Gardner, 1992). Also overlain by late Holocene pumice falls of units rrm and rdc. Equivalent to unit "mb6" of Scott and Gardner (1992), youngest unit of entire 25-km-long Mount Bachelor volcanic chain. Undated [BT]

mey **Basaltic andesite east of Yapoah Lake (late Pleistocene)**—Apron of mafic (52.8–53.2% SiO_2, at 1.3% TiO_2 and 0.85% K_2O) lava flows on north-northeast flank of North Sister that carry conspicuous clusters of olivine and plag mph. Glaciated flows crop out widely between 6,000 and 5,400 ft elevation between Yapoah Lake and Alder Creek. Source is probably North Sister or unidentified vent on its north flank. Ice-scoured ledges, ribs, and knobs are mostly devitrified and block jointed or slabby, but zones that remain partly glassy crop out locally. Phenocrysts: true phenocrysts are sparse, but clusters of olivine mph and clots of intergrown plag and olivine mph are abundant and diagnostic of unit; most clots are 0.5–1.5 mm across and rarely as big as 5 mm; altogether contains 3–5% olivine (0.2–2 mm) and <1% plag phenocrysts (0.5–1 mm), but abundant plag mph are seriate to groundmass microlites. Overlies units myl and bac (128±7 ka) and either overlies or intercalates with some clot-poor older North Sister lavas (unit mns). Overlain by units mfy, mwy, mys, and younger lavas of unit mns. Unit appears to be sequence of North Sister flows that represent subtly distinguishable variant intercalated within dominant sequences of unit mns lavas (which are chemically slightly different at 53–55% SiO_2, 1.0% TiO_2, and 0.7% K_2O). Undated [NS, TCB]

mfy **Basaltic andesite of fissure vent south of Yapoah Lake (late Pleistocene)**—Glaciated ridge of fissure-fed, brick-red mafic (56.2–57.6% SiO_2) scoria lapilli and bombs, just north of Knob 6435 and about 1 km south of Yapoah Lake. Scoria ridge is 400 m long, trends N. 10° to 20° E., has 40 to 60 m of relief, is strewn with varied erratics, and is surrounded by glacially eroded remnants of apron of comagmatic fountain-fed lavas. Scoria exposures generally are nonindurated, not agglutinated; lavas are massive, block jointed, and eroded into bold ledges that shed coarse talus. Phenocrysts: almost none; rare plag (0.5–1.5 mm); rarer olivine (<1 mm). Overlies units mey, mns, and myl. Overlain by unit mwa. Undated [NS] mhd **Basaltic andesite of Hayden Glacier–Diller Glacier cleaver (late Pleistocene)**—Stack of several mafic (54.5–56.2% SiO_2) lava flows and intercalated coarse scoria falls that make up prowlike cleaver between Diller and Hayden Glaciers below east face of Middle Sister. About seven flows, ranging in thickness from 5 to 30 m, form cliffy, 150-m-high section at head of cleaver. Scoria-fall intervals as thick as 10 m include spindle bombs. Lower flows dip west (as if they originally banked against ice or were later rotated?), whereas upper flows dip 15° east and project across ice-filled saddle into stack of about 15 ochre-weathering lava flows, which make up middle of three main sequences that constitute steep east face of Middle Sister. Lithology varies widely from vitrophyric and vesicular to massive devitrified interior facies, commonly slabby or block jointed. Phenocryst contents vary widely among flows: 7–15% plag (mph to 1.5 mm, rarely as big as 3 mm); 1–3% olivine (mph to 1 mm, rarely to 2 mm), some having spinel inclusions; rare to common oxide mph; most flows also contain sparse cpx (mph to as big as 0.7 mm). Cleaver is surrounded by till and ice, so base of stack is not exposed. On face of Middle Sister, stack of flows overlies stratified tephra fall of unit aef and underlies cone-forming stack of mms lavas. $^{40}Ar/^{39}Ar$ age: 37±9 ka, for thick flow at east end of cleaver [NS]

mhl **Basaltic andesite of headwaters of Linton Creek (late Pleistocene)**—Small (300 by 200 m) window of glacially scoured, moderately porphyritic mafic (54.6, 55.7% SiO_2) lava flows at head of middle fork of Linton Creek (UTM grid 949/876). Ledgy exposure at 6,550 to 6,750 ft elevation on west slope of Middle Sister is set of four flows, each 2 to 6 m thick, that have normal lithologic zoning, from rubbly bases to massive devitrified block-jointed interiors sandwiched by vitrophyric (commonly vesicular) tops and bottoms. Phenocrysts: ~5% plag (mph to 1.5 mm); <1% cpx (mostly mph, rarely as large as 0.7 mm); traces of olivine and oxide mph; also contains common crystal clots, either all plag, plag-cpx, or plag-cpx-oxide. Overlies unit dlc. Draped by unit ahl (21±3 ka) and by great apron of unit mms that largely conceals it. Chemically identical to lavas of unit mhd, which likewise is directly overlain by unit mms lavas on opposite side of Middle Sister edifice. Undated but probably older than unit alc (27.2±1 ka) [NS]

mhr **Basaltic andesite of The House Rock (late Pleistocene)**—Small, asymmetrical mafic (53.3–53.5% SiO_2) shield west of Wickiup Plain, built on south flank of much older larger shield, The Wife. Glaciated remnants of scoria cone and small plug (not mapped) crop out atop shield; lava-flow apron extends 2 km southward. Phenocrysts: 5–7% plag (0.5–2 mm); 3–5% olivine (mostly mph, rarely as big as 1.5 mm); sparse oxide mph. Groundmass rich in plag-lath mph. Northwest contact only approximate where lavas overlie unit mtw; adjacent lava-flow apron of glaciated Koosah Mountain shield (unit mkm) appears to be younger; postglacial lava flows of unit mlc bank against The House Rock. $^{40}Ar/^{39}Ar$ age: 67±4 ka [SS]

mkm **Basaltic andesite of Koosah Mountain (late Pleistocene)**—Small mafic (52.6–53.3% SiO_2) shield volcano centered 2 km west of Kokostick Butte, at southwest edge of map area. From vent complex marked by scoria cone (stippled on map) atop Koosah Mountain, apron lavas extend at least 1.5 km northward and at least 4 km southward beyond edge of map area. Everywhere glaciated, lava flows crop out as ice-smoothed ribs and steps, widely massive, block jointed, and well exposed. Unit forms undulating bedrock surface of ice-scoured basin that contains 25 or more lakes of Sisters Mirror Lake cluster. Scoria cone that caps shield is about 150 m high and 1.2 km long, elongate north-south, and is marked by fissure vent along its crest; ejecta near summit are generally oxidized and widely agglutinated, ranging from tack-welded through densely blobby to fully homogenized sheets of lava. Bombs along crest are commonly as big as 50 cm, rarely bigger than 1 m, and mostly brick red. Phenocrysts: 3–5% olivine (0.2–2 mm), commonly in clusters; plag sparse (0.5–1 mm). Groundmass is choked with plag laths, seriate from microlites to mph, rarely as long as 0.5 mm. Apron lavas appear to bank against unit mhr (67±4 ka); they are intruded by domes of unit dkb (27±3 ka) and overlain by lava apron of postglacial unit mlc. Distal lava flows near and southeast of highway are likewise glaciated but slightly more evolved, containing 54–55% SiO_2, less olivine, and slightly more plag than most of unit; although here assigned to this unit, they could represent a sequence of older flows. Undated [SS]

mlb **Basaltic andesite of Little Brother (late Pleistocene)**—Glacially sculpted mafic (52.2–53.1% SiO_2; n=10) edifice, about 2 km in diameter, at northwest toe of North Sister, as well as apron of numerous lava flows that extends 6 km west to Obsidian Creek and 6 km northwest to Frog Camp Creek (outside mapped area). Steep edifice has more than 300 m of proximal relief and consists of agglutinate, scoria-fall layers, and hundreds of thin lava flows, many of them fountain fed and only 1 to 5 m thick. On west ridge of edifice, as many as 30 such flows are exposed in given sections. A few late flows are 5 to 15 m thick. Near summit, many fragmental deposits, both loose and agglutinated, are oxidized brick red. On slopes, many scoria layers are black, although colorfully palagonitized locally. Several comagmatic dikes and small plug cut edifice strata, principally on north and northeast sides. Apron lavas tend to be thicker, 5 to 15 m, but are poorly exposed, glaciated, and till strewn; they commonly are glassy, or partly so, and vesicular, although massive devitrified interior zones are exposed in thicker flows. Window at 4,600 to 4,800 ft elevation along lower canyon of Obsidian Creek is mostly devitrified, massive, and slabby. Phenocrysts: 1–5% plag (0.5–1.5 mm), seriate to as much as 15% plag-lath mph in some samples; 3–5% olivine (mph to 1 mm, rarely as big as 2.5 mm); most samples have abundant olivine-plag clots and fewer all-plag clots, both types limited largely to mph. Schmidt (2005) listed chemical data for 30 additional samples, which range in SiO_2 content from 52.6 to 53.9%. Appears to overlie youngest (valley-floor) flows of unit mns near snout of Collier Glacier (UTM grid 966/9175; there, 46.2±5.6 ka). Overlain by units acc, alc, awc, mmm, msb, dss, roc (38±2 ka), and aoc (45–49 ka). Preserved locally atop west ridge of Little Brother edifice are remnants of two sets of stratified fallout, each about 50 cm thick, that are predominantly pumice lapilli and lithic fragments (both of aphyric rhyolite) probably related to unit roc (Sherrod and others, 2004). $^{40}Ar/^{39}Ar$ ages: 47.2± 5.8 ka (medial), 48.4±3.6 ka (distal) [LL, NS]

mlc **Basaltic andesite of Le Conte Crater (early Holocene or latest Pleistocene)**—Postglacial scoria cone (stippled on map) at southern margin of Rock Mesa and associated aprons of mafic (54.5–55.9% SiO_2) lava flows that extend 3 to 4 km northwest to Mesa Creek and 6 to 7 km south in tongues that bifurcate around Kokostick Butte (unit dkb). Cone is 120 m high, is 600 m in diameter, and has shallow 200-m-wide circular summit crater. Cone has no exposure, as it is heavily mantled with late Holocene pumice-fall deposit of unit rrm; where exposed through fallout, lava-flow surfaces are rubbly, scoriaceous, and virtually uneroded, having many ridges, hillocks, and blocky levees. Flows are not incised but ubiquitously have 2 to 10 m of local relief. Southeast tongue impounds Devils Lake. Phenocrysts: 3–5% olivine (mph to 1 mm, very rarely to 3 mm), some in clusters; virtually no truly phenocrystic plag. Groundmass commonly is rich in plag-lath mph (<0.5 mm long); plag antecrysts (sieved, partly resorbed, and 0.5–1.8 mm) are sparse but widespread. Clark (1983) reported resorbed quartz xenocrysts. Overlain by unit rrm and Mazama ash (7.7 ka). Younger than all other contiguous units, including slump mass from Katsuk Butte. Undated [SS]

mls **Basaltic andesite of Linton Spring (late or middle Pleistocene)**—Cliff-forming, phenocryst-poor mafic (55.1% SiO_2) lava flow adjacent to Linton Meadows, 4 km southwest of Middle Sister summit. Exposed as west-facing scarp for about 700 m, glaciated flow is more than 50 m thick. Voluminous Linton Spring (discharge roughly 2,000 l/s) gushes from numerous orifices in flow-breccia zone that makes up lower 20 m of outcrop. Most of unit is dark gray, chunk jointed, and glassy, aphanitic, or finely crystalline. Thickness, jointing, and texture suggest ice-contact emplacement. Phenocrysts: 1–2% plag (0.5–3 mm, mostly ~1 mm); <<1% olivine (mostly mph, rarely 1–2 mm). Base not exposed, but unit probably overlies unit mth. Overlain by unit mms. Undated [NS]

mmc **Basaltic andesite of Millican Crater (late Pleistocene)**—Mafic (53–54% SiO_2) scoria cone and associated lava-flow apron at north-central edge of map area. Fragmental cone has 250 m of relief, is 1,200 m wide, and banks against Black Crater edifice; its 2 by 3 km apron extends mostly to south and east. Glaciated apron consists of numerous block-jointed lava flows that are meagerly exposed but support several peripheral ledges 5 to 12 m high. Upper part of cone consists of radially dipping stratified scoria, extensively oxidized brick red, locally agglutinated, but only modestly eroded, probably having stood higher than regional glacial surface. Subhorizontal layers of scoria and agglutinate near summit are fallout that filled transient crater. Phenocrysts: sparse plag (0.5–1 mm); only tiny olivine (≤0.5 mm); sparse oxide mph; sparse olivine-plag clots; some lava flows have no phenocrysts (≥0.5 mm). Overlies unit mbc. Overlain by units bwm and mnt (20±5 ka). Normal paleomagnetic polarity (Taylor, 1987). Undated [NS, TCB] mmi **Basaltic andesite intrusion of Middle Sister (late Pleistocene)**—Vertical mafic (52.8, 53.3% SiO_2) intrusive mass exposed on northeast face of Middle Sister for about 200 m from Hayden Glacier nearly to ridgecrest just north of summit. Flares upward from thick dike below to as wide as 40 m at top. Probably one major conduit for later parts of 225-m-thick pile of (compositionally similar) thin rubbly flows (unit mms) that built top part of Middle Sister edifice. Porphyritic, having medium-grained groundmass. Phenocrysts: 30–40% plag (mph to 4 mm); 5% olivine (mph to 1.5 mm, rarely 3 mm), much of it altered; abundant oxides (0.1–0.2 mm) limited to groundmass. Cuts stacks of lava flows of units mms and mhd, and probably underlying tephra-fall deposit of unit aef as well. $^{40}Ar/^{39}Ar$ age: 18±4 ka [NS]

mml **Basaltic andesite of South Matthieu Lake (late Pleistocene)**—North-trending set of three separate glaciated windows of moderately porphyritic mafic (54.4–55.6% SiO_2) lava exposed along contacts between units mpn, mps, and postglacial lava flows from Yapoah Crater (unit myc). Ice-scoured ledges and knobs are massive, slabby to block jointed, or locally partly glassy and chunk jointed. Phenocrysts: 2–3% plag (0.5–1.5 mm, rarely to 3 mm); <1% olivine (0.2–1 mm); rare cpx mph; olivine commonly in clusters; olivine-plag intergrowths probably antecrystic. Overlies unit mps. Overlain by units mmn, mpn, and myc. Undated [NS]

mmm **Basaltic andesite of Montague Memorial (late Pleistocene)**—Single thick phenocryst-rich mafic (56.3–57.3% SiO_2) lava flow that extends about 2.5 km northwest from toe of Middle Sister edifice, as narrow tongue that is banked against southern margin of Obsidian Cliffs coulee (unit roc). Makes up narrow strip of glaciated knobs that may have been emplaced along margin of glacier during last major glacial episode. In periphery of southeastern knob (most proximal remnant exposed), unit was wholly removed by glacial erosion. Vent apparently was farther southeast, higher on Middle Sister, and is now concealed by younger units. Internal zones are devitrified and block jointed or slabby. Black vitrophyre and partly glassy zones are locally exposed, and scoriaceous oxidized rubbly base (atop unit aoc) crops out in several places. Small remnant of second flow unit caps largest (central) Knob 6543. Phenocrysts: 15–20% plag (mph to 2.5 mm, rarely as big as 4 mm); 3–5% pyroxenes (mph to 2 mm, rarely as long as 3.5 mm); sparse oxide mph. Overlies units aoc, mlb, and roc (37.8±1.8 ka). Overlain only by till, locally. $^{40}Ar/^{39}Ar$ age: 19±7 ka [NS]

mmn **Basaltic andesite of North Matthieu Lake (late Pleistocene)**—Phenocryst-poor mafic (54.6% SiO_2) lava flow that forms north-facing scarp 75 m high and ice-scoured bench 600 m wide that supports North Matthieu Lake. Knobby bench lava is massive, locally vesicular, and block jointed to slabby. Phenocrysts: 1–2% plag (0.5–1.5 mm, rarely to 3 mm); sparser olivine (mostly mph). Overlies unit mml. Overlain by unit mpn and by postglacial lava flow from Yapoah Crater (unit myc). Undated [NS]

mms **Basaltic andesite of Middle Sister (late Pleistocene)**—Shingled stacks of thin phenocryst-rich mafic lava flows and intercalated blocky rubble that constitute most of upper half of Middle Sister cone and mantle much of its south and west apron. Most flows contain 52.2–52.9% SiO_2 (n=25), but some late flows and dikes contain 53.3–54.1% SiO_2. Unit is 225 m thick on east face of edifice. Apron extends continuously 4 km south and west, and patchy remnants survive as far as 2 km north, 3 km northwest, and 5 km east of summit. Altogether, unit consists of hundreds of flows, many only 1 to 2 m thick; a few medial sections expose as many as 40. East face and lower parts of aprons are glacially excavated, but steep upper slopes of cone on south and west are not. Least modified surfaces remain scoriaceous and rubbly to blocky. Eroded flows form stairstep ledges that dip radially and tend to thicken downslope. Where 1 to 2 m thick, most flows remain partly glassy; where 3 to 7 m thick, most have devitrified internal zones (1–5 m thick) that are typically massive or slightly vesicular and block jointed. Oxidized, scoriaceous rubble zones are widely exposed between flows. A few remnants survive of distal flows that ponded as thickly as 10 to 15 m, perhaps along glacier margins. Several dikes, 1 to 2 m thick, are exposed on west slope and east face of Middle Sister; compositionally similar to lavas they cut, they supplied later increments to accumulating pile of flows; similar dikes also cut unit mcl on southeast slope. Summit area consists predominantly of ejecta, poorly or crudely stratified and having variably agglutinated stringers that grade outward into thin, ledge-forming, fountain-fed lava flows. Summit ridge is mantled locally by units dhr and dms and by one tiny remnant of unit mss (UTM grid

9736/8893; about 80 m north of high point at 10,047 ft elevation). Summit ridge is remnant of west rim of former vent complex sited slightly eastward that was subsequently removed by glacial excavation of east face of edifice; upward-flaring intrusive unit mmi is remnant or offshoot of feeder system. Fumarolic alteration of fragmental summit material, now orange, yellow, ochre, or brick red, and locally coated by white films on joint faces, extends about 200 m north and south of true summit and to depth of at least 30 m as exposed on east face. Phenocrysts: 25–35% plag (mph to 4 mm, equant or elongate); 5–10% olivine (mph to 2.5 mm), commonly in clusters and some with spinel inclusions. Few plag crystals are sieved except in near-vent samples from summit. Overlies units adl, ahl, alc, alg, anh (21±6 ka), aoc, asw (24.5±4.2 ka), awc, awm, dcl (26±2 ka), dlp, dsn (19±4 ka), dss (24.5±3.1 ka), mcl, mhl, mls, mnf, mrg (19.6±6.1 ka), msc (21.4±5.5 ka), and mth. On west slope of Middle Sister, several flows bank against previously eroded vent-filling extrusion of unit dlp (21.4±1.9 ka). Overlain by units dbh (18±2 ka), dhr (19±2 ka), dig (14±3 ka), dms, and mss; intruded and overlain by domes of unit dsw (17±15 ka). On medial cleaver of Collier Glacier, stack of five thin flows is sandwiched between lavas of unit awc (22±2 ka) below and dbh (18±2 ka) above. $^{40}Ar/^{39}Ar$ age: 16.4±11.7 ka, for sample from true summit of Middle Sister (0.79% K_2O). Ages of so many enclosing units bracket eruptive interval to about 20 ka; statistical propagation of ages of bracketing units yields 20.3±2.5 ka [NS, SS, TCB]

mms' **Pyroxene-bearing variant of the basaltic andesite of Middle Sister (late Pleistocene)**—Moderately porphyritic lava flows at or near top of sequence of flows of unit mms, distinguished by much lower total phenocryst content, presence of sparse cpx, and slightly more evolved bulk composition (54.5–54.9% SiO_2). Directly atop of, or intercalated near top with, stack of lavas of unit mms, this variant is presumed to be comagmatic with unit mms and to have been more extensive prior to glacial erosion. Recognized in two areas on opposite sides of Middle Sister: (1) banked against and lapped onto vent intrusion of unit dlp at 7,850 to 8,200 ft elevation on west slope, and (2) on east apron at 6,600 to 6,800 ft elevation, close to North Fork Whychus Creek. Steep western flows are 2 to 4 m thick, vesicular, rubbly, and partly glassy; on more gently sloping eastern apron, flows are 5 to 8 m thick, glacially scoured, massive, devitrified, and block jointed to slabby. Phenocrysts: 5–10% plag (mph to 3 mm); ~1% olivine (mph to 2 mm); sparse cpx (mostly mph, rarely 0.5–2 mm); trace oxide mph. Erupted at or near end of eruptive sequence of unit mms. Overlies units awm, dlp, and mcl. Undated, but same age as unit mms (about 20 ka) [NS, TCB]

mmt **Basaltic andesite tuff of Middle Sister (late Pleistocene)**—Discontinuous patches of poorly sorted mafic (51.7–55.2% SiO_2; n=3) tuff (samples of bulk tuff were picked free of lithic fragments), exposed in hollows on glacially scoured surface of multiflow lava apron of unit mms along west toe of Middle Sister. Originally intercalated between thin lava flows that were variably stripped by glacial erosion, abundant remnants of tuff suggest formerly continuous flow fan that extended from Separation Creek northward for 3.5 km to Lane Plateau. Exposures are limited to apron of modest relief below break in slope of steep cone of Middle Sister, ranging in elevation from 6,850 ft down to 6,000 ft near Linton Meadows. Flows may have originally extended farther down Linton Creek, as sandy postglacial alluvium there appears to be in considerable part derived from this tuff. Exposures are on walls of drainages or form broad ice-scoured whalebacks; tuff is moderately to poorly indurated, medium gray (weathering pale gray or tan when dry), and either massive or crudely stratified. Locally developed internal shear and crude size sorting produced vague partings that result in slabby splitting and ledgy outcrops that erode into ribs 5 to 50 cm thick. Base is rarely exposed, but observed thicknesses of remnants range from 4 to 25 m. Juvenile clasts are phenocryst-rich black scoriae, poorly to strongly vesicular, mostly 1 to 10 cm (but as big as 20 cm), and identical to material in lavas of enclosing unit mms. Matrix is predominantly crystal-rich coarse ash, which supports most clasts and commonly is vesicular. Accidental lithic clasts, rare or absent in higher exposures, are common distally, apparently entrained downslope; most are andesite-dacite lavas, and fewer are basalts; most clasts are smaller than 5 cm, but some are as large as 35 cm. Absence of welding makes mafic pyroclastic-flow emplacement process unlikely. Mud-lined vesicles in gritty matrix suggest dewatering of granular material and transport of sparse fines. Lack of wood fragments in deposit probably reflects barren edifice in late Pleistocene; upper slopes of Middle Sister remain barren today. Deposit can be interpreted as product of one or many primary lahars, presumably initiated by modest scoria showers or surges in summit region during eruptive interval that also produced lava flows of unit mms. Falling on snow or ice, hot pyroclasts would mix with meltwater and pour rapidly downslope, probably bulking by incorporation of loose ash and scoria during transit (but picking up accidental lithic fragments only distally, where units older than mms were exposed). Still today, upper slopes of Middle Sister remain snow covered for 9 to 10 months a year. Tuff has not been observed east of edifice, where apron is deeply eroded and extensively till covered. Phenocrysts: same as unit mms. In thin section, indurated tuff matrix (exclusive of basaltic lapilli) typically consists of ~25% glass shards (0.2–2 mm), 5–10% plag (mph to 2 mm), and 3–5% olivine (mph to 1 mm) in finely comminuted matrix of same constituents. Overlies units alc and msc. Undated (but same as unit mms, about 20 ka) [NS, SS]

mnf **Basaltic andesite of North Fork Whychus Creek (late Pleistocene)**—Glaciated, moderately porphyritic, mafic (53.6–54.4% SiO_2) lava flows exposed through till in several windows along, and north of, North Fork Whychus Creek between 6,200 and 7,200 ft elevation. Crops out along stream gorge, where set of four flows, each 1 to 3 m thick, is well exposed (UTM grid 012/8885). Conformably beneath them, fifth flow is compositionally similar but phenocryst richer and more than 10 m thick, its base not exposed. For 400 m north of North Fork gorge, unit crops out through till in isolated patches as ledges and gully walls, mostly devitrified. Largest exposure is 50-m-thick stack of 10 flows (each 2 to 7 m thick) that forms steep till-enveloped buttress (UTM grid 995/883) at 7,000 to 7,200 ft elevation near head of North Fork. Most lavas there are partly glassy and vesicular, but thicker ones expose devitrified massive block-jointed interiors. Phenocrysts: 5–10% plag (0.5–2.5 mm); 1–3% olivine (mph to 1.5 mm); ±sparse cpx (≤1 mm). In some coarsely crystalline samples, plag mph (0.1–0.4 mm) make up 30–40% and olivine mph as much as 10% of thin sections. Probably erupted at Middle Sister (prior to eruption of major summit-capping unit mms). Base not exposed. Overlain by units adl (24±1 ka), mcl, and mms. Chemically identical to lavas of unit mnh (2 km northwest). $^{40}Ar/^{39}Ar$ age: 48±10 ka [NS, TCB]

mnh **Basaltic andesite north of Hayden Glacier (late Pleistocene)**—Stack of thin, moderately porphyritic mafic lava flows that crops out through till as two ledges, each less than 100 m long, along north edge of Hayden Glacier. Upper ledge at 8,450 to 8,500 ft elevation exposes two flows, each partly glassy and 1 to 2 m thick (UTM grid 9793/8978). Lower ledge at 8,300 to 8,350 ft elevation exposes five flows (UTM grid 9806/8963), among which first four are similarly thin and compositionally like those of upper ledge (all 53.4–54.4% SiO_2); all have massive devitrified interior zones (1 m thick or less) enclosed by glassier, more vesicular tops and bottoms. Top flow of lower ledge is different, but it is not possible to represent it separately at scale of map; although conformable with those below, it is 7 to 10 m thick, has 57.1% SiO_2, and (in common with fourth flow) contains fewer crystals. Phenocrysts (most flows): 7–12% plag (mph to 2 mm); 1–2% olivine (mph to 1 mm); ±subordinate cpx. Top two flows of lower ledge contain only 2–3% plag (mph to 1 mm); ≤1% olivine (mph to 1 mm); ~1% cpx (0.5–1 mm); in other flows, cpx is sparse or absent. All flows contain sparse oxide mph and clots of all minerals, in varied combinations. Although contacts are everywhere obscured by till, unit probably underlies nearby units mms and dbh; it certainly is younger than nearby unit mns. All flows but top one are chemically similar to flows of unit mnf, about 2 km southeast. $^{40}Ar/^{39}Ar$ age: 21±6 ka (for top flow of lower ledge) [NS]

mns **Basaltic andesite of North Sister (late and middle Pleistocene)**—Glacially ravaged mafic stratocone (52.5–55.1% SiO_2; n=140; see also Schmidt, 2005) on Cascade Range axis just north of Middle Sister and 10 km south of McKenzie Pass. Steep, asymmetrically preserved edifice, which is 2 by 3 km across and has about 1,000 m of relief, consists of hundreds of thin rubbly lava flows that dip radially and steeply, are intercalated with proximal agglutinate and scoria falls, and are cut by 200 or more thin dikes (Schmidt and Grunder, 2009). As many as 70 such lava flows are exposed in individual sections on walls of several ridges and cirques. Gently dipping aprons of thicker lava flows extend from edifice as far as 7 km east and 9 km northeast of summit. South and west of cone, any such apron is concealed by younger units. Half or more of cone volume has been glacially excavated and redeposited as till, largely to east and northeast. Most flows on edifice are fountain fed, 1 to 5 m thick, extensively vesicular (though many have massive internal zones), and typically separated by 1 to 5 m of oxidized rubbly flow breccia, scoria-fall deposits, and lag breccias left by block-and-ash flows. Exposed on steep faces within stacks of such thin rubbly flows are a few massive lavas 10 to 20 m thick that may be either extrusive flows or thick sills. Northwest ridge is capped by a 200-m-thick stack of flows that have massive zones 10 to 20 m thick, thicker on average than elsewhere on cone. Remnants of two massive lavas (each ~54% SiO_2) cap summit and help retard edifice destruction: (1) Southern one ("Prouty Pinnacle") forms north-elongate wall 200 m long and 60 m high that appears to be plug that flares out radially over brick-red scoriaceous rubble; saddle on its crest separates two prongs, northern of which is true summit. (2) Other massive lava ("Glisan Pinnacle") lies 100 m northeast across deeper saddle and consists of 100-m-wide remnant of single flow about 35 m thick that dips to northeast away from plug, forms vertically jointed cliffs, and is capped by 10-m-thick agglutinate remnant.

North Sister was subdivided into several unconformable sets of flows by Schmidt (2005), who listed chemical data for 114 samples (including 38 dikes). Transition from myriad thin rubbly flows below to generally thicker and fewer flows higher on edifice is at elevations of about 9,300 ft on north face and about 9,200 ft on east face. Modest unconformities between sets of thin flows are common everywhere on edifice, but one profound unconformity crops out at about 8,750 ft elevation on east ridge, separating east-dipping flows below from west-dipping ones above; this suggests either shift in vent location, rim of filled paleocrater, or interval of severe erosion not observed elsewhere. Northeast face exposes higher proportion of intercalated brick-red scoria falls than elsewhere on edifice. West face is almost dipslope, slightly bevelling steeply dipping stack of thin brecciated flows and layers of brick-red scoria, all cut by numerous dikes.

Two parts of edifice (stippled on map) are pervasively altered to yellow-orange palagonite: entire east buttress, and 150-m-thick section low on north face. Both sections are riddled by numerous dikes (not shown on map). Buttress section, 250 m thick, consists dominantly of ash-rich, poorly sorted, fragmental-flow deposits, in thin to thick layers that dip 25° to 30° E. and display numerous scoured, modestly unconformable contacts. North-face section consists of ash-rich phreatomagmatic fallout, in layers 5 to 200 cm thick, some sloughed but mostly primary, many well sorted but others less so. In both sections, altered ashy matrix contains unaltered black or brick-red scoriae (mostly lapilli and small bombs) and angular fragments of dense gray lava 5 to 30 cm across. Lack of palagonitization of coarse clasts implies grain-size control on alteration, largely restricted to glassy ash-grade material; same can be inferred from unaltered condition of brick-red, ash-poor layers of scoria lapilli that intimately underlie, overlie, and interfinger with yellow palagonitized sections. Elsewhere on North Sister edifice, isolated ashy yellow layers within thick stratified sections of gray lava and red scoria confirm that alteration was controlled principally by grain size rather than depositional environment. Regularity of stratification in palagonitized sections and absence of convolution and slumping weighs against ice-contact emplacement.

Off cone proper, northeast planèze exposes about 10 lava flows, which have massive zones 2 to 20 m thick, are separated by thin rubbly layers, and are cut proximally by several dikes. Outflow lavas are, on average, thicker than most on edifice, commonly as thick as 10 to 20 m and typically are devitrified and block jointed or platy; they are discontinuously exposed through glacial deposits on forested peripheral apron. North of Pole Creek Spring, 2 km^2 driftless window was not overrun by ice and uniquely retains near-primary blocky scoriaceous surface.

Although numerous flows examined vary significantly in texture and in phenocryst content, nearly all are weakly porphyritic, carrying small but varied proportions of olivine and plag phenocrysts (and, in a few flows, rare cpx). Most common are lavas that have 0.5–3% plag (0.5–1 mm, rarely as large as 2.5 mm) and 1–5% olivine (mph to 1 mm, rarely as big as 3 mm), some in clusters. A few flows are nearly aphyric, and a few have as many as 8% plag phenocrysts. In samples that have coarse-grained groundmass, however, plag laths, seriate from 0.1 to 1 mm, can constitute 10–30% of rock. Many of largest plag (1.5–4 mm) are actually composite intergrowths of several crystals. Oxides typically are absent or limited to groundmass and seldom >0.1 mm. Plag-olivine clots are sparse, in contrast to associated north-distal set of clot-rich flows mapped as unit mey. Flows exposed in windows through till in east-distal part of apron (for 6 km along north rim of Whychus Creek and its north fork) are petrographically typical North Sister lavas, but they are slightly richer than most in Ti, K, and P, as well as relatively deficient in Al (shown as unit mns' in table 1 but not mapped separately). East-distal apron overlies units msp and mws. Northeast-distal apron overlies unit bac, and its flows intercalate with distinctive flows assigned to unit mey. Base of unit is not exposed to south or west. North Sister lavas are overlain by units anh, awa, dbh, mfy, mlb, mms, mnh, mps, mst, and mwa. $^{40}Ar/^{39}Ar$ ages: 119±6 ka, for flow at east-distal edge of apron on rim above confluence of Soap and Whychus Creeks; 83±25 ka, for flow on north rim of northeast planèze at 7,300 ft elevation; 71±3 ka, for flow at 8,600 ft elevation on crest of southeast ridge of edifice; 55±5 ka, for lava that forms true summit ("Prouty Pinnacle") of North Sister; 46±6 ka, for valley-floor flow near snout of Collier Glacier. Older ages for North Sister, which were reported by Hildreth (2007) and Schmidt and Grunder (2009), we now consider unreliable [NS, TCB]

mnt **Basaltic andesite north of Trout Creek (late Pleistocene)**—Major phenocryst-poor mafic (54.9–56.9% SiO_2) lava flow about 1 km wide, which extends 6.5 km east from beneath base of 150-m-high scoria cone (Cone 6302) across northern part of map area to 60-m-high eroded scarp at Trout Creek Swamp. Taylor (1987) correlated it with flow that extends to Cold Spring, additional 9 km northeast of map area. Within map area, flow is everywhere glaciated; not so farther northeast. Scoria cone (Cone 6302; 54.6% SiO_2; mapped as unit mpn) is widely oxidized, agglutinated, and draped by thin fountain-fed lavas; although comparably phenocryst poor, cone products are not chemically identical to lava flow of this unit and, thus, are not likely to represent same eruptive episode; cone buries source vent for lava flow. Exposures of main ice-scoured lava tongue typically are massive, devitrified, and block jointed, although flow-foliated and glassy chunk-jointed facies crop out locally (more extensively in proximal areas). Phenocrysts: distally, almost none; rare plag (1.5–3 mm); even rarer 1-mm olivine and cpx, all probably antecrysts. Medially, similar to distally, except that olivine mph (all <0.4 mm) are abundant; sparse plag (1–2.5 mm, sieved and partly resorbed). Proximally, sparse plag (0.5–1 mm) and cpx mph. Oxides scattered throughout, all ≤0.1 mm. Overlies units mmc and myl. Overlain by units mpn and mps. $^{40}Ar/^{39}Ar$ age: 20±5 ka [NS, TCB]

mpm **Basaltic andesite of Park Meadow (late or middle Pleistocene)**—Glaciated swath, about 200 m wide, of moderately porphyritic, oxidized agglutinate and fountain-fed mafic (55.5–56.0% SiO_2) lava flows that extends from eroded spatter cone (stippled on map) at about 6,600 ft elevation (UTM grid 030/844) for about 500 m northeast toward Park Meadow. Phenocrysts: cone has 7–10% plag (mph to 1.5 mm, rarely to 3 mm); ~3% olivine (mph to 1 mm); sparse cpx (mph to 1 mm); abundant plag-pyroxene clots (3–10 mm); sparse oxides, rarely >0.1 mm. Probably overlies unit mbt. Overlain by unit awf (24±1 ka). Undated [BT]

mpn **Basaltic andesite north of Scott Pass (late Pleistocene)**—North-trending ridge of fissure-fed, phenocryst-poor mafic (54.6–55.2% SiO_2; 1.48–1.54% TiO_2) scoria and agglutinate that extends 2.7 km northward from Scott Pass to pass on Millican Crater trail just north of map area (UTM grid 085/986). Glaciated ridge is 0.5 to 1 km wide and steep on both sides, having as much as 150 m of relief; its crest is marked by several hills that apparently were foci of enhanced ejection of pyroclasts, but only one shallow crater is preserved at Cone 6302. Exposures are dominated by loose lapilli and abundant bombs (many larger than 1 m) that range from black to predominantly brick red and from highly vesicular to fairly dense. Tack-welded layers are present locally, but exposures of denser cliff-forming agglutinate are few; this contrasts with adjacent fissure-fed alignment segment that continues south of Scott Pass (unit mps), which (although 2–3% more silicic) is dominated by thick sections of densely welded agglutinate. Vent alignment also continues for 2 km north of map area; however, northernmost 1-km-long reach (on west shoulder of Black Crater) produced mafic (54.4–54.5% SiO_2) scoria and agglutinate that is far richer in plag and olivine and poorer in Ti and Fe than this unit and unit mps. Phenocrysts: <1% plag (mph to 1.5 mm); sparse cpx mph (0.1–0.4 mm). Overlies units mml, mmn, mnt (20.3±4.6 ka), mps, and bwm. Steep narrow topography may, in part, reflect lateral confinement by glaciers owing to eruption during Last Glacial Maximum. Overlain by postglacial unit myc. Undated [NS]

mps **Basaltic andesite south of Scott Pass (late Pleistocene)**—South-trending ridge of fissure-fed, phenocryst-poor mafic (56.0–58.7% SiO_2; 1.25–1.64% TiO_2; n=18) scoria and agglutinate that extends about 6 km southward from Scott Pass; also includes intercalated fountain-fed lava flows. Glaciated ridge is as narrow as 100 m east of Yapoah Crater, but it is about 1 km wide near Collier Cone, and 600 m wide at Cone 6315, which has shallow degraded crater on top and 150 m of relief on its steep east side. Ejecta exhibit gradations from loose scoria that has spindle bombs as big as 1 m through tack-welded and blobby, rheomorphic (locally convolute) sheets to massive, homogenized lava flows that have hackly, slabby, or blocky jointing. Areas of weakly indurated, yellowish-orange-brown, ash-dominant lapilli tuff (stippled on map) were probably mildly palagonitized by fallout over snow or ice. Oxidation of ejecta likewise varies widely from black to gray to ochre to brick red. Exposed stacks of glaciated agglutinate as thick as 70 m form cliffs and steep ledgy slopes, although ridgecrest generally is strewn with loose or weakly welded ejecta. Phenocrysts: <1% plag (0.5–2 mm); rare olivine (mph only); very rare cpx mph, generally only in cpx-plag clots; polycrystalline plag intergrowths probably antecrystic. Overlies units awa (25±2 ka), mns, mnt (20±5 ka), mwa (59±4 ka), mwy, and mys. Steep narrow topography may, in part, reflect lateral confinement by glaciers owing to eruption during Last Glacial Maximum. Overlain by postglacial units acc and myc and by glaciated units mml and mpn. Along much of its western margin, it also overlies agglutinate and scoria of Ahalapam Cinder Field (not mapped), likewise glaciated and phenocryst poor, that erupted from different vent chain and differs chemically (55.5–56.5% SiO_2; 1.10–1.30% TiO_2; n=6). Undated [NS]

mrg **Basaltic andesite of Renfrew Glacier (late Pleistocene)**—Fan of moderately porphyritic mafic (54.6–54.8% SiO_2) lava flows about 1 km wide, in three lobes, on northwest flank of Middle Sister. Erupted high on edifice, but vent is covered by younger units. Highest exposures are windows, at 8,300 ft elevation, through Little Ice Age moraines of Renfrew Glacier; most distal exposure lies at 6,600 ft elevation near Pacific Crest Trail. Lavas are everywhere ice scoured but nowhere deeply incised; greatest thickness exposed is about 35 m. Flows are 3 to 20 m thick, separated by a few meters of oxidized flow breccia and rubble. Unit is eroded into knobs, ledges, and smooth ridges and generally is massive, devitrified, and block jointed or slabby. Flows drape previously eroded steep slopes cut on unit awr. Phenocrysts: 7–10% plag (0.5–2 mm), seriate to ~25% plag mph; trace to as much as 1% cpx (mph to 1 mm); <1% olivine (all mph); sparse tiny oxide mph. Overlies units dss (25±3 ka), awc, and awr (although extensively stripped off unit awr); banks against unit roc. Overlain by unit mms. $^{40}Ar/^{39}Ar$ age: 20±6 ka [NS]

msb **Basaltic andesite of Sims Butte (latest Pleistocene)**—Postglacial scoria cone near west edge of map area and associated intracanyon tongue of mafic (52.3–56.6% SiO_2) lava flows that extends about 15 km downcanyon to west (Sherrod and others, 2004). Cone (stippled on map) has 200 m of relief on east, 300 m on west. Lapilli-fall layer extends about 1 km beyond base of cone; ash fall, unmapped distance farther. Proximal scoriae commonly weather yellow to ochre. Thin proximal lavas are fountain fed, rubbly, and scoriaceous. Medial to distal stacks consist of numerous rubbly flows, each 0.3 to 5 m thick and finely to coarsely vesicular. Thick piles of oxidized rubble accumulated locally where flows broke up over steep pitches. Phenocrysts: ≤1% olivine (seriate 0.1–1 mm, but a few exceed 0.4 mm); plag phenocrysts (0.5–1.5 mm) rare; groundmass plag is seriate from microlites to abundant mph laths, small fraction of which are as long as 0.5 mm; sparse plag antecrysts (0.5–2 mm, sieved and resorbed). Analyses of 17 samples (table 1; see also Conrey and others, 2002) show no systematic compositional progression downcanyon; scoria cone, however, is least evolved, and levee at northwestern margin of lava-flow apron provides most evolved material sampled. Overlies unit mlb (47–49 ka). Overlain by unit acc and Mazama ash (7.7 ka). May be relatively early postglacial, in light of only modest weathering of late Pleistocene till beneath Sims Butte fall deposits (Sherrod and others, 2004). Undated [LL, NS]

msc **Basaltic andesite of Separation Creek (late Pleistocene)**—Glacially scoured 4 km^2 apron of phenocryst-rich mafic (56.7–57.3% SiO_2) lava flows at west-northwest foot of South Sister, between Hinton Creek and Linton Meadows, extending into west-trending lobe south of Separation Creek. Vent is marked by small scoria-spatter cone (stippled on map; 56.9–57.3% SiO_2) only 300 m wide and 60 m high, just north of Separation Creek. Greatest thicknesses exposed on lava apron are about 60 m, near southern limit of unit and at terminus of western tongue. Scoria and agglutinate of eroded cone are locally black, mostly oxidized brick red. Lavas are locally vitrophyric and chunk jointed (as near "Racetrack Meadow") but mostly ice scoured and plucked into ledges, knobs, and pavements that are massive, devitrified, and block jointed or slabby. Phenocrysts: 15–25% plag (mph to 3.5 mm); 3–5% pyroxenes (mph to 1.5 mm); sparse oxide and olivine mph; abundant plag-pyroxene-oxide clots. Overlies units bhs, mth, and ddl (32±2 ka); banks against toe of unit alg (27±1 ka). Overlain by units mms and mmt. $^{40}Ar/^{39}Ar$ age: 21.4±5.5 ka [NS, SS]

msf **Basaltic andesite of South Fork Whychus Creek (middle Pleistocene)**—Phenocryst-poor mafic (53.7–54.0% SiO_2) lava flows and tuff exposed only near floor of South Fork Whychus Creek, at 5,800 to 6,000 ft elevation, 300 to 500 m east and southeast of Demaris Lake. Unit is at least 25 m thick, but base is nowhere exposed. Tuff is nonindurated scoria-flow deposit exposed only on right-bank wall of stream gorge at about 5,920 ft elevation; at least 12 m thick and overlain by lava flow of identical composition. Black, crystal-poor scoriae are as large as 8 cm, enclosed in poorly sorted coarse-ash matrix, which weathers orange and includes varied accidental lithic fragments (1–5 cm). Lavas are exposed as glaciated and water-worn ledges and gully walls; massive, devitrified, and block jointed. Phenocrysts: 1–2% plag (mph to 2 mm, rarely to 4 mm); sparse olivine mph (rarely bigger than 0.2 mm). Groundmass rich in plag-lath mph, rarely as long as 0.5 mm. Overlain by units adl, mcl, and mdl. $^{40}Ar/^{39}Ar$ age: 166±16 ka [TCB]

msp **Basaltic andesite of Soap Creek–North Fork Whychus Creek confluence (late or middle Pleistocene)**—Small, glacially eroded mafic (54.2% SiO_2) scoria cone at 6,200 ft elevation between Soap Creek and North Fork Whychus Creek, as well as derivative phenocryst-poor mafic (54.6, 54.8% SiO_2) lava flows 2 to 4 km downstream, near their confluence. Cone (stippled on map) is 350 m wide and displays ice-scoured, ledgy slopes that reflect layering and varied degrees of agglutination (tack welded to moderately dense) in brick-red scoria-fall deposit; densest agglutination is on steep east face, which has 70 m of relief. Although dominantly lapilli, ejecta are as big as 50 cm. Deposit is locally palagonitized yellow-orange. Lava flows are exposed along stream gorge for about 600 m near confluence and extend additional 1.2 km northeast along left-bank rim of North Fork Whychus Creek canyon. Lavas crop out as massive, devitrified, block-jointed or slabby ledges as thick as 20 m. Oxidized rubbly zone separates two 10-m-thick flows, each supporting a waterfall at elevations 5,370 and 5,340 ft along North Fork gorge. Phenocrysts: in cone, <1% plag (mph to rarely as big as 1 mm), mostly sieved or partly resorbed; 2–3% olivine (mph to 0.7 mm), some rimmed by iddingsite. In lavas, almost none; groundmass is rich in plag-lath mph, seriate to a few as long as 0.7 mm; 2–3% olivine mph (0.1–0.4 mm), some in clusters; very rare olivine grains as large as 0.5–1 mm. Base of cone not exposed. Lavas overlie unit bnf (at 5,320 ft elevation on gorge floor and at 5,180 ft on canyon wall); also overlie unit mws (175±3 ka), which in turn rests on ignimbrite of unit spt. Both cone and lavas are widely overlain by till and by distal lava of North Sister (unit mns, dated nearby at 119±6 ka, where it rests directly upon this unit). $^{40}Ar/^{39}Ar$ age: 129±6 ka (scoria cone) [TCB]

mss **Basaltic andesite of Middle Sister summit (late Pleistocene)**—Sequence of thin, phenocryst-rich mafic (56.1% SiO_2) lava flows that caps ridgecrest 100 to 300 m north of true summit of Middle Sister, between 9,800 and 10,000 ft elevation; also exposed on sheer east face of ridge. All exposures along summit ridge consist of partly glassy, coarsely vesicular, loose blocks as big as 2 m that have yellow, white, and ochre alteration minerals and sublimates on most joint faces. Phenocrysts: 15–20% plag (mph to 4.5 mm); <1% olivine (mph to 1 mm). Overlies unit mms; banks against northern remnant of unit dms. Undated [NS]

mst **Basaltic andesite south of Trout Creek (late or middle Pleistocene)**—Isolated 1 km^2 window of moderately porphyritic mafic (53.3% SiO_2) lava along and south of headwaters of Trout Creek, at north edge of apron of North Sister lavas. May be single flow, cropping out best as glacially eroded, southeast-facing scarp 6 to 10 m high, crossed by Scott Pass trail. Exposures are massive, block jointed or slabby, and mostly devitrified. Phenocrysts: ~10% plag (mph to 3 mm); 2% olivine (0.5–2 mm); sparse cpx (~1 mm) and oxide mph. Overlies older set of distal lavas of unit mns. Overlain by unit myl and, although contact is covered by till, probably also by nearby unit mey. Undated [TCB]

mtb **Basaltic andesite and basalt of Trout Creek Butte (middle Pleistocene)**—Steep mafic (51.8–52.7% SiO_2) shield in northeast corner of map area, 4 km wide and having about 400 m of relief, as well as apron of lava flows that extends as far as 5 km northeast of shield's summit (Sherrod and others, 2004). Scores of flows are present; many thin proximal ones are fountain fed; flows are thicker on apron. Slopes of shield are mostly nonglaciated blocky colluvium that has few true outcrops; sparse exposures are block jointed and finely to coarsely vesicular. Two summit knolls consist of cliffy stratified agglutinate, widely oxidized, having layers that vary from tack welded through blobby to densely welded and nearly homogenized. Late Pleistocene moraines bank against west and southwest base of shield, but most of edifice is unglaciated. Associated ash-fall deposit is said to be preserved in nonglaciated area northeast of shield (Taylor, 1987). Phenocrysts: 1–3% plag (0.5–1 mm), most plag anhedral; 1–3% olivine (mostly mph, rarely 0.5–1 mm); sparse cpx in some flows; mph clots of plag or olivine+plag are ubiquitous and conspicuous. Groundmass typically choked with plag-lath mph, seriate to microlites. Older than units bss and bbd that bank against base of shield. $^{40}Ar/^{39}Ar$ age: 532±7 ka. Oldest unit identified in map area [TCB]

mth **Basaltic andesite of The Husband (middle Pleistocene)**—Glacially ravaged, polyintrusive, multivent mafic (52–57% SiO_2; n=22) stratovolcano centered 8 km northwest of South Sister summit. Edifice is 5 by 8 km (elongate northwest) and retains about 1,225 m of relief despite severe erosion. Not mapped in detail by us. Extent of lava apron and distribution of vent-related intrusions was shown by Sherrod and others (2004); numerous dikes were shown schematically by Taylor and others (1987). Lithology varies widely, from glassy and vesicular to massive, devitrified, and block jointed to slabby. Plugs tend to be microgranular, having abundant olivine and plag mph. Lavas are phenocryst poor, many containing only ~1% olivine and 1–2% plag (both ranging from mph to as big as 1.5 mm). Overlies unit bhs, which may, in part, be an early product of The Husband center. Overlain by units acc, alc, mls, mms, and msc. Knob 6760, 3 km north of Indian Holes on southeast apron of The Husband, is glaciated flank vent (unit mth′; 52.8% SiO_2) that intruded and overlies less mafic apron of this unit. $^{40}Ar/^{39}Ar$ age for lava of Knob 6760 (149±5 ka), thus, provides minimum age for The Husband edifice and for subjacent lavas of unit bhs [LL, NS, SS]

mtp **Basaltic andesite of Teardrop Pool (late Pleistocene)**—Mafic (53.8–56.1% SiO_2) agglutinate and scoria-fall deposit that caps summit of South Sister. Crudely stratified deposit mantles 350-m-wide summit crater (from which it erupted), which includes ice-ringed pond called Teardrop Pool. Ice-radar measurements show crater to be flat-floored, funnel-shaped depression filled to rim with ice as thick as 60 m at crater center (Driedger and Kennard, 1986). Deposit also mantles outer slopes of cone on south and west, thinning but extending 200 to 400 m outboard from crater rim. On north and east, however, outboard part of sheet has been eroded away, leaving edge of deposit as steep rim scarp 2 to 20 m high. Sheet grades up, down, and outboard from densely agglutinated (even rheomorphic) to tack welded, then to loose scoria; locally black but widely oxidized brick red; gray in 10-m-thick densely massive core of sheet exposed above headwall of Lewis Glacier. Easily confused with red and gray agglutinates and fountain-fed lavas of cone-forming unit aeg, which it drapes in places. Blocky surface of unit in summit bowl is glassy and scoriaceous, having many scoria bombs variably deformed in nondense parts of agglutinate. Just west of Teardrop Pool, stratified agglutinate (10 m thick) dips steeply (45°–65°) both inboard and outboard, draping rim of inner crater blasted through outward-dipping strata of fragmental unit des. Around Teardrop Pool, surface of sheet dips radially inward, probably reflecting differential compaction (welding) of thicker central accumulation where infilling its own crater. This inner crater is not to be confused with outer crater (700 m wide at its rim) that was earlier filled by units dlg and des. Phenocrysts: 7–15% plag (mph to 5 mm); 1–3% cpx (mph to 1.5 mm); ≤1% olivine mph. Overlies units aeg, dlg, des, dnt, and dnt′. Youngest unit erupted from South Sister summit vents. $^{40}Ar/^{39}Ar$ age: 22±13 ka [SS]

mts **Basaltic andesite southeast of “Todd Creek” (middle Pleistocene)**—Small glaciated mafic (56.1–56.8% SiO_2) spatter and scoria cone about 1 km due south of Todd Lake and 100 m northeast of Cascade Lakes Highway (UTM grid 0540/7435). Only about 25 m high and 120 m in diameter, this degraded knoll largely consists of oxidized agglutinate that crops out as blobby to densely homogenized ledges on most slopes; north slope is strewn with loose red scoria. Phenocrysts rare: trace amounts of plag (0.5–3 mm) and mph of olivine and pyroxene. Knoll is wrapped by postglacial lava flows of unit mec. North end of cone is in contact with glaciated rhyodacite lava (not mapped by us), which may be younger, as its surface is devoid of scoria lapilli from this contiguous cone. Undated [BT]

mtw **Basaltic andesite of The Wife (middle Pleistocene)**—Deeply eroded mafic (52.1–53.6% SiO_2) shield west of Wickiup Plain and Rock Mesa. Massive summit plug, steeply jointed, intrudes stratified, radially dipping, scoria-fall deposits and agglutinate. Several vertical dikes, 2 to

5 m thick, cut proximal strata. Apron of glacially eroded lava flows extends 2 km north and south and several kilometers west beyond map area. Scoria falls exposed about 500 m southeast and 170 m lower than shield summit are intercalated with lava flows and are palagonitized yellow orange, unlike red and black scoriae near summit. Lavas exposed largely are massive and devitrified. Phenocrysts: 2–5% plag (0.5–1.5 mm long), seriate to felty groundmass rich in plag mph; 2–5% olivine (mph to 0.7 mm); oxide mph abundant in plug, sparse to absent in lavas. Some proximal scoria bombs appear to contain more plag phenocrysts than apron lava flows. Base not recognized in map area. Overlain by units bsb (279±6 ka), mhr, bjc (148±4 ka), ddl, mlc, and rrm. $^{40}Ar/^{39}Ar$ age: 374±6 ka, for massive lava on east face of summit. Second oldest unit identified in map area [SS]

mwa **Basaltic andesite west of upper Alder Creek (late Pleistocene)**—Moderately porphyritic mafic (53.2–56.1% SiO_2) lava flows exposed as glacially sculpted ridges and cliffs, 3 to 5 km north of North Sister summit. Sets of two or three flows form east-facing cliffs that extend 2 km north-south, directly beneath ridge of phenocryst-poor pyroclastic unit mps; branching from that cliff (at UTM 985/945), second sharp ridge, about 250 m wide and as high as 100 m, extends 1.2 km northeast to bank against Knob 6435 (unit myl). Individual flows are 25 to 60 m thick, and stacks of two or three are as thick as 100 m; lavas are massive, block jointed or slabby, pale to medium gray, and everywhere ice scoured. Phenocryst contents vary widely among flows: 5–15% plag (0.5–2 mm, rarely to 4 mm); 1–3% olivine (mph to 2 mm); sparse to common cpx (0.5–1.5 mm); stellate clusters of 10 to 25 crisscrossed plag laths (each 0.2–1 mm long) are common. Overlies units mns; banks against units mfy, myl, and (probably) mys. Overlain by unit mps and intruded by thick aphyric mps dike; also intruded by apparent plug of unit asy. May have vented from same fissure-vent system that later produced pyroclastic unit mps. Distinguished from unit awa, which crops out along same wall just south, by much lower phenocryst content, lower Al_2O_3 content (<17%), and higher FeO content (>8%) of unit awa. $^{40}Ar/^{39}Ar$ age: 59±4 ka, for basal flow of northeast ridge [NS]

mwh **Basaltic andesite of Whychus Creek (middle Pleistocene)**—Seven mutually isolated exposures of moderately porphyritic mafic (53.2–55.2% SiO_2) lava flows on upstream floor and downstream rims of Whychus Creek. Five are scattered for 4 km, from 4,900 ft elevation in bed of North Fork Whychus Creek to 4,500 ft elevation in right-bank roadcut near confluence with Snow Creek; exposures are correlated with fair confidence on basis of petrographic similarity and narrow compositional arrays on chemical variation diagrams. These five crop out as ice-scoured, till-strewn knobs or ledges, massive, devitrified, and block jointed or slabby; exposures are less than 10 m thick except 70-m-thick knobby outcrop on left-bank rim (UTM grid 063/920); nowhere has base been observed. Two additional exposures lie along Whychus and Pole Creeks near and just beyond limits of late Pleistocene moraines, near east edge of map area. Blocky, scoriaceous levee is exposed along north bank of Pole Creek at about 4,200 ft elevation, and sets of slabby, water-worn ledges on both walls of Whychus Creek at 4,100 to 4,200 ft elevation provide 15 to 20 m of vertical exposure. Phenocrysts: 5–10% plag (1–3 mm and abundant mph); ≤1% olivine (seriate from mph to 1 mm); rare cpx (≤1 mm, mostly in sparse clots with olivine and plag); sparse oxide mph. Overlies units awy (299±1 ka), mbw, and bwy. Overlain by units acp, bnf, bwl, bss, and mws (175±3 ka); appears to lie closely beneath ignimbrite of unit spt in North Fork Whychus Creek gorge. $^{40}Ar/^{39}Ar$ age: 195±5 ka [TCB]

mws **Basaltic andesite west of Snow Creek (middle Pleistocene)**—Phenocryst-poor mafic (53.6–55.0% SiO_2) lava flows recognized in three mutually separated locations along forks of Whychus Creek; correlated on basis of unusually high Ti and Fe contents. Upstreammost exposure is 600 m east of Upper Chush Falls, suggesting derivation from Broken Top volcano. Medial exposure along lower North Fork Whychus Creek rests directly atop ignimbrite of unit spt. Distal exposure, more than 80 m thick, forms west-bank wall for 800 m downstream from confluence of North and South Forks, Whychus Creek. All three are glacially eroded, predominantly devitrified, massive, and block jointed or slabby. Phenocrysts: ~1% plag (mph to 1.5 mm laths); sparse olivine and cpx (both 0.5–1 mm); rare oxide mph. Overlies units spt and mwh (195±5 ka). Overlain by units adl (24±1 ka), msp, bnf, and ruc (169±2 ka). $^{40}Ar/^{39}Ar$ age: 175±3 ka [TCB]

mwy **Basaltic andesite scoria cone west of Yapoah Lake (late Pleistocene)**—Small mafic (56.4–56.6% SiO_2) cone, 600 to 800 m across, just northwest of Yapoah Lake. Built on east-facing paleoslope, cone has maximum relief of about 90 m on its east side but only 10 m on its west side. Crater on top is 300 m wide and has 75 m of relief on its inner west wall. Rimrock is largely agglutinate, showing gradation from loose oxidized scoria through tack-welded scoria and knobbly dense agglutinate to streaky or homogenized lava, which is locally block jointed and slabby. On 5,800-ft-high nose just south of crater, its density-graded agglutinate mantles glaciated ridge of unit mys and small cliffy window of unit myw. Cone is degraded but only modestly eroded; may have stood above or aside main late Pleistocene ice streams. Phenocrysts: almost aphyric; groundmass plag includes rare laths as long as 0.8 mm; <<1% olivine (0.2–0.4 mm); very rare oxide mph. Overlies units myl, mys, and myw. Probably overlain marginally by unit mps, but surficial deposits render that conclusion uncertain. May be related to nearby chain of scoria cones and ridges that runs north-south past Matthieu Lakes, but cone (this unit) lies east of that alignment. Undated [NS]

myc **Basaltic andesite of Yapoah Crater (Holocene)**—Moderately porphyritic mafic (54.5–57.0% SiO_2) lava flows that extend as far as 12 km northward from an uneroded scoria cone (stippled on map), 160 m high and about 500 m in diameter, located about 5 km north of North Sister. Easternmost eruptive unit of postglacial McKenzie Pass volcanic field (fig. 2); only eastern of several flows from Yapoah Crater is mapped here, essentially as border for our map area. Full extent of Yapoah lava apron has been depicted by Taylor (1968) and Sherrod and others (2004). Flows are blocky to rubbly, vesicular, little eroded, and extensively leveed. Phenocrysts: varied amounts of plag and olivine; sparse cpx. Undated, but age is bracketed by enclosing units to roughly 2.5 ka (Licciardi and others, 1999; Sherrod and others, 2004) [NS]

myl **Basaltic andesite of Yapoah Lake (late Pleistocene)**—Glacially eroded, phenocryst-poor mafic (53.4–54.2% SiO_2) lava flows that form walls enclosing Yapoah Lake and extend about 3 km east-northeast and about 1 km south from lake. Stack is more than 70 m thick on scarp south of lake, but base is not exposed there. Bold ice-sculpted outcrops form knolls, ledges, ridges, and cliffs that are generally massive, devitrified, and block jointed or slabby. Vent plug is preserved as stout Knob 6435, about 1.5 km south of Yapoah Lake; steep-walled, glaciated knob is 75 m high, 200 by 250 m wide, and consists of massive fine-grained lava that has widely spaced, irregular joints and veneers of brick-red blobby agglutinate fused to its north and east faces. Phenocrysts: few crystals >0.5 mm; rare equant plag (1–2 mm) may be antecrystic; groundmass plag laths are seriate to as many as 20% mph, including rare laths as long as 1.5 mm; 1–3% olivine mph (0.2–0.4 mm, rarely to 0.8 mm); distal flows have abundant oxides (rarely >0.1 mm). Overlies units mst and bwm. Overlain by units mey, mfy, mnt (20±5 ka), and mwa (59±4 ka), as well as by scoria cone of unit mwy. Undated [NS, TCB]

mys **Basaltic andesite southwest of Yapoah Lake (late Pleistocene)**—Moderately porphyritic mafic (52.5–53.2% SiO_2) lava flow that forms east-facing cliff as high as 50 m and ice-scoured bench at 6,050 to 6,100 ft elevation. Bench extends 1.5 km northward from prominent crag at 6,400 ft elevation (UTM grid 982/959) as far as scoria cone of unit mwy west of Yapoah Lake. Fine exposures are massive and slabby or block jointed. Phenocrysts: 3–5% plag (0.5–1.5 mm, rarely 4 mm); 5–8% olivine (0.5–1 mm, commonly in clusters; rarely as big as 3 mm). Steeply jointed crag is vent plug, intruding and fusing its own oxidized scoria deposit and displaying 60-m-high scarp on its east face. North of scoria cone of unit mwy, 600 m along strike from principal cliffy exposures, massive angular blocks of this lava crop out poorly through till and colluvium along Scott Pass trail at 5,640 ft elevation (UTM grid 9905/9765). Overlies units mey and, inferentially, myw. Overlain by scoria cone of unit mwy and by variably agglutinated facies of phenocryst-poor pyroclastic unit mps, which banks against west wall of vent crag. Unit mwa apparently banks against south wall of vent crag, but surficial deposits obscure contact relations. Undated [NS]

myw **Basaltic andesite window west of Yapoah Lake (late or middle Pleistocene)**—Moderately porphyritic mafic (53.0% SiO_2) lava flow that crops out only as ledgy window (UTM grid 989/971), less than 100 m long, at 5,720 to 5,760 ft elevation on northeast-facing scarp above crater wall of scoria cone of unit mwy. Steep outcrops are massive and block jointed. Unit is chemically similar to predominant lavas of unit mns but differs in being plag-dominant and richer in total phenocrysts. Phenocrysts: 7–10% plag (mph to 3 mm); 2–3% olivine (mph to 2 mm); some composite intergrowths. Base not exposed. Draped and largely concealed by agglutinate of unit mwy. Inferred also to underlie nearby unit mys. Undated [NS]

rct **Rhyolite of South Sister climbers trail (late Pleistocene)**—Phenocryst-rich pyroxene-rhyolite (72.7–73.4% SiO_2) lava flows that emerge from beneath Lewis Glacier moraines high on south slope of South Sister. Main flow apron divides into two lobes that extend 2 km and 3 km downslope, respectively, latter of which reaches lowland toe of edifice. Smaller third lobe about 200 m east of upper end is largely covered by surficial deposits. All exposures are glacially eroded, strongly flow foliated, and widely spherulitic or vitrophyric. Phenocrysts: 7–10% plag (mph to 3 mm); ~1% opx (mph to 0.8 mm, plus rare quench needles 1–2 mm long); sparse oxide mph. Also contains sparse clots: either all plag, pyroxene-oxide, or plag-pyroxene-oxide. Maximum thickness exposed is about 75 m proximally and about 60 m at southwestern lowland flow front. Medial exposures are eroded into cliffy ridges where foliation exhibits sweeping ramps and folds. Lowland lobe is heavily mantled by late Holocene pumice-fall deposits associated with unit rrm and is intruded by fissure-aligned minidomes of unit rrm. Overlies units dcg (31±3 ka), dmn, dmw, dwp, and rse (34±1 ka). Overlain (inferentially) by unit aeg. $^{40}Ar/^{39}Ar$ ages: 30±8 ka, 24±5 ka [SS]

rdc **Rhyolite of "Devils chain" (late Holocene)**—Chain of nearly contiguous, virtually uneroded, rhyolite lava domes (72.3–72.8% SiO_2; n=31; see also Scott, 1987), 5 km long and aligned north-south on southeast apron of South Sister. Chain consists of seven main lavas and several minidomes (Scott, 1987). Three domes issued short coulees; largest coulee is 2-km-long Newberry flow, which accounts for 60 percent of total eruptive volume and, only 2.5 km from summit of South Sister, is northernmost vent along principal chain. Dike-fed alignment is expressed between domes by fissures and graben cut in 10-m-thick proximal subplinian pumice-fall deposits that preceded effusion of most lavas. Only exception to generality of lavas following fallout is southwest lobe (unit rdc′) of Newberry flow, much of which is tephra mantled (white stipple on map). Ejecta ring (black stipple on map) wraps west end of Newberry flow near its vent; ridges of thick ejecta likewise flank chain of four small domes about 1 km south of Newberry vent, heavily mantling and locally concealing subjacent unit rse. For composite (multivent) subplinian-fall deposit, 10-cm isopach extends 11 km east and 6 km south of vent chain, as mapped by Scott (1987), who calculated eruptive (magma) volumes of 0.3 km^3 for lavas and 0.02 km^3 for tephras (mostly fallout but including thin proximal pyroclastic flows). Unit has sometimes been called "Devils Hill chain," but its name is here shortened to avoid confusion with the (subjacent) Pleistocene rhyolite of Devils Hill (unit rdh). Spring-fed Hell Creek emerges from beneath unit rdh; Satan Creek from beneath this unit. Beyond 3.5-km-long gap north of Newberry flow, second north-south fissure alignment near Carver Lake on north-northeast slope of South Sister is marked by 1.2-km-long chain of minor vents that released very small volumes of lava and pumice (Scott, 1987); these, however, are high enough in elevation to have been scoured by Neoglacial ice. Nonetheless, because products of all 20 or so vents (along two chains) are compositionally identical, parallel en echelon chains probably erupted contemporaneously. Thickest exposures are about 120 m (north side of Newberry flow) and about 50 m for several southern domes and for small lava flow northwest of Carver Lake. Lavas are either coarsely blocky, dense black vitrophyre or pale gray and vesicular; strongly to weakly flow foliated. Spherulitic layers are rarely exposed, but oxidized rehealed flow-breccia layers are common. Slabby, tan, partly devitrified interior facies is exposed locally on ice-scoured lavas near Carver Lake. For interpretation of brecciated obsidian-bearing margin (largely tephra free) of otherwise tephra-mantled southwest lobe of Newberry flow (unit rdc′), see Scott (1987, his fig. 9). Phenocrysts: 5–7% plag (mph to 3.5 mm); <1% opx (mph to 0.7 mm); sparse oxide mph; many plag crystals carry prominent melt inclusions, and others are coarsely sieved; unit also contains common plag-pyroxene-oxide clots. ^{14}C age: about 2,000 yr B.P. (Scott, 1987; Sherrod and others, 2004). Unit is younger than all others nearby except Little Ice Age till. Intervening weak soil suggests that pumice fall of this unit postdates that from Rock Mesa (unit rrm) by at least a century (Scott, 1987) [BT, SS]

rdh **Rhyolite of Devils Hill (late Pleistocene)**—Steep rhyolite (73.4–74.1% SiO_2) lava dome that has sprawling flow lobes to south and east; altogether, 2 km across, having nearly 500 m of total relief. Dome stands 6 km south of South Sister summit and is almost everywhere glacially scoured. Lithologically varied: widely vitrophyric, partly glassy or spherulitic; block jointed and only locally vesicular or vuggy but pervasively flow foliated; gray to white, only locally oxidized. Little pumiceous carapace preserved except near its summit. Phenocrysts: 3–5% plag (mph to as big as 3 mm, but few >1 mm); 1–2% pyroxenes (mostly mph, rarely as long as 1.2 mm); sparse oxide mph; sparse clots, either all plag or plag-pyroxene. May be roughly contemporaneous with chemically identical (but phenocryst poorer) adjacent dome of unit rkb. Unit dml (34±1 ka) banks against and wraps around dome (this unit). Intruded, and overlain by, late Holocene domes of unit rdc. Overlain by fallout associated with units rdc, rrm, and btk. $^{40}Ar/^{39}Ar$ age: 34.8±1.5 ka [BT, SS]

rgl **Rhyolite of Green Lakes (late Pleistocene)**—Rhyolite (72.2–72.9% SiO_2) lava dome partly buried by dacite lava flows (unit dgl) at east toe of South Sister edifice, just west of Green Lakes. Exposure is 700 m long and 150 m high. Glacially eroded, flow-foliated lava varies from dark-gray vitrophyre to pale-gray felsite, partly devitrified and locally spherulitic; widely vesicular or vuggy. Jointing causes rock to break into chunks or blocks. Phenocrysts: 5–7% plag (mph to as big as 3 mm); ~1% pyroxenes (mph to 0.5 mm, plus rare rods to 1 mm long); sparse oxide mph; also contains common plag-pyroxene-oxide clots. Base not exposed. Overlain by South Sister lavas of unit dgl. $^{40}Ar/^{39}Ar$ age: 31.9±0.7 ka [BT]

rkb **Rhyolite of Kaleetan Butte (late Pleistocene)**—Rhyolite (73.5–73.6% SiO_2) dome-flow complex adjacent to west side of Devils Hill dome (unit rdh) and 6 km south of South Sister summit. Complex is 2 km wide and has 320 m of relief on its steep south side. East and west lobes are compositionally identical but may have extruded independently; also is chemically similar to adjacent Devils Hill dome (unit rdh) but carries fewer phenocrysts. Glacially scoured surface consists largely of flow-foliated vitrophyre, although partially devitrified layers locally alternate with obsidian and spherulitic lenses; commonly is finely vesicular but only locally is oxidized streaky pink. Deeper erosion has exposed ledges of thinly platy felsitic interior on steep southeast face. Phenocrysts: 2–3% plag (mph to 1 mm); <1% opx (all mph); sparse plag-opx clots. Abuts the (chemically identical) rhyolite of Devils Hill (unit rdh); units may be roughly contemporaneous, but age relation is not clear at contact. Overlies unit dwp (34±3 ka). Unit dml (34±1 ka) banks against northeast margin of dome; west side of dome is wrapped by postglacial mafic lava flows from Le Conte Crater (unit mlc). K-Ar age: 30±5 ka [SS]

rmc **Rhyolite of Mesa Creek (late Pleistocene)**—Moderately phenocryst-rich rhyolite (72.3–72.6% SiO_2) lava flow or lobe of partly buried lava dome exposed for 800 m along uppermost Mesa Creek at southwest toe of South Sister. Flow direction was toward southwest, down steep slope; exposed relief is about 340 m, but true thickness probably is only about 150 m. Glaciated south cliffs are pervasively flow foliated, exposing black vitrophyre, vesicular and oxidized layers, and zones of platy felsite. Ice-scoured lava benches above are variably devitrified and mostly medium gray, weathering cream to pale gray. Phenocrysts: 5–7% plag (mph to 2 mm), some slightly rounded; <<1% opx (mph, rarely as big as 0.6 mm, plus rare rods 0.2 by 3 mm); still sparser hornblende (mph to 0.7 mm, along with tiny needles), mostly opacitized; sparse oxide mph. Normal magnetic polarity (laboratory determination by D.E. Champion, 2006). Overlain, and extensively buried, by South Sister lava flows of unit dcg (31±3 ka); coulee of postglacial unit rrm banks against it. $^{40}Ar/^{39}Ar$ ages: 47±8 ka, 45±15 ka [SS]

roc **Rhyolite of Obsidian Cliffs (late Pleistocene)**—High-silica rhyolite (76.4–76.7% SiO_2) coulee that emerges from beneath younger lavas of Middle Sister edifice about 3 km northwest of its summit and extends 3 km farther northwest. Everywhere glacially scoured, flow is 1 km wide and as thick as 120 m near Obsidian Falls and 135 m at its distal flow front. Aphyric lava is strongly flow foliated and ranges from black obsidian to white felsite, some layers being vesicular or oxidized. Unit is most silicic Quaternary lava in Oregon Cascade Range. Phenocrysts: strictly aphyric. Overlies units mlb (47–49 ka) and aoc (~48 ka). Syneruptive lapilli-fall deposit (white stipple on map) containing clasts of aphyric pumice, obsidian, and felsite is preserved atop west ridge of Little Brother. Abutted by unit mrg (20±6 ka) and wrapped by Holocene lava flows from Collier Cone (unit acc). Overlain near Sister Spring by thick lava of unit dss (25±3 ka), which drapes down across successive lithologic zones in rhyolite of this unit. $^{40}Ar/^{39}Ar$ age: 37.8±1.8 ka [NS]

rpc **Rhyolite of Park Creek (late Pleistocene)**—Moderately porphyritic, glaciated rhyolitic (72.5% SiO_2) lava flow that crops out as single 30-m-high bench (less than 100 by 350 m) on north wall of West Fork Park Creek at about 7,000 ft elevation (UTM grid 014/852). Flow-foliated lava is dominantly black vitrophyre but includes layers and lenses of gray or pink felsite, some strongly spherulitic, and thin shear zones of pink to brick-red breccia. Phenocrysts: 5–7% plag (0.5–2 mm); <1% opx (0.1–0.5 mm); sparse oxide mph. Base not exposed. Overlain by unit drm (29±1 ka); unit awf (24±1 ka) banks against base of unit [BT]

rpg **Rhyodacite of Prouty Glacier (late Pleistocene)**—Rhyodacitic (68.1–68.4% SiO_2) lava flow high on South Sister edifice, cropping out principally as prominent ledge that wraps northwest corner of headwall of Prouty Glacier, 0 to 20 m above ice surface. At 9,300 ft elevation, this is highest exposure on South Sister edifice of any lava flow that is more silicic than dacite. Glacially eroded, slabby lava is exposed laterally for about 500 m; lava generally is about 10 m thick, thickening northward where it disappears beneath younger units. Locally vesicular to vuggy and has pink oxidized films along joint planes. Second outcrop, compositionally identical, is exposed through Little Ice Age moraines about 500 m east of terminus of Prouty Glacier as narrow, 300-m-long, ice-sculpted, northeast-trending rib of massive to vuggy gray lava (at about 7,900 ft elevation, 500 m southeast of Carver Lake; UTM grid 001/846). Phenocrysts: ~5% plag (mph to 2 mm, plus rare antecrysts to 8 mm long); <1% pyroxenes (mph to 0.7 mm, nearly all in clots with plag and oxides); <1% hornblende (0.1–1 mm long, mostly opacitized); sparse oxide mph; also contains sparse plag-pyroxene-oxide clots, plag-bearing mafic blebs (as big as 5 mm), and olivine xenocrysts (0.1–0.5 mm). Underlain on Prouty Glacier headwall by units aph and aph′; overlain there by unit dpg, which is, in turn, overlain by units ahc and aeg (27±2 ka). Second outcrop (southeast of Carver Lake) is overlain by unit drm (29±1 ka). $^{40}Ar/^{39}Ar$ age: 32.8±1.5 ka [BT, SS]

rrm **Rhyolite of Rock Mesa (late Holocene)**—Pancake-shaped rhyolite (73.3–73.6% SiO_2; n=9; see also Scott, 1987) coulee, associated subplinian pumice-fall deposits, and nearby chain of satellitic minidomes. Virtually uneroded coulee is 2 by 3 km in diameter, 50 m thick at most margins, and as thick as 85 m at northwest terminus where descent into Mesa Creek stalled. Small early lava lobe spread northeast, but main outflow was south, southwest, and northwest from vent. Broad swell over vent is 320 m higher than northwest terminus of coulee. Lava is strongly blocky and has steep flow fronts, consisting principally of dense to pumiceous, flow-foliated vitrophyre. Stratified pumice-fall deposit is more than 10 m thick proximally and includes agglutinate locally exposed along gullies. Its 10-cm isopach extends 17 km east and 13 km south of vent, as mapped by Scott (1987), who calculated eruptive (magma) volumes of 0.5 km^3 for lava and 0.03 km^3 for tephra (mostly fallout but also includes 1-m-thick pyroclastic flows that extend as far as 1 km); traces of ash are recognized as far as 30 km downwind. About 1 km east of principal vent, a fissure vent aligned N. 5° to 10° E. (“Rock Mesa ENE” assemblage of Scott, 1987) produced 200-m-wide dome, as well as several tiny extrusions only meters across, modest ejecta rings, and small volumes of pumiceous fallout and pyroclastic flows. Eruptive reach of fissure system is about 500 m long, but fractures and graben continue for another 700 m northward across previously glaciated surface of unit dcg. Main ejecta ring around fissure-vent system heavily blankets and widely obscures subjacent unit rct. Lavas of fissure-vent system are uneroded, flow foliated, and coarsely blocky, having coarsely to finely pumiceous surfaces. Products of coulee and fissure are compositionally identical. Phenocrysts: 5–7% plag (mph to 2 mm), many slightly rounded; <1% opx (mph only); trace amounts of hornblende and oxide mph; also contains sparse plag-opx-oxide clots. ^{14}C age: 2,150±150 yr B.P. (preferred age of Scott, 1987). Younger than all nearby units except rdc, fallout of which overlies weak soil developed atop fallout of this unit, which may, thus, be a century or more older (Scott, 1987) [SS]

rsc **Rhyolite of Separation Creek (late Pleistocene)**—Rhyolite (69.6–73.9% SiO_2) of Dome 7930 just west of Chambers Lakes in saddle between Middle Sister and South Sister, about 2.5 km from summit of each. Steep, compact, glacially scoured dome is 1 km in diameter and has 350 m of relief. Most exposures are flow-foliated, dark- or medium-gray vitrophyre, dense or pumiceous, and eroded into hackly jointed knobs and ledges. Some layers are vuggy or oxidized, and many joints have pink oxidation films. Pale-gray, devitrified, slabby interior crops out locally. Apparent chemical heterogeneity may reflect disaggregation and dispersal of material from relatively mafic, phenocryst-poor enclaves, 1 to 20 cm across and ovoid or crenulate. Phenocrysts: 2–3% plag (mph to 2.5 mm); <1% pyroxenes (mph to 0.7 mm, mostly in clots with plag and oxides); trace amounts of hornblende (0.1–0.7 mm), rims opacitized; sparse oxide mph. At southwest toe of dome, what appears to be early lobe of this unit (subunit rsc′; 72.3% SiO_2) differs in that it contains larger feldspar phenocrysts, some as big as 8 mm. Overlies distal flows of units aeg (here, 27±3 ka) and alg (27±1 ka) at Separation Creek. Dome is wrapped by two tongues of dacite coulee of unit dig (14±3 ka). $^{40}Ar/^{39}Ar$ age: 25.4±1.3 ka [NS, SS]

rse **Rhyolite southeast of Lewis Glacier (late Pleistocene)**—Phenocryst-poor rhyolite (73.6–74.0% SiO_2) lava flows on south slope of South Sister. Flows extend 2.5 km southward from exposures as high as 8,050 ft elevation along recently deglaciated trough of Lewis Glacier to eroded flow fronts as low as 6,500 ft (northeast of Moraine Lake) and 6,400 ft (just south of Newberry flow, unit rdc). All exposures are glacially scoured, and some are deeply incised. Two flow units are exposed on glaciated cliff just north of vent for Newberry flow, which overran their southeast apron. Nearly all exposures are flow foliated, whether glassy or devitrified. Unit is lithologically varied, from massive, block-jointed or platy, white felsite to pale-gray, micropumiceous or dark-gray, dense vitrophyre; oxidized layers and breccia zones are not uncommon. Fused rheomorphic flow breccia crops out near base of unit both north and south of Newberry flow. Phenocrysts: 1–2% plag (mph, rarely as big as 1.5 mm); <<1% opx (all mph); <<1% hornblende (mph to as long as 1 mm); sparse oxide mph (0.1–0.2 mm). Overlies units asn and dml (34±1 ka). Overlain by units dmn (28±1 ka, 25±1 ka) and rct (30±8 ka, 24±5 ka); intruded, and overlain, by several domes of unit rdc and heavily mantled and widely concealed by proximal pumice falls that preceded extrusion of those domes. $^{40}Ar/^{39}Ar$ ages: 35.0±2.7 ka, 33.6±0.5 ka [BT, SS]

rsf **Rhyolite of South Fork Whychus Creek (late Pleistocene)**—Large rhyolite (73.8–74.4% SiO_2) coulee on lower northeast flank of South Sister that extends from just north of Carver Lake for 3 km east along Whychus Creek drainage. Glacially scoured coulee is about 1 km wide and as thick as 300 m proximally, where three (compositionally identical) flow units are locally discernible; unit is 150 m thick at its northeast lowland terminus. Vertical jointing prominent in high vent region; flow foliated elsewhere, commonly convolutely. Lithologically varied, from dense vitrophyre or obsidian to platy, slabby, or block-jointed felsite, in addition to local spherulitic zones and oxidized flow-breccia zones. Extensive vitrophyre preserved atop flow where only lightly scoured by ice. Phenocrysts: widely aphyric, but locally has <1% plag (generally ≤1 mm) and rare opx mph; in thin section, rare rounded or partly resorbed plag grains (0.2–1 mm) are probably antecrysts. Overlies unit mdl (181±21 ka). Overlain by unit aeg (here, 27±2 ka) and is wrapped by units dcn, drm (29±1 ka), and mcl. $^{40}Ar/^{39}Ar$ age: 35.8±2.0 ka [BT, NS, SS, TCB]

rsg **Rhyodacite southwest of Golden Lake (late or middle Pleistocene)**—Rhyodacite (70.1% SiO_2) plug that intrudes brick-red mafic (56.5% SiO_2) scoria cone of unit mbt at elevation of 7,150 ft on distal nose of northwest ridge of Broken Top volcano, 1 km southwest of Golden Lake. Glaciated plug is only 70 m in diameter; its finely crystalline interior is block jointed or slabby to platy, is variably mottled in shades of gray, and has sparse irregular vugs. Locally black, glassy or aphanitic at its margins, plug intrudes and fuses adjacent red scoriae. Phenocrysts: 3–5% plag (mph to 1 mm, rarely as big as 4 mm); <1% pyroxenes (0.2–0.4 mm, rarely as large as 0.8 mm); sparse oxide mph; contains sparse clots, either all plag or plag-pyroxene-oxide. No associated lava flows are preserved. Taylor (1978) suggested that thick stratified pumice-fall deposit preserved atop same ridgecrest about 1 km southeast is correlative with compositionally similar plug; if so, plug may be late Pleistocene and, thus, related magmatically to nearby South Sister rather than to much older Broken Top. Ridge hosting scoria cone and rhyodacite plug consists of middle Pleistocene stack of mafic lava flows that erupted at Broken Top. Undated [BT]

rsw **Rhyolite southwest of Lewis Glacier (late Pleistocene)**—Phenocryst-poor rhyolite (73.3, 73.6% SiO_2) lava exposed only in two small windows on south flank of South Sister. Upper one is cliffy knob that has 150 m of relief, its top at elevation 8,550 ft on south end of cleaver between Clark and Lewis Glaciers; remnant of possible vent dome, it sheds large talus. Lower exposure about 1 km southwest is 150-m-long window incised through apron of unit dcg lavas by uppermost tributary of Mesa Creek. Phenocrysts: 1–2% plag (mph to 1 mm); <<1% opx (all mph). Contrasts with nearby crystal-rich rhyolite units rct and rmc, just east and west. Glacially eroded, flow foliated, varying from coarsely block jointed and massive to slightly vesicular; mostly gray or grayish brown, weathering pale gray or purplish brown. Obsidian widespread in lower window. Base not exposed. Underlies units dcg (31±3 ka) and aeg. $^{40}Ar/^{39}Ar$ age: 51±10 ka [SS]

rtl **Rhyodacite southwest of Todd Lake (middle Pleistocene)**—Glaciated rhyodacite lava dome (69.4% SiO_2; see Taylor, 1978) above southwest shoreline of Todd Lake. Dome is 500 m wide, 100 m high, and part of cluster of such silicic lavas that extends east and northeast of lake (Taylor, 1978). Scattered outcrops through extensive colluvium are mostly gray or pink felsite and local remnants of black vitrophyre. Phenocrysts: 5–10% plag (0.5–3 mm); ~1% opx and <1% cpx (each mph to 1 mm). Abutted by younger lavas of unit mbl. Undated [BT]

ruc **Rhyodacite of Upper Chush Falls (middle Pleistocene)**—Rhyodacite (69.1–69.7% SiO_2) coulee as thick as 110 m and as wide as 1.5 km that crops out 5 to 7 km north of Broken Top volcano. Supports spectacular waterfalls on forks of both Park and Whychus Creeks, along which strongly flow-foliated felsites form gorge walls. Rocks are partly glassy or devitrified and block jointed or slabby to platy; foliation is locally convolute. Rarely exposed base of glaciated flow consists of massive or slabby black glass and flow breccia. Phenocrysts: 2–3% plag (mph to 1 mm, rarely 2 mm); <1% pyroxenes (all mph); sparse oxide mph. Overlies unit bwy. Overlain by avalanche and glacial deposits and mafic lava flows, all derived from Broken Top, and by unit apc (31±9 ka) and probably by unit drm (29±1 ka). Coulee may represent part of silicic eruptive interval that produced similar pyroxene rhyodacites of Tam McArthur Rim, about 6 km southeast. $^{40}Ar/^{39}Ar$ age: 169.3±2.1 ka [TCB]

r58 **Rhyolite of Dome 5803 (late Pleistocene)**—Aphyric rhyolite (74.0% SiO_2) lava dome centered 7.5 km northwest of North Sister and 700 m southeast of Condon Butte. Compact dome is 300 m in diameter, 60 m high, glacially stripped of its glassy vesicular carapace, and strewn with erratics of mafic lavas. Consists of dense, fine-grained felsite, pale gray to cream white, that splits platy, chunky, or into small blocks. Obsidian and flow-foliated glassy blocks were found only in colluvium on slopes of dome. Overlies apron of uncorrelated glaciated mafic lavas. Abutted by lava flow from andesitic Four in One Cone (about 2 ka; Sherrod and others, 2004). Located 4 km north of Obsidian Cliffs (unit roc; 38±2 ka), Dome 5803 is northwesternmost unit in belt of rhyolites for which age of onset has propagated northwestward across Oregon since middle Miocene (MacLeod and others, 1975). $^{40}Ar/^{39}Ar$ age: 40.4±1.4 ka [NS]

spt **Shevlin Park Tuff (middle Pleistocene)**—Compositionally heterogeneous andesite-dacite ignimbrite that (within map area) crops out only along 800-m-long reach of North Fork Whychus Creek (UTM grid 050/902), ending about 1 km upstream from confluence with South Fork Whychus Creek. Outcrop is westernmost exposure of widespread ash-flow sheet that extends about 30 km southeast to city of Bend and as far as toe of Newberry Volcano. Regionally, multiflow, simple cooling unit typically is dark gray, nonwelded to modestly sintered but locally is densely welded; tuff is seriate from gritty matrix to large scoria blocks. Unit fills dissected paleotopography, ranging in thickness from a few meters on plateaus to as much as 45 m along paleovalleys (Taylor, 1981; Mimura, 1984, 1992; Sherrod and others, 2004). Juvenile scoriae predominantly are black, range from 55 to 62% SiO_2, and contain only about 1% plag and traces of opx, cpx, oxides, and olivine; sparse white to buff pumices range in composition from 64 to 68.5% SiO_2 and contain same phenocryst suite minus olivine (Conrey and others, 2001a). Maximum thickness along North Fork Whychus Creek is 18 m. Except for basal 1 m, unit is unstratified, nongraded, fines poor, rich in scoria lapilli and blocks, and indurated though nonwelded; basal 1 m is sintered and locally eutaxitic, having black fiamme. Largest black scoriae here are 20 to 35 cm, and largest white pumice clasts are about 5 cm; latter make up only 1 to 2% of juvenile lapilli and are virtually absent in lower third of deposit. Accidental lithic fragments are nearly all sparsely or moderately porphyritic, mafic and intermediate lavas, mostly 1 to 4 cm and as big as 6 cm; lithic fragments are sparse in upper parts of deposit but are as abundant as 5% in its basal few meters. Upper half of deposit is dark gray, but much of lower half is oxidized brick red. Northward direction of flow at this site was suggested by Mimura (1984) on basis of weak imbrication of clasts. Overlain directly by lava flow of unit mws (175±3 ka). Base of ignimbrite rests on fine-grained paleosol, dark gray to reddish brown and 6 to 20 cm thick. Beneath paleosol, in descending sequence, are following subunits (not possible to represent separately at scale of map):

(a) Unstratified dacitic scoria fall, brick red, 30 to 70 cm thick, and well sorted; most scoriae are 1 to 2 cm across, and largest is 4 cm.

(b) Dacitic nonwelded ash-flow deposit, about 4 m thick, cream to tan, containing sparse tan crystal-poor pumice clasts as big as 5 cm; separable into three flow units by thin lithic-concentration zones; plag separated from juvenile pumice yielded $^{40}Ar/^{39}Ar$ age of 225±10 ka.

(c) Reworked stratified interval of sand and gravel as thick as 4 m, including channel fill cut into underlying diamict, which supplied most of reworked clasts.

(d) Massive diamict, gray to ochre, fines poor, more than 5 m thick (base not exposed) marked by vague internal shear planes and dominated by angular blocks of crystal-rich mafic lava (in addition to subordinate crystal-poor lavas), mostly smaller than 30 cm but some as big as 1.5 m, nearly all densely nonvesicular and many glassy. Exposed only at this site, subunit may be block-and-ash-flow deposit or its stream-modified successor.

(e) Glaciated lava of unit mwh (195±5 ka) crops out at stream level about 400 m downstream from section described but is not exposed between them.

With these stratigraphic constraints, Shevlin Park Tuff is now bracketed in age between 225±10 ka and 175±3 ka, most likely between 195±5 ka and 175±3 ka; this requires that unit be younger than published plag $^{40}Ar/^{39}Ar$ age of 260±15 ka (Lanphere and others, 1999) [TCB]

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Table 1. Chemical data for Three Sisters volcanic cluster.

[Data are listed numerically by sample number within map units, which are listed alphabetically by unit label: initial letter a indicates andesite; b, basalt; d, dacite; m, (mafic) basaltic andesite; r, rhyolite or rhyodacite. Volcanic group refers to groupings of volcanic rocks in Correlation of Map Units and in List of Map Units: BT, Broken Top and vicinity; MS, Middle Sister and vicinity; NS, North Sister and vicinity; P, peripheral centers and other lavas; s of BT, surficial deposits of Broken Top; SS, South Sister and vicinity. Other abbreviations: LOI, weight loss on ignition at 900°C; na, not analyzed. Whole-rock major-element analyses are given in weight percent; trace elements, in ppm. Major elements normalized to volatile-free total of 99.6% (leaving 0.4% for trace oxides and halogens). Original total is volatile-free weight before normalization. FeO* is total Fe calculated as FeO. Determinations by x-ray fluorescence spectrometry at U.S. Geological Survey laboratory in Lakewood, Colo., supervised by J.E. Taggart (Taggart and others, 1987), or at GeoAnalytical Lab, Washington State University, Pullman, Wash., supervised by J.A. Wolff (www.sees.wsu.edu/Geolab/note/xrf.html)]

Sample	Unit label	Volcanic group	SiO_2	TiO_2	Al_2O_3	FeO*	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI	Original total
						Andesite and dacite of Broken Top								
TS-324	abt	BT	63.60	1.20	15.57	6.03	0.13	1.61	3.87	5.38	1.84	0.38	0.02	99.13
TS-325	abt	BT	59.91	1.22	16.96	6.67	0.13	2.42	5.86	4.70	1.39	0.33	<0.01	99.25
TS-326	abt	BT	64.95	0.99	15.58	5.26	0.11	1.46	3.68	4.87	2.35	0.35	0.21	99.06
TS-331	abt	BT	59.52	1.26	16.74	6.99	0.14	2.71	5.95	4.61	1.35	0.33	0.02	99.39
TS-332	abt	BT	59.95	1.21	16.81	6.72	0.13	2.54	5.84	4.68	1.38	0.33	<0.01	99.52
TS-335	abt	BT	63.03	1.24	15.78	5.94	0.14	1.73	4.15	5.40	1.81	0.39	na	99.17
TS-343	abt	BT	68.64	0.63	15.29	3.67	0.11	0.69	2.18	5.95	2.23	0.22	0.04	99.69
TS-344	abt	BT	63.58	1.21	15.62	6.01	0.13	1.60	3.95	5.28	1.80	0.41	0.09	99.47
TS-716	abt	BT	63.62	1.20	15.88	5.79	0.14	1.51	3.78	5.45	1.90	0.34	na	99.41
						Andesite of Pole Creek scoria cone								
TS-250	acp	P	57.73	1.60	16.57	8.60	0.15	3.17	6.53	3.78	1.03	0.44	-0.03	99.20
TS-614	acp	P	56.38	1.64	16.81	8.54	0.16	3.35	6.70	4.57	1.05	0.41	na	99.67
						Andesite dome of Lewis Glacier headwall								
TS-690	adh	SS	62.57	1.09	16.23	5.78	0.12	2.00	4.62	5.06	1.86	0.27	na	99.83
						Andesite of Demaris Lake								
TS-187	adl	MS	62.86	1.03	16.52	5.49	0.10	1.89	4.81	4.65	1.97	0.27	0.19	98.87
TS-447	adl	MS	61.07	1.16	16.99	6.27	0.11	2.16	5.40	4.36	1.75	0.33	0.09	99.65
TS-462	adl	MS	62.26	1.11	16.81	5.83	0.11	2.01	5.11	4.17	1.85	0.34	0.15	100.14
TS-562	adl	MS	61.30	1.16	16.94	6.05	0.11	2.09	5.32	4.52	1.85	0.27	<0.01	98.79
TS-679	adl	MS	61.99	1.10	16.82	5.78	0.11	1.98	4.99	4.70	1.88	0.26	na	100.28
TS-681	adl	MS	61.95	1.09	16.77	5.72	0.11	1.97	5.14	4.72	1.87	0.26	na	99.68
						Andesite tephra fall at base of east face of Middle Sister								
TS-475A	aef	MS	62.58	1.25	16.25	6.37	0.14	1.83	4.41	4.75	1.58	0.44	0.83	99.32
TS-475B	aef	MS	62.66	1.25	16.22	6.36	0.14	1.78	4.41	4.77	1.57	0.43	0.94	98.87
TS-476A	aef	MS	62.57	1.25	16.35	6.51	0.14	1.68	4.40	4.78	1.48	0.43	1.25	98.69
TS-476B	aef	MS	63.07	1.26	16.40	6.07	0.13	1.55	4.31	4.64	1.73	0.44	1.76	98.38
						Andesite of Eugene Glacier								
TS-45A	aeg	SS	60.28	1.21	17.24	6.23	0.11	2.63	5.93	4.38	1.30	0.29	0.41	98.80
TS-45B	aeg	SS	56.61	1.16	17.45	8.74	0.11	3.49	6.71	4.08	0.93	0.33	1.31	98.18
TS-46	aeg	SS	58.24	1.17	17.18	7.07	0.13	3.45	6.30	4.44	1.31	0.32	<0.01	99.70
TS-49	aeg	SS	60.43	1.11	16.66	6.83	0.11	2.65	5.38	4.45	1.70	0.28	0.85	99.22
TS-195	aeg	SS	57.09	1.24	17.36	7.59	0.13	3.68	6.77	4.30	1.13	0.29	-0.09	99.26
TS-196	aeg	SS	57.16	1.24	17.38	7.58	0.13	3.64	6.77	4.28	1.15	0.28	-0.05	99.15
TS-197	aeg	SS	56.55	1.25	17.38	7.70	0.13	3.96	7.11	4.19	1.05	0.29	0.03	99.17
TS-198	aeg	SS	57.41	1.24	17.12	7.53	0.13	3.66	6.75	4.29	1.19	0.28	0.27	98.89
TS-200	aeg	SS	57.56	1.27	17.18	7.54	0.13	3.44	6.70	4.32	1.19	0.29	0.16	99.16
TS-202	aeg	SS	56.52	1.25	17.46	7.77	0.13	3.86	7.10	4.18	1.05	0.29	-0.05	98.68
TS-203	aeg	SS	57.54	1.26	17.09	7.59	0.13	3.51	6.67	4.31	1.19	0.29	0.40	98.49
TS-229	aeg	SS	56.73	1.26	17.45	7.74	0.13	3.79	6.94	4.22	1.07	0.29	-0.21	99.90
TS-230	aeg	SS	56.49	1.27	17.47	7.76	0.14	3.90	7.02	4.21	1.05	0.30	-0.17	99.80
TS-232	aeg	SS	56.39	1.32	17.10	8.85	0.14	3.35	6.88	4.30	1.00	0.28	-0.19	99.62
TS-259	aeg	SS	56.65	1.25	17.48	7.64	0.13	3.87	7.03	4.20	1.08	0.28	0.28	99.16

Ba	Ce	Cr	Cu	Ga	La	Nb	Nd	Ni	Rb	Sr	V	Y	Zn	Zr
Andesite and dacite of Broken Top														
564	41	na	23	25	18	14	24	na	38	355	114	50	82	276
468	34	6	41	15	8	8	15	3	26	427	139	27	72	170
750	55	<5	14	16	33	13	47	3	53	292	76	40	55	293
457	34	6	37	16	11	8	13	3	24	423	152	26	71	170
465	33	<5	34	17	10	8	<10	3	26	426	137	27	64	171
525	42	0	19	20	20	10	26	0	34	366	79	37	90	202
712	49	<5	<2	16	22	10	30	3	39	241	8	39	62	257
581	41	<5	19	15	18	11	43	3	36	347	80	39	78	222
545	40	1	30	19	20	11	26	0	38	330	76	37	88	219
Andesite of Pole Creek scoria cone														
334	26	6	33	20	12	7	13	14	17	517	216	28	93	128
358	29	7	67	21	11	5	20	3	16	531	226	27	88	125
Andesite dome of Lewis Glacier headwall														
552	38	7	39	19	19	8	22	1	33	403	123	27	78	197
Andesite of Demaris Lake														
588	33	9	26	20	19	12	26	10	41	388	107	27	69	212
570	36	<5	25	16	13	8	30	3	32	421	142	22	68	195
605	38	<5	23	15	17	8	<10	3	36	406	127	22	63	202
597	34	<5	25	16	14	8	20	8	32	420	127	23	58	193
568	38	12	26	18	19	8	22	7	35	400	125	25	73	196
552	33	12	30	19	17	9	17	8	36	406	130	25	69	191
Andesite tephra fall at base of east face of Middle Sister														
627	45	<5	12	16	15	8	42	3	25	415	93	29	105	211
637	43	<5	22	16	13	9	29	3	25	419	90	30	116	212
646	42	<5	2	16	18	8	29	3	27	418	84	29	79	212
620	40	39	4	17	13	9	35	3	27	415	102	31	89	213
Andesite of Eugene Glacier														
456	29	25	25	21	12	9	11	9	22	469	144	23	68	173
370	26	60	28	22	12	7	17	34	15	478	159	23	65	151
417	27	34	42	21	14	8	17	18	21	466	151	23	79	168
511	30	13	37	22	16	8	8	17	31	423	144	29	72	180
378	23	38	57	21	11	8	<10	23	18	497	168	24	79	154
381	24	33	66	21	10	7	<10	24	19	500	175	23	77	153
361	30	46	65	20	12	7	16	24	16	506	174	22	80	147
383	27	36	54	20	13	8	17	22	20	487	170	23	78	156
390	29	31	61	20	15	8	<10	21	21	485	183	24	83	156
353	29	39	50	19	12	7	15	26	16	513	168	23	76	146
387	28	27	68	20	12	8	22	18	21	487	177	24	84	155
367	30	37	64	19	15	7	17	24	17	510	174	23	85	151
362	29	41	75	20	14	7	12	25	16	513	171	22	85	145
381	30	9	94	19	14	8	17	16	16	556	234	23	87	134
370	27	47	68	22	11	9	16	30	18	505	172	24	81	153

Table 1. Chemical data for Three Sisters volcanic cluster.—Continued

Sample	Unit label	Volcanic group	SiO_2	TiO_2	Al_2O_3	FeO*	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI	Original total
Andesite of Eugene Glacier—Continued														
TS-274	aeg	SS	59.81	1.21	16.69	6.87	0.12	2.84	5.77	4.53	1.48	0.29	0.13	99.09
TS-275	aeg	SS	58.12	1.26	16.97	7.42	0.13	3.33	6.37	4.44	1.26	0.29	0.08	99.22
TS-276	aeg	SS	58.27	1.27	16.94	7.40	0.13	3.23	6.34	4.46	1.28	0.29	0.09	98.80
TS-277	aeg	SS	58.27	1.26	16.91	7.39	0.13	3.26	6.41	4.41	1.27	0.29	-0.23	98.96
TS-278	aeg	SS	57.29	1.25	17.25	7.63	0.13	3.58	6.77	4.29	1.14	0.28	-0.07	98.75
TS-279	aeg	SS	56.84	1.24	17.34	7.62	0.13	3.84	6.97	4.23	1.10	0.28	0.04	99.35
TS-485	aeg	SS	57.55	1.18	17.45	7.31	0.13	3.86	6.80	3.84	1.16	0.32	<0.01	99.86
TS-513	aeg	SS	57.44	1.22	17.20	7.59	0.13	3.70	6.87	4.00	1.13	0.32	<0.01	99.02
TS-546	aeg	SS	56.33	1.28	17.53	7.78	0.14	4.00	7.08	4.16	1.03	0.26	<0.01	98.84
TS-547	aeg	SS	56.04	1.32	17.61	7.85	0.15	3.96	7.10	4.28	1.02	0.26	<0.01	99.53
TS-573	aeg	SS	56.39	1.29	17.59	7.75	0.13	3.88	7.00	4.25	1.06	0.26	<0.01	99.08
TS-577	aeg	SS	59.15	1.19	16.83	6.99	0.13	3.07	6.01	4.49	1.40	0.34	<0.01	100.03
TS-585	aeg	SS	57.07	1.17	17.48	7.33	0.13	3.89	6.85	4.21	1.14	0.33	0.36	99.13
TS-586	aeg	SS	56.21	1.19	17.73	7.58	0.13	4.15	7.28	4.02	0.99	0.31	0.31	99.40
TS-583	aeg	SS	57.03	1.17	17.44	7.35	0.13	3.89	6.87	4.23	1.15	0.34	0.17	99.37
TS-584	aeg	SS	56.69	1.18	17.50	7.43	0.13	4.06	7.02	4.18	1.07	0.33	<0.01	100.14
TS-721	aeg	SS	57.11	1.25	17.42	7.38	0.13	3.68	6.82	4.40	1.15	0.27	na	99.60
Andesite tephra fall of Hodge Crest														
TS-713A	ahc	SS	61.85	1.18	16.39	6.05	0.12	2.06	4.89	4.98	1.79	0.28	na	99.18
TS-713D	ahc	SS	61.68	1.20	16.31	6.06	0.13	2.20	4.95	4.70	2.09	0.28	na	98.57
TS-713E	ahc	SS	61.65	1.19	16.40	6.08	0.12	2.25	5.06	4.67	1.90	0.28	na	98.77
Andesite intrusive complex of Hodge Crest														
TS-44	ahi	SS	60.52	1.19	16.64	6.76	0.11	2.42	5.35	4.65	1.62	0.33	0.82	98.74
TS-689	ahi	SS	56.56	1.19	17.62	7.24	0.13	4.03	7.24	4.24	1.10	0.25	na	99.24
TS-714	ahi	SS	61.95	1.30	15.96	6.39	0.11	2.21	4.50	4.94	1.89	0.34	na	98.92
Andesite of headwaters of Linton Creek														
TS-269	ahl	MS	57.92	1.33	16.85	8.20	0.14	2.90	6.12	4.60	1.22	0.31	0.37	98.71
TS-281	ahl	MS	57.76	1.33	16.98	8.25	0.15	2.90	6.11	4.64	1.17	0.31	0.03	99.14
TS-282	ahl	MS	57.73	1.33	16.96	8.25	0.14	2.90	6.16	4.63	1.18	0.32	0.39	98.69
TS-283	ahl	MS	57.86	1.32	16.85	8.25	0.14	2.88	6.11	4.68	1.18	0.32	-0.24	99.32
TS-285	ahl	MS	57.14	1.33	17.01	8.49	0.14	3.08	6.42	4.56	1.12	0.30	-0.26	99.53
Andesite of Linton Creek														
TS-267	alc	MS	61.77	1.22	16.39	6.35	0.13	1.98	4.65	5.06	1.72	0.34	0.01	99.65
TS-284	alc	MS	61.60	1.21	16.56	6.37	0.13	2.00	4.63	5.08	1.69	0.33	0.64	98.63
TS-286	alc	MS	61.74	1.22	16.34	6.39	0.13	1.98	4.61	5.12	1.73	0.33	-0.10	99.38
TS-293	alc	MS	61.84	1.23	16.19	6.39	0.13	1.99	4.67	5.05	1.78	0.32	0.84	98.41
TS-298A	alc	MS	61.90	1.22	16.35	6.37	0.13	1.91	4.62	5.02	1.75	0.33	0.00	99.28
TS-298B	alc	MS	61.86	1.22	16.29	6.39	0.13	2.01	4.64	4.99	1.75	0.32	-0.03	99.02
TS-299	alc	MS	61.89	1.21	16.35	6.38	0.13	2.01	4.62	4.95	1.74	0.32	-0.04	99.30
TS-300	alc	MS	62.16	1.20	16.34	6.28	0.13	1.89	4.50	4.98	1.78	0.32	0.06	99.35
TS-301	alc	MS	62.08	1.20	16.20	6.30	0.13	1.97	4.62	5.00	1.78	0.32	0.42	98.99
TS-548	alc	MS	61.73	1.26	16.31	6.42	0.13	2.03	4.70	4.95	1.78	0.29	<0.01	99.55
TS-549	alc	MS	62.99	1.14	16.15	5.84	0.12	1.88	4.40	4.89	1.94	0.26	0.86	98.67
TS-557	alc	MS	61.88	1.24	16.43	6.34	0.14	1.99	4.67	4.89	1.74	0.29	0.05	98.83
Andesite west of Lost Creek Glacier														
TS-256	alg	SS	62.20	1.17	16.40	6.06	0.12	2.01	4.62	4.84	1.85	0.33	-0.03	99.60
TS-258	alg	SS	62.28	1.16	16.32	6.04	0.12	2.00	4.64	4.88	1.84	0.32	-0.09	99.47
TS-260	alg	SS	61.67	1.18	16.36	6.25	0.12	2.18	4.91	4.86	1.76	0.32	-0.18	99.82
TS-261	alg	SS	61.45	1.19	16.41	6.37	0.12	2.26	4.97	4.78	1.72	0.31	-0.08	99.52

Ba	Ce	Cr	Cu	Ga	La	Nb	Nd	Ni	Rb	Sr	V	Y	Zn	Zr
Andesite of Eugene Glacier—Continued														
459	31	19	43	20	15	9	15	12	26	448	152	29	79	180
402	31	25	53	20	11	8	14	17	22	477	172	24	80	164
408	29	23	54	20	10	7	15	15	22	475	172	24	80	166
412	30	24	56	23	17	8	<10	17	22	478	170	23	77	162
379	22	33	62	23	9	8	14	23	19	495	170	24	83	154
363	29	49	63	20	11	9	20	27	18	506	175	24	80	150
413	27	38	47	16	10	6	<10	24	18	501	177	21	72	157
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
389	24	28	45	14	6	5	<10	22	17	520	194	19	69	139
382	27	31	32	16	7	5	15	21	14	521	182	19	66	138
391	28	28	53	14	9	7	<10	19	14	502	211	23	68	171
476	34	13	33	16	11	6	<10	5	23	464	143	23	67	173
410	27	30	50	15	11	5	<10	20	20	498	170	20	70	154
371	29	36	58	16	10	6	14	21	17	527	179	17	71	139
410	29	31	51	16	8	5	<10	23	19	501	170	21	67	155
391	28	32	45	15	8	5	<10	21	17	514	158	19	65	150
385	33	41	53	20	10	7	19	20	19	499	179	23	83	150
Andesite tephra fall of Hodge Crest														
533	37	4	27	19	19	8	23	0	33	420	137	27	86	188
521	37	4	27	19	19	7	23	2	34	417	139	28	82	185
518	40	4	27	20	20	8	22	2	33	422	141	26	83	187
Andesite intrusive complex of Hodge Crest														
504	28	22	54	20	17	8	12	11	29	428	131	29	73	185
364	26	50	62	19	13	6	14	24	18	513	176	21	82	138
565	45	3	21	20	19	10	24	0	33	393	268	30	74	213
Andesite of headwaters of Linton Creek														
439	31	<5	38	22	12	9	16	7	19	534	191	25	97	158
450	34	<5	52	19	17	8	16	4	18	538	178	24	88	159
440	37	<5	40	23	13	9	13	6	19	540	188	25	89	160
442	35	<5	39	23	16	9	18	6	19	538	185	25	88	158
423	30	<5	56	21	14	8	20	7	17	549	211	24	81	149
Andesite of Linton Creek														
543	39	<5	14	22	18	10	19	9	31	434	121	33	85	208
571	34	<5	15	22	15	10	21	7	30	427	120	29	86	212
545	37	<5	11	21	19	10	20	6	30	429	111	32	79	205
542	34	<5	16	20	15	10	21	4	30	423	109	33	81	205
550	31	<5	12	20	14	9	20	7	31	429	119	33	75	206
540	35	<5	24	21	18	10	23	6	31	426	114	32	83	205
551	33	<5	12	22	15	10	22	5	30	429	112	33	79	207
557	35	<5	17	20	12	10	20	4	32	418	110	33	86	208
541	36	<5	16	21	16	10	18	3	31	422	123	33	85	210
603	39	<5	6	15	13	8	18	3	29	427	114	23	64	195
644	37	<5	8	13	13	8	20	3	35	403	97	22	63	200
595	37	<5	3	16	15	8	26	3	29	427	109	24	62	196
Andesite west of Lost Creek Glacier														
563	38	7	34	20	18	10	29	12	34	400	116	37	72	223
563	34	<5	28	21	17	9	23	7	32	400	113	35	70	218
533	32	10	36	19	18	9	21	12	32	411	117	33	78	213
527	36	9	32	20	18	9	25	9	31	417	128	33	68	208

Table 1. Chemical data for Three Sisters volcanic cluster.—Continued

Sample	Unit label	Volcanic group	SiO_2	TiO_2	Al_2O_3	FeO*	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI	Original total
Andesite west of Lost Creek Glacier—Continued														
TS-262	alg	SS	62.11	1.17	16.40	6.12	0.12	2.00	4.63	4.90	1.83	0.32	-0.04	99.59
TS-263	alg	SS	62.16	1.16	16.39	6.05	0.12	2.04	4.66	4.87	1.84	0.32	-0.10	99.66
TS-264	alg	SS	62.29	1.17	16.30	6.06	0.12	1.98	4.61	4.89	1.86	0.32	-0.14	99.61
TS-265	alg	SS	62.05	1.15	16.44	6.10	0.12	2.05	4.68	4.86	1.82	0.32	-0.06	99.36
TS-272	alg	SS	62.08	1.17	16.12	6.41	0.12	2.11	4.79	4.70	1.81	0.28	0.05	99.47
TS-312	alg	SS	62.25	1.16	16.37	6.03	0.11	1.96	4.61	4.94	1.86	0.31	-0.10	99.20
TS-313	alg	SS	62.12	1.16	16.36	6.10	0.12	2.04	4.64	4.91	1.84	0.31	-0.16	99.24
TS-314	alg	SS	62.11	1.17	16.23	6.14	0.12	2.04	4.71	4.94	1.82	0.32	-0.06	99.43
TS-316	alg	SS	62.01	1.17	16.36	6.19	0.12	2.05	4.68	4.90	1.81	0.32	-0.06	99.26
TS-317	alg	SS	62.07	1.17	16.42	6.10	0.12	1.99	4.65	4.94	1.83	0.32	-0.09	99.49
TS-318	alg	SS	61.90	1.17	16.40	6.17	0.12	2.07	4.65	4.97	1.82	0.33	-0.03	99.60
TS-319	alg	SS	62.19	1.17	16.32	6.07	0.12	2.02	4.55	4.99	1.84	0.32	-0.04	99.45
TS-273	alg	SS	63.46	1.04	16.17	5.62	0.11	1.75	4.29	4.94	1.96	0.27	0.15	99.20
Andesite of Lewis Glacier headwall														
TS-580	alh	SS	62.03	1.13	16.20	6.10	0.12	1.98	4.65	5.20	1.82	0.36	0.16	100.19
TS-687	alh	SS	62.93	1.10	16.17	5.79	0.11	1.87	4.44	4.99	1.93	0.27	na	99.80
TS-688	alh	SS	62.61	1.10	16.19	5.76	0.12	1.99	4.65	5.05	1.86	0.27	na	99.32
TS-688R	alh	SS	62.58	1.10	16.17	5.81	0.12	2.00	4.64	5.05	1.86	0.27	na	99.57
Andesite south of Lewis Glacier														
TS-479	als	SS	62.35	1.04	16.18	6.11	0.11	2.48	5.21	4.08	1.76	0.28	<0.01	100.33
Andesite agglutinate north of Hayden Glacier														
TS-182	anh	NS	57.86	1.42	16.85	8.11	0.14	2.86	6.04	4.73	1.23	0.36	-0.24	99.32
TS-472	anh	NS	58.04	1.42	16.90	8.20	0.15	2.93	6.13	4.23	1.20	0.39	<0.01	100.21
Andesite of Obsidian Creek														
TS-104	aoc	MS	61.53	0.77	16.40	5.52	0.10	3.89	5.73	3.89	1.60	0.19	0.09	100.20
TS-294	aoc	MS	59.91	0.83	16.60	6.02	0.11	4.36	6.38	3.83	1.41	0.14	0.10	99.58
TS-295	aoc	MS	60.04	0.82	16.61	5.95	0.11	4.32	6.31	3.87	1.42	0.14	0.05	99.54
TS-296	aoc	MS	62.18	0.74	16.07	5.37	0.10	3.70	5.72	3.93	1.66	0.14	0.39	99.16
TS-386	aoc	MS	58.60	0.89	16.71	6.38	0.11	4.73	6.95	3.81	1.25	0.17	<0.01	98.92
TS-426	aoc	MS	61.78	0.75	16.17	5.48	0.10	3.82	5.82	3.92	1.61	0.15	0.14	99.14
TS-427	aoc	MS	61.73	0.79	16.41	5.54	0.10	3.74	5.90	3.60	1.60	0.19	0.79	98.91
TS-553	aoc	MS	60.81	0.79	16.46	5.75	0.11	4.12	6.08	3.84	1.52	0.11	0.10	99.25
TS-559	aoc	MS	60.12	0.83	16.61	5.95	0.12	4.32	6.35	3.75	1.43	0.11	<0.01	99.56
TS-560	aoc	MS	62.39	0.74	16.00	5.29	0.12	3.68	5.62	3.96	1.67	0.13	0.21	99.61
TS-610	aoc	MS	63.15	0.71	15.91	4.92	0.10	3.51	5.40	4.05	1.75	0.11	na	100.64
Andesite of Park Creek														
TS-498	apc	SS	61.44	1.20	16.26	6.68	0.12	2.45	5.33	4.08	1.73	0.32	0.02	99.86
TS-621	apc	SS	60.96	1.20	16.20	6.57	0.12	2.49	5.39	4.67	1.74	0.27	na	97.43
TS-622	apc	SS	61.60	1.13	16.16	6.27	0.12	2.39	5.20	4.68	1.79	0.25	na	98.58
Andesite of Prouty Glacier headwall														
TS-708	aph	SS	61.40	1.28	16.17	6.42	0.13	2.23	5.08	4.81	1.75	0.32	na	99.09
TS-712	aph	SS	61.61	1.28	16.11	6.31	0.09	2.31	4.90	4.82	1.84	0.32	na	98.26
Andesite tephra fall near base of Prouty Glacier headwall														
TS-709	aph′	SS	59.29	1.31	16.66	7.05	0.13	2.81	6.05	4.62	1.39	0.29	na	98.52
TS-710	aph′ [lithic]	SS	61.81	1.28	16.08	6.49	0.11	1.84	5.04	4.83	1.80	0.32	na	98.83
TS-711	aph′	SS	63.74	1.10	15.95	5.50	0.12	1.66	4.21	5.12	1.89	0.30	na	99.10

Ba	Ce	Cr	Cu	Ga	La	Nb	Nd	Ni	Rb	Sr	V	Y	Zn	Zr
Andesite west of Lost Creek Glacier—Continued														
565	36	6	36	21	19	10	24	8	33	400	111	36	74	222
558	38	7	31	22	21	11	21	11	34	401	104	37	77	222
556	34	6	35	21	16	10	32	9	34	401	109	35	71	222
556	36	7	31	21	19	10	17	8	32	398	114	32	74	219
548	37	<5	30	20	16	11	28	7	34	409	145	25	78	201
562	37	<5	34	22	15	10	23	8	33	395	110	34	74	221
565	36	7	33	20	17	9	23	7	33	399	111	34	69	221
559	37	<5	27	22	19	10	17	8	33	399	118	32	74	216
551	33	6	35	22	14	10	24	11	31	397	122	32	72	216
559	34	8	31	20	16	10	19	9	33	397	108	34	74	218
557	42	6	34	21	18	9	31	7	33	398	109	33	78	220
567	35	11	34	20	20	9	22	9	33	394	117	30	75	218
589	36	6	18	20	17	10	<10	7	38	391	101	26	72	213
Andesite of Lewis Glacier headwall														
606	37	<5	16	16	9	8	28	3	31	415	123	23	62	201
574	36	4	23	20	20	9	19	0	36	399	120	26	81	194
552	39	5	24	21	19	8	22	0	34	404	121	26	81	190
556	36	6	23	20	20	8	19	0	34	407	120	27	80	192
Andesite south of Lewis Glacier														
566	30	<5	20	13	10	8	<10	3	31	404	147	21	59	187
Andesite agglutinate north of Hayden Glacier														
434	34	<5	45	23	15	9	22	9	18	516	194	27	89	177
516	64	<5	42	22	72	15	44	25	25	540	282	43	114	198
Andesite of Obsidian Creek														
483	25	63	33	18	10	5	10	49	33	352	107	16	60	111
422	20	75	47	17	9	5	15	48	28	384	125	17	64	106
436	23	77	34	18	11	6	12	53	29	381	128	17	56	107
487	21	69	35	16	11	6	15	40	34	351	116	17	56	111
378	23	81	33	19	11	7	12	na	26	436	161	23	62	130
486	23	67	43	22	13	8	12	na	35	374	149	22	63	137
520	27	56	30	12	11	3	<10	27	31	357	131	15	52	107
518	22	54	32	11	11	4	18	44	28	369	133	15	48	104
486	21	59	20	13	8	4	<10	48	27	383	130	15	48	103
557	26	51	28	11	10	5	<10	39	33	348	118	14	48	109
514	23	63	34	16	12	5	12	39	37	349	115	18	55	110
Andesite of Park Creek														
573	37	<5	34	15	12	8	15	3	29	406	147	20	59	189
518	35	14	36	18	16	8	19	8	32	404	165	24	75	183
522	34	14	36	19	17	8	19	8	34	399	158	24	70	185
Andesite of Prouty Glacier headwall														
543	40	8	27	21	19	9	23	1	32	412	139	29	87	200
537	39	5	23	19	18	9	23	1	32	397	133	29	88	204
Andesite tephra fall near base of Prouty Glacier headwall														
469	36	21	42	20	19	8	21	12	28	451	175	26	84	176
538	38	8	25	21	17	10	21	3	30	408	154	28	81	199
615	42	3	21	19	19	10	23	0	38	371	139	29	80	218

Table 1. Chemical data for Three Sisters volcanic cluster.—Continued

Sample	Unit label	Volcanic group	SiO_2	TiO_2	Al_2O_3	FeO*	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI	Original total
Andesite south of Newberry flow														
TS-589	asn	SS	61.72	1.25	16.51	6.27	0.12	1.83	4.72	4.89	1.85	0.44	0.25	99.57
Andesite of southwest slope of Middle Sister														
TS-225	asw	MS	61.53	1.13	16.99	6.22	0.14	1.93	4.61	5.24	1.45	0.36	-0.01	99.06
TS-280	asw	MS	61.56	1.14	16.84	6.18	0.14	1.93	4.65	5.33	1.45	0.36	-0.11	99.33
Hornblende-bearing andesite southeast of Yapoah Crater														
TS-764	asy	NS	58.68	1.07	17.96	6.82	0.15	2.50	5.75	5.16	1.14	0.38	na	99.62
Avalanche blocks (in the debris-avalanche deposit unit)														
TS-517	av	s of BT	57.99	1.05	17.36	7.15	0.11	3.80	6.87	3.78	1.20	0.29	1.75	97.56
TS-618	av	s of BT	57.24	1.09	17.62	7.15	0.12	3.70	6.94	4.28	1.21	0.24	na	97.63
Andesite west of upper Alder Creek														
TS-655	awa	NS	57.53	1.53	16.80	8.14	0.14	2.97	6.15	4.76	1.26	0.33	na	99.26
TS-754	awa	NS	57.60	1.53	16.73	8.21	0.14	2.96	6.12	4.73	1.25	0.33	na	99.23
Andesite west of Collier Glacier														
TS-367	awc	MS	62.17	1.27	16.12	6.45	0.14	1.78	4.46	5.18	1.58	0.45	<0.01	99.48
TS-369	awc	MS	62.07	1.26	16.09	6.47	0.14	1.81	4.50	5.24	1.58	0.44	<0.01	99.64
TS-371	awc	MS	62.00	1.26	16.20	6.43	0.14	1.81	4.41	5.31	1.60	0.43	<0.01	99.59
TS-372	awc	MS	62.06	1.25	16.17	6.43	0.14	1.80	4.42	5.30	1.61	0.42	<0.01	99.18
TS-374	awc	MS	62.25	1.26	16.01	6.42	0.14	1.81	4.43	5.22	1.59	0.45	<0.01	99.51
TS-376	awc	MS	62.11	1.27	16.08	6.44	0.14	1.80	4.49	5.23	1.58	0.46	<0.01	99.74
TS-377	awc	MS	61.63	1.33	16.16	6.56	0.14	1.90	4.51	5.30	1.62	0.45	<0.01	98.59
TS-380	awc	MS	62.25	1.21	16.24	6.31	0.14	1.77	4.38	5.27	1.57	0.44	<0.01	99.35
TS-392	awc	MS	62.12	1.25	16.10	6.41	0.14	1.79	4.44	5.32	1.59	0.44	<0.01	99.58
TS-393	awc	MS	62.19	1.27	16.00	6.44	0.14	1.81	4.45	5.26	1.60	0.45	0.15	99.62
TS-394	awc	MS	62.18	1.27	16.07	6.42	0.14	1.80	4.43	5.24	1.62	0.44	0.55	99.16
TS-396	awc	MS	62.18	1.27	16.02	6.43	0.14	1.80	4.44	5.24	1.60	0.46	0.10	98.83
TS-399	awc	MS	62.00	1.26	16.08	6.44	0.14	1.85	4.48	5.35	1.59	0.43	<0.01	99.13
Andesite of West Fork Park Creek														
TS-506	awf	SS	59.58	1.22	16.84	6.98	0.13	3.05	5.94	4.11	1.42	0.33	<0.01	99.97
TS-510	awf	SS	59.96	1.21	16.42	7.06	0.13	2.86	5.99	4.13	1.52	0.32	<0.01	99.50
TS-518	awf	SS	59.66	1.23	16.67	7.06	0.12	2.76	6.21	4.10	1.48	0.32	<0.01	99.17
TS-574	awf	SS	60.71	1.30	16.28	7.00	0.14	2.33	5.32	4.63	1.60	0.29	<0.01	99.09
TS-576	awf	SS	60.26	1.19	16.39	6.81	0.12	2.76	5.75	4.39	1.61	0.33	<0.01	99.66
TS-718	awf	SS	59.20	1.24	16.79	6.96	0.13	2.83	6.12	4.55	1.50	0.27	na	99.82
Andesite west of Middle Sister														
TS-302	awm	MS	59.72	1.47	16.30	7.58	0.15	2.40	5.23	5.00	1.37	0.38	-0.15	99.57
TS-303	awm	MS	60.21	1.44	16.36	7.23	0.15	2.25	5.02	5.14	1.42	0.39	-0.19	99.25
TS-305	awm	MS	60.17	1.44	16.29	7.29	0.15	2.24	5.07	5.14	1.42	0.39	-0.10	99.65
TS-306	awm	MS	60.28	1.43	16.27	7.22	0.15	2.27	5.05	5.14	1.42	0.39	-0.16	99.80
TS-307	awm	MS	59.11	1.50	16.52	7.76	0.15	2.46	5.46	4.94	1.31	0.39	0.58	98.90
TS-416	awm	MS	59.23	1.52	16.49	7.89	0.15	2.51	5.52	4.57	1.32	0.41	0.40	99.05
TS-418	awm	MS	60.62	1.42	16.33	7.21	0.15	2.21	4.97	4.81	1.45	0.42	<0.01	99.40
TS-420	awm	MS	60.54	1.43	16.39	7.18	0.15	2.21	5.05	4.81	1.43	0.42	1.49	99.05
TS-425	awm	MS	59.76	1.48	16.40	7.58	0.15	2.42	5.33	4.71	1.36	0.41	<0.01	99.01
Andesite west of Renfrew Glacier														
TS-400	awr	MS	60.94	1.37	16.13	6.99	0.14	2.12	4.92	5.09	1.45	0.44	<0.01	100.02
TS-401	awr	MS	60.83	1.41	16.16	7.04	0.14	2.13	4.98	5.04	1.45	0.43	<0.01	99.87
TS-408	awr	MS	61.48	1.33	16.37	6.73	0.14	2.00	4.70	4.89	1.53	0.44	<0.01	99.79
TS-413	awr	MS	61.39	1.32	16.40	6.78	0.14	2.03	4.69	4.90	1.52	0.44	<0.01	99.62

Ba	Ce	Cr	Cu	Ga	La	Nb	Nd	Ni	Rb	Sr	V	Y	Zn	Zr
Andesite south of Newberry flow														
630	42	<5	17	15	16	10	27	3	33	399	119	28	68	226
Andesite of southwest slope of Middle Sister														
548	37	<5	19	21	15	10	23	6	22	488	77	32	90	191
538	36	<5	14	20	16	11	27	5	23	497	80	33	87	194
Hornblende-bearing andesite southeast of Yapoah Crater														
431	38	1	22	21	17	10	22	5	13	557	110	28	96	175
Avalanche blocks (in the debris-avalanche deposit unit)														
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
400	34	37	77	20	17	7	19	20	22	577	184	24	79	143
Andesite west of upper Alder Creek														
442	32	4	54	21	16	8	21	5	19	465	222	28	90	180
430	37	3	51	21	15	9	21	9	21	467	218	29	90	179
Andesite west of Collier Glacier														
614	43	<5	9	15	16	8	19	3	26	422	<5	29	82	211
603	41	<5	9	16	16	9	21	3	27	429	96	30	83	213
630	62	na	22	32	35	13	34	na	31	481	119	40	120	279
577	39	na	19	24	16	13	28	na	27	450	131	45	100	271
623	42	<5	8	17	17	9	30	3	25	419	97	31	84	214
610	41	<5	3	17	14	8	37	3	26	434	96	30	81	209
574	39	na	18	23	20	13	22	na	29	446	129	45	99	271
617	42	<5	6	16	14	9	23	3	25	432	77	29	86	206
575	39	na	20	24	22	13	25	na	27	453	124	45	89	268
621	41	<5	9	16	15	9	37	3	26	423	79	30	84	212
616	42	<5	9	16	17	9	27	3	27	416	92	30	89	211
615	44	na	12	16	15	9	42	3	26	421	inf	30	86	210
574	38	na	23	26	16	13	27	na	28	453	121	44	97	268
Andesite of West Fork Park Creek														
495	33	12	32	16	9	6	21	4	25	461	143	23	66	175
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
542	36	<5	3	14	12	11	13	3	28	432	185	28	64	227
542	35	<5	32	15	11	8	<10	4	27	427	153	21	66	186
476	30	21	37	20	18	8	18	13	26	448	179	26	78	173
Andesite west of Middle Sister														
495	33	<5	30	22	15	10	24	8	23	453	143	35	88	191
511	38	<5	24	22	17	9	23	7	23	446	120	36	92	199
506	36	<5	24	22	15	10	26	8	23	448	130	35	89	192
512	36	<5	29	23	16	11	14	7	23	453	131	35	93	196
477	36	<5	44	22	16	10	23	6	21	456	154	33	95	189
512	39	<5	30	17	12	8	<10	3	21	459	156	28	83	187
562	41	<5	11	17	12	8	22	3	25	450	126	29	82	200
565	42	<5	17	17	15	8	17	3	23	451	128	29	79	199
546	39	<5	25	17	12	7	29	3	23	451	149	27	81	187
Andesite west of Renfrew Glacier														
572	43	<5	15	16	15	8	<10	3	24	439	123	29	81	197
567	38	<5	11	16	14	8	31	3	24	449	119	28	80	197
595	40	<5	11	16	13	8	29	3	24	433	100	31	82	206
589	39	<5	15	17	15	8	31	3	25	436	105	30	81	206

Table 1. Chemical data for Three Sisters volcanic cluster.—Continued

Sample	Unit label	Volcanic group	SiO_2	TiO_2	Al_2O_3	FeO*	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI	Original total
Andesite west of Renfrew Glacier—Continued														
TS-414	awr	MS	61.58	1.33	16.37	6.70	0.14	1.98	4.61	4.92	1.55	0.42	0.06	99.15
TS-415	awr	MS	61.27	1.34	16.39	6.86	0.15	2.02	4.68	4.93	1.53	0.44	<0.01	99.65
Andesite of Whychus Creek														
TS-439	awy	BT	61.68	1.11	16.81	6.01	0.09	2.13	5.29	4.27	1.79	0.43	0.03	11.67
TS-452	awy	BT	62.03	1.11	16.69	5.94	0.11	2.08	5.15	4.30	1.87	0.32	0.34	99.06
TS-453	awy	BT	61.30	1.08	17.13	6.04	0.13	1.97	4.98	5.06	1.56	0.34	0.17	99.43
Basalt of Alder Creek														
TS-601	bac	NS	51.23	1.44	17.23	9.13	0.16	7.49	8.39	3.61	0.61	0.30	na	98.38
TS-652	bac	NS	53.11	1.32	18.09	8.13	0.15	5.28	8.58	3.78	0.81	0.35	na	97.56
Basalt of Brush Draw														
TS-528	bbd	NS	51.06	1.34	18.73	8.11	0.14	5.48	10.37	3.36	0.65	0.34	0.20	98.90
TS-615	bbd	NS	51.44	1.29	18.39	7.94	0.14	5.53	10.39	3.38	0.76	0.34	na	100.16
TS-615R	bbd	NS	51.41	1.30	18.40	7.89	0.14	5.58	10.40	3.37	0.76	0.34	na	99.66
Basalt of Sparks Lake boat ramp														
TS-672	bbr	P	50.75	1.36	17.52	8.64	0.15	7.93	9.07	3.31	0.61	0.26	na	99.50
TS-673	bbr	P	51.02	1.30	17.24	8.38	0.16	8.06	9.17	3.34	0.65	0.27	na	100.34
TS-674	bbr	P	51.46	1.21	17.47	8.19	0.15	7.45	9.43	3.34	0.64	0.25	na	99.40
TS-771	bbr	P	51.20	1.31	17.03	8.50	0.15	7.98	9.10	3.39	0.66	0.27	na	99.76
TS-772	bbr	P	51.49	1.22	17.52	8.30	0.15	7.30	9.45	3.32	0.59	0.25	na	99.81
TS-773	bbr	P	51.39	1.28	17.27	8.33	0.15	7.68	9.23	3.36	0.65	0.27	na	99.53
Basalt of Cayuse Crater														
TS-625	bcc	P	51.72	1.07	16.57	8.42	0.15	8.65	9.07	3.11	0.61	0.22	na	99.99
TS-626	bcc	P	51.79	1.06	16.47	8.36	0.15	8.69	9.11	3.12	0.64	0.21	na	100.21
TS-627	bcc	P	51.90	1.05	16.40	8.39	0.15	8.66	9.06	3.12	0.65	0.21	na	100.63
CR-42	bcc	P	51.48	1.04	16.26	8.70	0.15	8.74	9.40	2.97	0.65	0.21	na	99.83
Basalt east of Sparks Lake														
TS-671	bes	P	49.77	1.49	17.89	9.58	0.16	7.32	9.17	3.63	0.38	0.22	na	100.17
TS-770	bes	P	49.72	1.50	17.50	9.70	0.16	7.75	9.12	3.49	0.41	0.24	na	100.28
CR-40	bes	P	49.33	1.48	17.74	10.16	0.16	7.40	9.30	3.46	0.35	0.22	na	99.95
Basalt south of The Husband														
TS-121	bhs	P	52.97	1.40	17.76	8.34	0.14	5.02	8.57	3.87	0.99	0.54	-0.26	99.29
TS-122	bhs	P	51.11	1.39	17.20	8.85	0.15	6.91	9.52	3.37	0.72	0.37	-0.26	99.57
TS-123	bhs	P	52.89	1.20	18.00	8.18	0.14	5.80	8.62	3.53	0.89	0.35	0.00	99.06
TS-124	bhs	P	51.38	1.50	17.53	8.56	0.15	6.61	9.34	3.39	0.80	0.34	-0.04	99.44
TS-126	bhs	P	52.50	1.40	17.33	8.62	0.15	5.99	8.50	3.67	0.98	0.47	-0.35	99.99
TS-152	bhs	P	52.49	1.22	18.06	8.21	0.14	6.08	8.72	3.47	0.84	0.35	0.20	99.25
TS-153	bhs	P	52.68	1.41	17.93	8.40	0.14	5.14	8.60	3.83	0.94	0.53	0.01	99.45
Basalt of James Creek														
TS-110	bjc	P	51.78	1.37	17.36	8.50	0.15	6.81	9.15	3.40	0.75	0.32	-0.21	99.26
TS-116	bjc	P	51.54	1.28	17.45	8.70	0.15	7.14	8.93	3.41	0.68	0.32	-0.14	99.34
TS-119	bjc	P	51.62	1.42	17.47	8.52	0.15	6.79	9.26	3.32	0.73	0.32	0.07	99.18
Basalt of North Fork Whychus Creek														
TS-434	bnf	P	51.09	0.98	21.99	6.67	0.11	4.35	10.80	2.98	0.41	0.22	0.06	99.62
TS-503	bnf	P	52.51	1.25	20.15	7.71	0.13	4.15	9.69	3.17	0.57	0.28	0.01	100.34
TS-526	bnf	P	50.92	1.03	21.80	6.86	0.13	4.29	10.65	3.30	0.44	0.17	0.01	99.16
Basalt of Sphinx Butte														
TS-130	bsb	P	52.68	1.10	17.33	7.73	0.13	7.11	8.65	3.53	0.99	0.35	-0.21	99.45

Ba	Ce	Cr	Cu	Ga	La	Nb	Nd	Ni	Rb	Sr	V	Y	Zn	Zr
Andesite west of Renfrew Glacier—Continued														
596	40	<5	13	16	18	9	<10	3	23	427	<5	29	82	208
593	41	<5	11	17	17	9	20	3	25	437	113	31	83	208
Andesite of Whychus Creek														
590	38	<5	21	16	12	7	29	3	34	414	136	22	62	200
607	34	<5	20	16	13	8	31	3	35	404	117	23	63	200
567	40	<5	12	17	13	8	19	3	26	529	107	27	60	194
Basalt of Alder Creek														
265	26	256	60	18	8	6	17	151	8	476	200	24	85	117
323	28	84	65	19	14	9	20	57	11	504	192	25	84	150
Basalt of Brush Draw														
402	39	96	78	15	10	7	20	38	3	726	212	19	63	123
363	37	126	86	18	15	8	21	41	10	720	216	23	74	124
366	39	126	84	18	17	8	23	41	9	714	213	23	75	123
Basalt of Sparks Lake boat ramp														
215	27	269	67	17	9	9	16	155	10	450	190	24	78	128
222	24	292	67	17	10	7	16	159	11	427	200	25	78	131
225	27	221	74	17	11	7	17	127	11	419	202	25	77	121
220	24	281	70	17	11	8	17	159	12	434	198	26	77	130
237	31	216	73	18	12	8	17	125	12	433	195	27	74	122
227	26	248	74	18	13	9	17	145	12	438	201	27	74	126
Basalt of Cayuse Crater														
230	23	434	65	17	10	6	14	158	10	454	199	20	79	101
231	23	445	65	18	14	6	12	157	11	454	200	20	77	99
225	23	447	62	16	11	6	14	155	12	451	200	19	76	99
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Basalt east of Sparks Lake														
152	18	152	70	18	8	3	14	117	5	413	203	24	85	106
158	26	207	65	17	7	7	16	140	6	417	205	27	80	113
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Basalt south of The Husband														
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Basalt of James Creek														
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Basalt of North Fork Whychus Creek														
187	12	74	35	15	7	3	<10	13	3	642	157	12	51	70
226	17	34	46	15	9	5	<10	11	7	581	174	18	58	91
187	14	72	42	15	5	3	<10	28	4	627	161	12	47	71
Basalt of Sphinx Butte														
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na

Table 1. Chemical data for Three Sisters volcanic cluster.—Continued

Sample	Unit label	Volcanic group	SiO_2	TiO_2	Al_2O_3	FeO*	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI	Original total
Basalt of Sphinx Butte—Continued														
TS-131	bsb	P	51.52	1.10	16.94	8.22	0.14	8.02	9.27	3.32	0.77	0.30	0.43	98.80
TS-132	bsb	P	51.25	1.43	17.15	8.90	0.15	6.71	9.45	3.42	0.76	0.38	0.23	98.74
Basalt southeast of Sparks Lake														
TS-769	bsl	P	51.10	1.21	17.74	8.28	0.14	7.88	9.09	3.38	0.56	0.22	na	99.98
Basalt of Spruce Spring														
CR-116	bss	P	50.11	1.56	17.34	9.33	0.15	7.41	9.24	3.39	0.68	0.40	na	99.97
TS-527	bss	P	50.35	1.64	17.45	9.26	0.17	7.15	9.07	3.39	0.72	0.40	<0.01	99.31
TS-592	bss	P	50.00	1.49	17.77	8.89	0.16	7.75	9.08	3.45	0.62	0.37	na	98.29
TS-592R	bss	P	50.07	1.49	17.77	8.87	0.16	7.75	9.06	3.45	0.62	0.37	na	98.89
Basalt and basaltic andesite of Talapus and Katsuk Buttes														
TS-346	btk	P	53.44	1.31	17.81	8.94	0.15	5.10	8.05	3.74	0.69	0.36	<0.01	99.53
TS-347	btk	P	51.66	1.31	16.85	8.75	0.15	7.42	9.10	3.30	0.66	0.38	<0.01	99.28
TS-642	btk	P	51.66	1.37	16.93	8.64	0.16	7.38	9.02	3.43	0.68	0.33	na	99.85
Basalt of lower Whychus Creek														
TS-617	bwl	P	50.77	1.49	17.44	8.99	0.16	7.32	8.85	3.56	0.65	0.37	na	100.65
Basalt west of Millican Crater														
TS-727	bwm	P	50.56	1.67	17.70	8.97	0.16	6.44	9.43	3.62	0.71	0.35	na	100.37
TS-729	bwm	P	49.84	1.55	16.81	9.28	0.16	8.63	8.98	3.37	0.65	0.33	na	100.55
TS-730	bwm	P	49.53	1.53	16.72	9.43	0.16	9.13	8.80	3.35	0.63	0.33	na	100.08
TS-734	bwm	P	50.26	1.58	17.17	9.20	0.16	7.64	9.11	3.50	0.64	0.34	na	99.72
TS-743	bwm	P	50.13	1.56	17.14	9.27	0.16	7.84	9.14	3.42	0.60	0.34	na	99.88
TS-744	bwm	P	50.52	1.64	17.61	9.13	0.16	6.55	9.37	3.60	0.67	0.35	na	100.21
NS-07-198	bwm	P	49.82	1.55	16.57	9.40	0.16	8.92	8.84	3.38	0.63	0.33	na	100.69
NS-07-206	bwm	P	49.48	1.49	16.21	9.54	0.16	9.85	8.63	3.29	0.62	0.32	na	100.64
Basalt of Whychus Creek														
TS-458	bwy	BT	51.11	1.23	17.14	8.93	0.15	7.92	9.18	2.94	0.70	0.31	<0.01	99.39
TS-500	bwy	BT	51.71	1.35	18.63	8.99	0.15	5.95	8.72	3.31	0.49	0.31	<0.01	99.97
TS-676	bwy	BT	51.83	1.39	18.56	8.65	0.15	5.76	8.60	3.86	0.54	0.26	na	100.19
Dacite of "Black Hump"														
TS-100	dbh	MS	64.04	0.91	16.41	5.44	0.14	1.23	3.42	5.93	1.70	0.38	<0.01	99.54
TS-215	dbh	MS	64.47	0.93	16.04	5.51	0.14	1.27	3.35	5.79	1.73	0.36	-0.11	99.34
TS-215A	dbh	MS	64.24	0.95	16.09	5.52	0.14	1.32	3.41	5.84	1.74	0.36	0.43	99.07
TS-216	dbh	MS	64.35	0.92	16.16	5.50	0.14	1.29	3.40	5.75	1.72	0.36	-0.13	99.21
TS-368	dbh	MS	64.47	0.93	15.94	5.54	0.14	1.23	3.38	5.83	1.73	0.40	0.21	99.33
TS-370	dbh	MS	64.36	0.95	15.97	5.56	0.14	1.29	3.44	5.76	1.72	0.42	0.07	99.81
TS-397	dbh	MS	64.38	0.93	15.94	5.52	0.14	1.27	3.45	5.84	1.71	0.41	0.26	99.33
TS-405	dbh	MS	64.05	0.98	16.31	5.62	0.14	1.38	3.63	5.40	1.67	0.40	<0.01	99.52
Dacite breccia of Lewis Glacier headwall														
TS-582	dbl	SS	62.83	1.09	16.39	5.92	0.12	2.00	4.58	4.30	1.99	0.36	2.06	98.44
TS-582-2	dbl	SS	62.62	1.08	16.25	5.88	0.12	2.05	4.63	4.62	2.08	0.27	n.d.	97.39
TS-691	dbl	SS	62.60	1.10	16.22	5.86	0.12	2.07	4.69	4.64	2.01	0.27	na	97.80
Dacite southwest of Clark Glacier														
TS-71	dcg	SS	63.23	1.08	16.33	5.57	0.11	1.71	4.30	4.94	1.98	0.36	<0.01	100.03
TS-117	dcg	SS	63.31	1.10	16.18	5.66	0.11	1.72	4.24	4.94	2.00	0.34	-0.01	99.12
TS-120	dcg	SS	63.36	1.11	16.09	5.61	0.11	1.74	4.29	4.96	1.98	0.34	-0.06	99.03
TS-133	dcg	SS	63.19	1.09	16.17	5.64	0.11	1.80	4.31	4.96	1.98	0.34	-0.56	99.15
TS-134	dcg	SS	63.22	1.10	16.18	5.64	0.11	1.76	4.30	4.96	1.99	0.34	0.06	99.09

Ba	Ce	Cr	Cu	Ga	La	Nb	Nd	Ni	Rb	Sr	V	Y	Zn	Zr
Basalt of Sphinx Butte—Continued														
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Basalt southeast of Sparks Lake														
201	22	251	63	18	7	8	14	160	9	480	193	22	74	102
Basalt of Spruce Spring														
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
306	34	162	58	13	12	11	20	122	8	496	203	23	67	151
268	30	210	50	18	13	12	18	141	8	496	193	24	80	139
265	30	214	52	18	16	11	19	143	8	497	194	24	79	141
Basalt and basaltic andesite of Talapus and Katsuk Buttes														
330	25	77	56	16	9	5	<10	69	8	605	223	18	88	97
267	28	286	54	16	11	8	<10	115	9	497	188	22	72	127
274	25	285	68	18	13	8	18	127	10	478	202	25	80	127
Basalt of lower Whychus Creek														
288	31	214	62	19	14	9	20	153	8	505	203	26	84	136
Basalt west of Millican Crater														
246	28	142	65	17	14	12	18	84	9	468	214	25	79	145
225	27	310	70	16	12	11	19	190	9	445	197	23	82	133
222	23	356	70	16	12	12	18	213	8	437	197	23	81	131
246	25	238	75	17	10	10	15	145	7	454	210	24	82	136
242	28	253	73	17	13	10	17	153	8	456	205	24	82	135
242	33	147	72	18	15	14	20	91	8	481	203	27	79	142
232	23	343	74	16	13	12	16	204	8	453	202	24	79	134
218	25	425	71	17	11	14	18	266	8	441	198	25	82	130
Basalt of Whychus Creek														
266	19	267	58	13	8	8	<10	129	8	476	184	21	65	120
252	13	57	51	15	10	4	<10	78	3	560	251	18	69	99
237	16	85	77	18	9	5	13	97	6	553	198	22	85	104
Dacite of "Black Hump"														
593	38	<3	3	24	17	12	30	3	25	363	33	41	90	250
603	46	<5	5	23	23	11	34	6	25	341	43	42	98	254
586	43	<5	6	22	17	11	24	6	27	351	41	44	96	255
588	43	<5	<2	21	20	11	34	7	25	350	44	43	87	251
635	47	<5	2	17	16	10	43	3	26	343	29	35	85	254
637	42	<5	2	19	15	10	43	3	24	349	31	34	85	248
642	47	<5	2	17	21	10	38	3	25	354	17	34	89	249
627	44	<5	2	17	16	10	39	3	24	370	19	33	81	243
Dacite breccia of Lewis Glacier headwall														
627	35	<5	17	15	9	8	31	3	36	396	103	24	65	208
556	36	8	20	17	19	8	21	0	41	393	117	27	76	193
557	33	7	17	20	20	8	21	1	42	396	118	27	80	195
Dacite southwest of Clark Glacier														
616	40	<3	18	21	21	10	33	8	38	410	96	28	74	217
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na

Table 1. Chemical data for Three Sisters volcanic cluster.—Continued

Sample	Unit label	Volcanic group	SiO_2	TiO_2	Al_2O_3	FeO*	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI	Original total
Dacite southwest of Clark Glacier—Continued														
TS-139	dcg	SS	63.21	1.10	16.15	5.66	0.11	1.80	4.30	4.95	1.99	0.33	-0.18	99.27
TS-140	dcg	SS	63.20	1.10	16.35	5.63	0.11	1.73	4.24	4.92	1.99	0.34	0.01	99.29
TS-142	dcg	SS	63.24	1.11	16.16	5.69	0.11	1.78	4.27	4.91	2.00	0.34	0.11	99.22
TS-143	dcg	SS	63.16	1.10	16.17	5.65	0.11	1.80	4.32	4.97	1.99	0.33	0.01	99.19
TS-145	dcg	SS	63.24	1.09	16.14	5.67	0.11	1.78	4.31	4.94	1.97	0.34	0.11	99.37
TS-146	dcg	SS	63.12	1.11	16.18	5.69	0.11	1.80	4.34	4.93	1.98	0.34	0.26	99.09
TS-154	dcg	SS	63.14	1.11	16.24	5.67	0.11	1.80	4.34	4.90	1.96	0.33	-0.11	99.38
TS-155	dcg	SS	63.11	1.11	16.28	5.65	0.11	1.77	4.30	4.94	2.00	0.33	-0.19	99.12
TS-158	dcg	SS	63.14	1.11	16.24	5.70	0.11	1.77	4.29	4.91	1.98	0.34	-0.08	99.38
TS-530	dcg	SS	63.08	1.13	16.27	5.66	0.13	1.76	4.31	4.96	2.00	0.30	0.13	99.16
TS-531	dcg	SS	63.28	1.12	16.29	5.64	0.12	1.76	4.30	4.78	2.01	0.30	0.09	99.64
TS-532	dcg	SS	63.08	1.12	16.27	5.66	0.13	1.78	4.31	4.98	2.01	0.27	0.02	99.79
TS-533	dcg	SS	63.05	1.11	16.34	5.66	0.11	1.76	4.35	4.99	1.90	0.31	0.01	99.36
TS-534	dcg	SS	63.00	1.12	16.40	5.68	0.11	1.80	4.29	4.92	2.00	0.28	<0.01	99.60
TS-535	dcg	SS	62.95	1.12	16.27	5.72	0.13	1.81	4.37	4.91	2.01	0.30	0.60	98.56
TS-538	dcg	SS	63.16	1.12	16.49	5.62	0.12	1.73	4.28	4.86	1.94	0.29	0.01	99.67
TS-539	dcg	SS	63.07	1.12	16.50	5.66	0.11	1.75	4.25	4.92	1.93	0.29	<0.01	99.02
TS-540	dcg	SS	63.13	1.12	16.26	5.70	0.13	1.79	4.27	4.93	1.98	0.30	0.03	99.87
TS-541	dcg	SS	63.20	1.12	16.23	5.63	0.12	1.71	4.36	4.93	2.00	0.30	0.01	99.44
TS-543	dcg	SS	63.46	1.13	16.22	5.58	0.11	1.67	4.21	4.92	1.98	0.31	<0.01	98.87
TS-544	dcg	SS	63.15	1.12	16.36	5.58	0.11	1.72	4.31	4.97	1.99	0.29	<0.01	99.21
Dacite of Chambers Lakes														
TS-6	dcl	SS	65.22	0.95	15.85	4.75	0.10	1.39	3.63	5.04	2.31	0.35	0.06	99.27
TS-7	dcl	SS	65.01	0.97	16.23	4.82	0.10	1.38	3.63	4.88	2.24	0.35	1.15	98.82
TS-19	dcl	SS	65.41	0.95	15.80	4.71	0.10	1.35	3.56	5.09	2.30	0.33	0.11	98.98
TS-20	dcl	SS	65.70	0.94	15.70	4.65	0.10	1.36	3.58	4.96	2.28	0.32	0.06	99.59
TS-21	dcl	SS	65.65	0.94	15.74	4.68	0.10	1.35	3.56	4.98	2.28	0.32	0.29	99.37
TS-170	dcl	SS	65.93	0.92	15.73	4.62	0.10	1.31	3.50	4.88	2.32	0.29	0.00	99.41
TS-171	dcl	SS	65.36	0.94	15.66	5.05	0.10	1.52	3.78	4.71	2.23	0.25	-0.04	99.20
TS-208	dcl	SS	65.44	0.97	15.83	4.80	0.10	1.39	3.65	4.88	2.25	0.29	0.32	98.78
TS-211	dcl	SS	65.43	0.96	15.76	4.80	0.10	1.38	3.67	4.93	2.27	0.29	0.10	99.24
TS-212	dcl	SS	65.18	0.99	15.87	4.92	0.10	1.40	3.73	4.89	2.24	0.29	0.04	99.17
TS-213	dcl	SS	65.36	0.96	15.84	4.79	0.10	1.44	3.68	4.88	2.26	0.29	-0.02	99.36
TS-214	dcl	SS	65.74	0.93	15.78	4.63	0.10	1.32	3.58	4.92	2.31	0.29	0.11	99.09
TS-239	dcl	SS	64.78	1.01	15.92	5.07	0.10	1.50	3.89	4.87	2.15	0.31	0.20	99.47
Dacite north of Carver Lake														
TS-10	dcn	SS	66.89	0.70	15.65	3.98	0.08	1.45	3.63	4.54	2.45	0.24	0.35	99.92
TS-11	dcn	SS	67.39	0.64	15.57	3.78	0.08	1.43	3.54	4.44	2.50	0.23	0.21	99.76
TS-12	dcn	SS	67.12	0.67	15.56	3.94	0.08	1.49	3.60	4.46	2.46	0.23	0.36	99.87
Dacite of Dew Lake														
TS-68	ddl	SS	64.10	1.06	16.00	5.34	0.12	1.48	3.82	5.21	2.08	0.39	<0.01	99.60
TS-115	ddl	SS	64.26	1.04	16.09	5.30	0.11	1.43	3.69	5.19	2.11	0.38	0.08	99.04
TS-118	ddl	SS	64.43	1.04	15.98	5.26	0.11	1.46	3.80	5.08	2.10	0.35	0.14	99.09
TS-151	ddl	SS	64.12	1.07	15.88	5.39	0.12	1.56	3.86	5.18	2.06	0.37	0.07	99.11
Dacite ejecta of South Sister summit														
TS-480	des	SS	62.87	0.98	16.22	5.80	0.11	2.43	5.02	3.69	2.19	0.27	1.86	98.22
TS-481A	des	SS	62.82	0.98	16.13	5.80	0.11	2.40	4.97	3.24	2.88	0.27	1.75	98.78
TS-481B	des	SS	62.76	0.98	16.32	5.72	0.11	2.31	4.92	3.51	2.72	0.26	1.36	98.86
TS-484	des	SS	63.86	0.96	15.99	5.60	0.11	2.15	4.60	3.97	2.08	0.27	1.79	98.41
TS-630B-1	des	SS	64.08	0.97	16.44	5.43	0.09	1.72	4.27	4.15	2.26	0.19	na	96.25

Ba	Ce	Cr	Cu	Ga	La	Nb	Nd	Ni	Rb	Sr	V	Y	Zn	Zr
Dacite southwest of Clark Glacier—Continued														
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
682	39	<5	14	14	18	9	34	3	36	405	87	25	59	214
671	41	<5	10	16	13	8	32	3	36	400	81	24	65	211
661	37	<5	13	16	15	9	26	3	36	393	95	23	63	215
668	35	<5	9	14	16	10	32	3	35	399	94	24	59	211
676	42	<5	16	15	22	9	25	3	35	400	93	24	61	214
673	42	<5	12	15	14	9	35	4	35	398	85	24	64	213
668	40	<5	15	13	13	9	31	3	39	402	101	26	62	217
690	43	<5	13	15	20	9	30	3	36	395	90	26	58	215
688	42	<5	14	14	19	9	23	3	37	403	98	26	64	215
679	45	<5	16	14	19	9	26	3	37	398	95	24	64	213
679	43	<5	15	16	18	9	27	3	37	386	95	24	60	214
689	42	<5	11	14	19	9	27	3	37	395	88	26	57	215
Dacite of Chambers Lakes														
667	40	<3	10	22	19	12	26	4	45	351	73	27	73	240
671	43	<3	19	20	22	11	22	8	43	337	71	26	72	237
689	39	<3	22	19	20	10	20	5	43	332	67	24	70	236
678	40	4	11	20	21	11	22	5	46	335	70	25	64	236
680	40	4	12	19	21	11	23	4	45	332	68	26	73	234
692	41	<5	22	17	19	11	23	6	46	332	78	27	65	234
670	36	<5	17	18	21	12	23	8	44	338	86	25	67	226
668	40	<5	19	20	19	12	26	6	46	352	79	27	73	242
674	40	<5	12	21	19	12	20	3	45	341	84	27	67	237
672	39	<5	18	19	18	11	20	6	43	349	72	26	65	234
680	42	<5	16	20	24	11	25	3	43	342	75	26	65	233
678	41	<5	17	18	21	11	29	6	46	340	73	27	68	237
655	43	<5	18	19	23	11	25	6	42	358	85	27	70	232
Dacite north of Carver Lake														
699	32	12	22	19	20	9	20	15	51	309	60	19	56	207
707	39	14	20	17	23	9	25	13	55	307	57	17	52	206
698	41	14	30	19	25	9	29	14	55	308	65	18	51	205
Dacite of Dew Lake														
629	41	4	8	22	21	13	24	4	39	371	62	31	82	246
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Dacite ejecta of South Sister summit														
616	34	<5	44	14	11	6	<10	3	43	388	124	21	59	187
964	32	<5	51	14	13	7	<10	3	44	379	118	22	60	187
845	33	6	45	16	13	7	12	3	42	383	126	22	60	189
642	36	<5	19	15	13	8	<10	3	38	368	109	22	56	201
573	34	13	11	19	16	8	19	3	44	375	121	24	59	188

Table 1. Chemical data for Three Sisters volcanic cluster.—Continued

Sample	Unit label	Volcanic group	SiO_2	TiO_2	Al_2O_3	FeO*	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI	Original total
						Dacite ejecta of South Sister summit—Continued								
TS-630B-2	des	SS	64.20	0.98	16.20	5.57	0.09	1.75	4.26	4.05	2.31	0.20	na	97.56
TS-632A	des	SS	63.98	0.96	15.69	5.48	0.16	2.13	4.52	4.28	2.19	0.22	na	96.66
TS-632B	des	SS	63.47	0.94	16.12	5.40	0.10	2.08	4.61	4.46	2.19	0.21	na	97.71
TS-632C	des	SS	63.12	1.00	16.14	5.62	0.11	2.20	4.69	4.35	2.15	0.22	na	96.14
TS-695	des [lithic]	SS	63.84	1.10	16.26	5.05	0.07	1.66	4.19	5.02	2.10	0.31	na	98.72
TS-696A	des	SS	63.52	1.10	16.16	5.51	0.12	1.80	4.40	4.55	2.14	0.30	na	96.86
TS-696B	des	SS	63.73	1.10	16.26	5.48	0.12	1.99	4.42	4.04	2.17	0.30	na	95.85
TS-696D	des	SS	63.41	1.07	16.47	5.55	0.12	2.03	4.48	3.99	2.17	0.30	na	95.55
TS-696DR	des	SS	63.41	1.08	16.42	5.56	0.12	2.08	4.48	3.99	2.17	0.30	na	95.79
						Dacite of Goose Creek								
TS-92	dgc	SS	64.81	0.99	16.03	4.94	0.10	1.46	3.84	4.88	2.19	0.36	0.02	100.04
TS-323	dgc	SS	65.13	0.99	15.94	4.76	0.10	1.43	3.78	4.95	2.23	0.28	na	99.68
TS-336	dgc	SS	65.28	0.99	15.84	4.86	0.10	1.34	3.76	4.83	2.24	0.35	<0.01	99.33
TS-340	dgc	SS	65.15	0.99	15.73	4.89	0.10	1.45	3.83	4.86	2.24	0.35	0.32	98.76
TS-706	dgc	SS	65.17	0.96	16.09	4.72	0.10	1.35	3.66	5.01	2.27	0.27	na	99.25
						Dacite of Green Lakes								
TS-508	dgl	SS	64.17	1.10	15.89	5.63	0.11	1.67	4.17	4.42	2.08	0.36	0.50	99.65
TS-509	dgl	SS	64.19	1.09	15.77	5.65	0.11	1.65	4.17	4.55	2.07	0.34	<0.01	99.15
TS-519	dgl	SS	64.22	1.07	15.83	5.60	0.11	1.63	4.25	4.51	2.04	0.34	<0.01	99.42
TS-520	dgl	SS	64.20	1.09	15.77	5.63	0.11	1.67	4.26	4.51	2.03	0.34	<0.01	99.14
TS-578	dgl	SS	62.85	1.11	16.13	5.92	0.12	1.87	4.49	4.91	1.86	0.34	<0.01	100.00
TS-579	dgl	SS	63.56	1.01	15.99	5.60	0.11	1.89	4.30	4.87	1.97	0.31	<0.01	100.29
						Dacite of Hayden Glacier–Renfrew Glacier col								
TS-410	dhr	MS	64.05	0.95	16.19	5.42	0.15	1.32	3.55	5.86	1.75	0.35	na	99.31
TS-411	dhr	MS	64.31	0.93	16.35	5.60	0.14	1.27	3.45	5.49	1.67	0.39	<0.01	99.28
TS-412	dhr	MS	63.58	1.01	15.94	5.91	0.14	1.51	3.71	5.71	1.66	0.42	<0.01	99.33
						Dacite of Irving Glacier								
TS-5	dig	MS	64.23	0.92	16.16	5.53	0.14	1.26	3.33	5.90	1.73	0.39	<0.01	99.24
TS-5A	dig	MS	64.11	0.92	16.23	5.56	0.14	1.27	3.31	5.92	1.73	0.41	0.05	100.05
TS-238	dig	MS	64.21	0.91	16.23	5.50	0.14	1.27	3.42	5.85	1.70	0.37	0.22	99.43
						Dacite of Kokostick Butte								
TS-63	dkb	SS	63.05	0.99	16.29	5.57	0.11	2.03	4.62	4.77	1.91	0.27	0.10	99.04
TS-246	dkb	SS	62.54	1.02	16.46	5.83	0.11	2.07	4.85	4.63	1.84	0.26	0.01	99.22
TS-348	dkb	SS	62.45	1.04	16.37	5.79	0.11	2.05	5.01	4.64	1.84	0.30	0.96	98.57
TS-349	dkb	SS	62.80	1.04	16.30	5.70	0.11	1.97	4.67	4.81	1.91	0.28	0.08	98.96
TS-563	dkb	SS	62.49	1.05	16.41	5.76	0.12	2.07	4.81	4.69	1.94	0.25	0.97	98.34
						Dacite of Linton Creek								
TS-268	dlc	MS	66.82	0.81	15.54	4.37	0.09	1.32	3.38	4.73	2.32	0.21	0.55	98.68
						Dacite of Lewis Glacier headwall								
TS-14	dlg	SS	64.35	1.01	15.79	5.33	0.10	1.65	4.09	4.86	2.12	0.32	<0.01	99.68
TS-43	dlg	SS	63.58	1.09	16.07	5.53	0.11	1.70	4.22	4.94	2.00	0.35	0.77	98.53
TS-205	dlg	SS	63.65	1.10	15.91	5.68	0.11	1.70	4.24	4.85	2.04	0.31	-0.14	98.90
TS-581	dlg	SS	63.55	1.09	16.11	5.52	0.11	1.70	4.25	4.85	2.03	0.38	0.44	99.53
TS-631	dlg	SS	63.75	1.09	16.00	5.46	0.11	1.64	4.23	4.97	2.03	0.30	na	99.38
TS-692	dlg	SS	63.67	1.09	16.10	5.35	0.11	1.68	4.24	5.02	2.04	0.30	na	98.63
TS-693	dlg	SS	63.82	1.09	16.12	5.13	0.11	1.69	4.22	5.08	2.04	0.31	na	99.58
TS-694	dlg	SS	63.61	1.09	16.06	5.38	0.12	1.73	4.22	5.04	2.03	0.30	na	98.86

Ba	Ce	Cr	Cu	Ga	La	Nb	Nd	Ni	Rb	Sr	V	Y	Zn	Zr
Dacite ejecta of South Sister summit—Continued														
586	35	14	12	20	19	8	19	4	45	369	126	26	61	194
678	34	12	36	17	16	8	21	5	40	359	121	24	66	181
572	38	12	27	17	20	7	20	4	41	378	117	24	63	187
560	38	12	26	18	19	7	17	6	40	371	129	24	69	182
613	44	1	18	19	20	9	25	0	38	394	96	28	80	212
594	41	1	18	18	23	10	22	0	38	392	93	26	77	206
585	35	1	20	19	21	8	19	0	37	393	96	28	79	203
572	40	3	17	18	20	9	24	2	36	395	95	28	75	200
574	42	3	17	19	21	10	24	3	35	398	91	27	76	201
Dacite of Goose Creek														
659	41	<3	22	20	19	11	30	9	44	363	75	27	69	235
661	42	4	15	19	17	9	23	0	43	357	80	26	66	220
722	40	<5	14	15	16	9	25	3	42	348	76	23	53	232
706	38	<5	14	13	13	9	37	3	41	346	76	24	60	232
659	44	2	12	19	21	9	22	1	43	344	76	27	65	221
Dacite of Green Lakes														
668	41	<5	24	15	15	9	25	3	39	360	93	24	63	224
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
624	36	<5	14	16	14	8	28	3	34	403	115	23	63	205
654	37	<5	5	15	14	8	13	2	35	375	95	22	54	206
Dacite of Hayden Glacier–Renfrew Glacier col														
570	47	2	5	22	18	10	28	0	26	360	27	39	101	235
642	47	<5	2	17	15	9	35	3	23	352	25	34	84	249
563	38	na	8	26	18	14	33	na	25	386	77	50	94	302
Dacite of Irving Glacier														
598	46	<3	5	24	22	12	28	5	24	341	33	41	96	254
595	41	<3	4	25	18	11	28	10	25	336	36	42	98	254
588	44	<5	7	22	20	12	32	5	24	348	32	42	95	256
Dacite of Kokostick Butte														
573	36	6	12	18	19	10	15	3	36	404	107	21	64	191
560	32	11	16	23	18	9	18	12	35	425	113	23	66	190
584	37	<5	23	15	13	9	28	3	34	432	136	22	57	187
576	34	5	15	23	18	12	16	na	37	441	141	37	66	247
613	35	<5	6	14	13	8	29	3	34	413	120	21	54	186
Dacite of Linton Creek														
697	34	<5	10	20	19	8	16	8	46	332	72	20	62	217
Dacite of Lewis Glacier headwall														
628	37	5	22	19	20	10	23	3	40	355	93	24	68	216
618	39	<3	20	20	20	11	24	4	39	392	95	27	78	227
614	36	<5	21	23	17	11	24	6	39	369	91	27	71	226
685	38	<5	10	14	16	9	33	3	37	385	99	26	62	218
603	43	1	20	18	18	9	23	0	39	398	94	27	74	211
606	44	1	20	19	20	10	22	0	39	390	94	28	77	209
609	45	2	19	19	21	9	25	0	38	389	92	28	77	211
603	42	1	20	20	21	10	22	0	38	390	94	27	78	211

Table 1. Chemical data for Three Sisters volcanic cluster.—Continued

Sample	Unit label	Volcanic group	SiO_2	TiO_2	Al_2O_3	FeO*	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI	Original total
Dacite of Lewis Glacier headwall—Continued														
TS-697	dlg	SS	63.73	1.09	16.08	5.37	0.11	1.68	4.24	4.93	2.06	0.31	na	98.66
Dacite of Lane Plateau														
TS-103	dlp	MS	65.31	0.73	16.18	5.22	0.14	0.97	2.85	6.07	1.83	0.30	<0.01	99.13
TS-287	dlp	MS	64.22	0.92	16.18	5.51	0.14	1.25	3.36	5.93	1.73	0.37	-0.08	99.11
TS-308	dlp	MS	64.21	0.91	16.20	5.48	0.14	1.27	3.40	5.92	1.71	0.35	0.09	99.58
TS-419	dlp	MS	64.35	0.91	16.04	5.48	0.14	1.25	3.35	5.95	1.76	0.37	<0.01	98.74
Dacite of Mesa Creek														
TS-111	dmc	P	65.08	0.87	16.52	4.74	0.10	1.37	3.82	5.00	1.87	0.23	0.36	98.87
Dacite southeast of Moraine Lake														
TS-337	dml	SS	64.43	0.99	16.01	5.07	0.11	1.57	4.11	4.92	2.05	0.33	0.22	99.55
TS-353	dml	SS	64.64	1.00	15.88	5.05	0.10	1.51	3.96	4.93	2.19	0.34	0.44	98.47
TS-354	dml	SS	65.02	1.01	15.76	4.96	0.10	1.44	3.89	4.88	2.20	0.35	0.27	99.87
TS-355	dml	SS	65.17	0.99	15.77	4.88	0.10	1.42	3.85	4.86	2.22	0.35	0.24	99.80
TS-357	dml	SS	64.43	1.00	16.13	5.10	0.11	1.55	4.03	4.85	2.05	0.34	0.15	100.02
TS-359	dml	SS	64.39	1.00	16.05	5.09	0.11	1.58	4.11	4.89	2.05	0.32	0.21	99.30
TS-361	dml	SS	65.14	1.01	15.79	5.00	0.10	1.41	3.75	4.83	2.22	0.36	<0.01	99.69
TS-362	dml	SS	65.72	0.95	15.68	4.72	0.10	1.34	3.63	4.84	2.29	0.33	0.24	99.72
TS-440	dml	SS	64.30	1.00	16.38	5.07	0.11	1.58	4.12	4.68	2.04	0.32	0.31	99.13
TS-441	dml	SS	64.57	1.00	16.30	5.07	0.11	1.54	3.94	4.67	2.10	0.31	0.63	98.41
TS-442	dml	SS	64.27	1.01	16.34	5.10	0.11	1.58	4.11	4.69	2.03	0.34	0.31	99.33
TS-704	dml	SS	64.05	0.99	16.44	5.04	0.11	1.54	4.06	5.06	2.06	0.26	na	99.34
TS-705	dml	SS	64.01	1.00	16.59	5.07	0.11	1.48	3.97	5.04	2.07	0.26	na	99.66
Dacite north of Moraine Lake														
TS-161	dmn	SS	65.14	0.93	15.98	4.79	0.10	1.44	3.78	5.02	2.13	0.28	-0.06	99.07
TS-363	dmn	SS	65.37	0.96	15.79	4.83	0.10	1.40	3.67	4.91	2.26	0.32	0.13	99.04
TS-363	dmn	SS	65.38	0.97	15.79	4.82	0.10	1.41	3.68	4.88	2.26	0.31	0.14	99.02
TS-478	dmn	SS	66.25	0.94	15.74	4.62	0.10	1.33	3.57	4.44	2.30	0.32	<0.01	99.98
TS-488	dmn	SS	66.32	0.92	15.66	4.60	0.10	1.32	3.57	4.47	2.33	0.32	0.14	99.88
TS-491	dmn	SS	66.14	0.93	15.88	4.61	0.10	1.29	3.57	4.43	2.33	0.33	0.06	99.70
TS-492	dmn	SS	65.67	0.92	16.04	4.75	0.10	1.47	3.76	4.45	2.15	0.29	0.09	99.95
TS-495	dmn	SS	65.76	0.96	15.89	4.78	0.10	1.36	3.71	4.44	2.27	0.34	<0.01	99.66
TS-496	dmn	SS	66.13	0.87	15.93	4.53	0.10	1.38	3.71	4.48	2.18	0.28	0.27	99.40
TS-588	dmn	SS	66.06	0.86	15.54	4.64	0.09	1.50	3.63	4.69	2.31	0.29	0.22	99.37
Dacite of Middle Sister summit														
TS-233	dms	MS	66.73	0.77	15.39	4.27	0.08	1.48	3.43	4.28	2.94	0.22	1.04	98.36
TS-236	dms	MS	65.92	0.84	15.42	4.57	0.08	1.64	3.64	4.39	2.85	0.24	0.78	98.81
TS-237A	dms	MS	63.88	0.99	15.95	5.31	0.09	1.93	4.24	4.40	2.52	0.29	0.34	99.31
TS-237B	dms	MS	65.70	0.83	15.77	4.57	0.08	1.63	3.64	4.35	2.78	0.24	0.61	99.14
Dacite coulee west of Moraine Lake														
TS-72	dmw	SS	64.63	0.97	16.16	4.96	0.11	1.52	3.85	5.01	2.07	0.33	0.09	99.87
TS-162	dmw	SS	65.45	0.90	16.01	4.84	0.10	1.44	3.58	4.85	2.17	0.25	0.30	98.92
TS-163	dmw	SS	64.92	0.96	15.98	4.91	0.11	1.53	3.87	4.94	2.10	0.28	0.19	99.12
TS-356	dmw	SS	65.11	0.95	15.93	4.87	0.11	1.46	3.81	4.91	2.12	0.33	<0.01	99.44
Dacite north of Teardrop Pool														
TS-629A	dnt	SS	63.10	0.95	16.11	5.55	0.11	2.20	4.61	4.75	2.00	0.21	na	98.00
TS-629B	dnt	SS	62.74	0.96	16.29	5.55	0.11	2.30	4.78	4.73	1.94	0.21	na	96.88
TS-698	dnt	SS	63.12	0.95	16.35	5.41	0.10	2.18	4.71	4.44	2.10	0.23	na	98.24

Ba	Ce	Cr	Cu	Ga	La	Nb	Nd	Ni	Rb	Sr	V	Y	Zn	Zr
Dacite of Lewis Glacier headwall—Continued														
608	49	0	19	20	22	9	24	0	38	391	93	28	77	210
Dacite of Lane Plateau														
662	49	4	5	24	29	11	36	2	27	297	23	51	96	274
604	43	<5	6	22	22	12	29	7	25	349	37	47	100	254
590	45	<5	4	22	19	13	28	4	26	351	38	45	102	257
608	43	na	8	27	20	14	34	na	26	370	67	53	100	319
Dacite of Mesa Creek														
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Dacite southeast of Moraine Lake														
653	36	<5	5	14	16	10	24	3	38	390	92	22	59	216
666	38	na	12	22	18	13	24	na	44	383	116	32	71	292
690	36	<5	10	14	13	10	35	3	42	360	73	25	59	234
700	42	<5	10	15	16	9	33	3	42	356	77	24	63	234
671	41	<5	3	14	19	9	28	3	37	394	87	23	60	218
667	39	<5	4	16	18	10	24	3	37	395	90	24	67	219
720	40	<5	10	15	19	9	30	3	41	351	75	25	70	234
738	42	<5	7	13	18	9	33	3	43	343	60	24	57	234
675	42	<5	2	14	13	10	<10	3	37	393	89	22	61	214
698	38	<5	2	13	16	10	24	3	37	383	69	23	56	222
664	39	<5	7	15	15	10	36	3	36	397	85	24	62	217
612	42	3	11	19	18	10	22	0	37	396	90	26	67	207
616	44	3	9	20	20	10	20	0	38	398	91	25	69	209
Dacite north of Moraine Lake														
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
680	37	na	23	22	21	14	20	na	49	370	108	38	70	296
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
753	42	<5	10	15	18	10	31	3	45	339	58	25	57	237
737	43	<5	6	13	17	9	25	3	45	336	68	23	58	231
753	40	<5	15	14	15	9	25	3	44	333	62	23	56	231
698	38	<5	<2	13	14	10	41	3	38	364	73	21	52	221
738	44	<5	10	14	19	9	30	3	44	347	60	25	51	232
711	42	<5	2	13	15	9	24	3	41	364	75	20	55	215
742	36	<5	7	14	13	9	21	3	45	323	80	20	52	224
Dacite of Middle Sister summit														
717	45	12	30	19	20	12	22	12	65	291	67	28	54	275
696	45	14	36	19	22	12	26	14	62	307	76	30	55	273
654	47	15	46	20	22	12	27	18	54	339	107	31	64	265
696	45	12	32	19	20	12	30	13	60	312	77	28	57	272
Dacite coulee west of Moraine Lake														
632	37	<3	9	21	17	12	18	7	40	383	83	25	70	226
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
637	40	6	7	19	20	12	24	7	40	382	81	24	75	226
687	37	<5	2	15	15	10	32	3	39	380	73	22	60	225
Dacite north of Teardrop Pool														
565	33	16	47	19	18	7	20	7	40	373	120	24	67	186
552	32	15	72	19	15	6	17	7	38	378	122	24	68	180
567	31	16	64	19	18	7	16	8	41	378	136	24	78	185

Table 1. Chemical data for Three Sisters volcanic cluster.—Continued

Sample	Unit label	Volcanic group	SiO_2	TiO_2	Al_2O_3	FeO*	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI	Original total
						Silicic dacite north of Teardrop Pool								
TS-483	dnt′	SS	67.08	0.70	15.34	4.18	0.09	1.71	3.63	3.61	3.03	0.22	1.26	99.33
						Dacite pumice fall of Prouty Glacier headwall								
TS-204	dpg	SS	64.56	1.01	15.99	5.27	0.11	1.44	3.72	4.99	2.15	0.36	2.60	96.58
						Dacite of Red Meadow								
TS-189	drm	SS	63.86	1.03	16.12	5.40	0.11	1.69	4.17	4.90	2.03	0.29	0.76	98.26
TS-431	drm	SS	63.73	1.04	16.38	5.42	0.11	1.78	4.21	4.62	1.98	0.32	0.41	99.09
TS-432	drm	SS	65.30	0.86	16.23	4.72	0.09	1.60	4.05	4.21	2.28	0.26	0.24	98.83
TS-460	drm	SS	63.57	1.05	16.30	5.52	0.11	1.82	4.34	4.55	2.01	0.32	1.05	98.39
TS-461	drm	SS	63.97	1.04	16.32	5.44	0.11	1.72	4.22	4.45	2.00	0.33	<0.01	100.11
TS-497	drm	SS	64.49	1.01	16.32	5.21	0.11	1.60	4.09	4.46	1.98	0.33	0.40	99.46
TS-511	drm	SS	64.30	1.01	16.05	5.40	0.11	1.64	4.21	4.55	2.01	0.32	0.30	98.67
TS-570	drm	SS	63.70	1.05	16.18	5.34	0.11	1.65	4.20	5.08	2.03	0.26	0.23	98.50
TS-571	drm	SS	63.04	1.11	16.41	5.61	0.12	1.80	4.39	4.91	1.91	0.29	0.23	99.54
TS-575	drm	SS	64.25	1.02	16.16	5.18	0.11	1.59	4.04	4.91	2.07	0.28	0.18	99.83
TS-619	drm	SS	63.40	1.06	16.21	5.45	0.12	1.77	4.28	5.04	1.99	0.27	na	97.48
TS-620	drm	SS	63.87	1.05	16.06	5.35	0.12	1.70	4.12	5.06	1.99	0.28	na	99.38
TS-623	drm	SS	64.27	1.00	16.10	5.10	0.12	1.61	4.07	5.05	2.03	0.26	na	99.90
TS-635	drm	SS	64.05	1.01	16.08	5.24	0.11	1.66	4.15	5.00	2.04	0.26	na	98.90
TS-677	drm	SS	64.08	1.01	16.16	5.12	0.11	1.62	4.10	5.10	2.04	0.26	na	98.73
TS-678	drm	SS	63.92	1.02	16.27	5.21	0.11	1.63	4.11	5.04	2.02	0.27	na	99.23
TS-680	drm	SS	66.34	0.75	15.80	4.13	0.08	1.47	3.80	4.66	2.40	0.18	na	98.23
TS-719	drm	SS	63.77	1.04	16.24	5.22	0.12	1.64	4.17	5.11	2.00	0.27	na	99.47
TS-720	drm	SS	63.08	1.09	16.31	5.61	0.12	1.76	4.44	5.00	1.92	0.27	na	99.04
TS-723	drm	SS	62.64	1.12	16.22	5.73	0.12	1.97	4.58	4.98	1.94	0.30	na	100.28
						Dacite east of Sink Creek								
TS-641	dse	P	66.20	0.63	16.47	4.02	0.09	1.24	3.65	5.04	2.05	0.20	na	97.32
						Dacite north of Separation Creek								
TS-228	dsn	MS	64.31	0.97	16.05	5.65	0.14	1.32	3.46	5.53	1.80	0.37	-0.02	99.28
TS-257	dsn	MS	64.40	0.97	16.00	5.64	0.14	1.28	3.41	5.59	1.81	0.37	0.06	99.61
						Dacite of Sister Spring								
TS-101	dss	MS	63.58	1.01	16.32	5.69	0.14	1.43	3.71	5.56	1.69	0.46	<0.01	100.10
TS-387	dss	MS	63.74	1.02	15.99	5.73	0.14	1.49	3.80	5.58	1.70	0.42	<0.01	99.69
						Dacite domes southwest of Middle Sister								
TS-222	dsw	MS	65.45	0.72	16.19	5.15	0.14	0.93	2.79	6.13	1.85	0.26	-0.10	99.67
TS-222A	dsw	MS	65.47	0.71	16.14	5.18	0.14	0.92	2.83	6.12	1.83	0.26	-0.01	99.34
TS-223	dsw	MS	65.42	0.70	16.33	5.14	0.14	0.88	2.79	6.10	1.84	0.26	-0.08	99.42
TS-224	dsw	MS	65.48	0.71	16.12	5.22	0.14	0.95	2.77	6.10	1.84	0.27	0.08	99.48
						Dacite of Todd Lake								
TS-700	dtl	P	62.62	1.08	16.50	5.80	0.12	1.83	4.33	4.85	2.17	0.31	na	98.65
TS-782	dtl	P	63.49	0.99	16.10	5.64	0.11	1.83	4.25	4.68	2.22	0.28	na	99.64
TS-783	dtl	P	62.75	1.15	15.83	6.26	0.14	1.84	4.33	4.89	2.07	0.35	na	99.92
						Dacite west of Lost Creek Glacier								
TS-315	dwl	SS	63.10	1.07	16.15	5.78	0.12	1.82	4.34	5.03	1.90	0.29	0.01	99.29
TS-545	dwl	SS	64.60	0.92	15.85	5.19	0.10	1.85	3.99	4.68	2.21	0.21	0.14	99.29
						Dacite of Wickiup Plain								
TS-64	dwp	SS	64.05	0.99	16.29	5.06	0.11	1.61	4.08	5.06	2.04	0.32	0.06	99.67
TS-135	dwp	SS	64.16	0.99	16.27	5.08	0.11	1.58	4.08	4.98	2.05	0.30	0.00	99.19

Ba	Ce	Cr	Cu	Ga	La	Nb	Nd	Ni	Rb	Sr	V	Y	Zn	Zr
Silicic dacite north of Teardrop Pool														
724	33	5	16	13	12	7	26	3	52	298	81	19	43	178
Dacite pumice fall of Prouty Glacier headwall														
634	41	<5	11	18	21	12	27	5	37	345	69	30	79	241
Dacite of Red Meadow														
608	37	<5	8	21	17	11	19	7	38	388	96	25	74	218
676	40	<5	3	14	17	10	22	3	35	404	87	24	61	225
721	33	<5	22	14	14	8	26	3	46	342	91	19	51	213
649	37	<5	4	15	13	10	24	3	36	399	93	23	60	211
674	40	<5	5	14	15	10	23	3	36	402	93	23	64	218
695	42	<5	4	13	20	10	30	3	32	391	83	25	63	222
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
684	37	<5	2	14	16	12	30	3	35	387	102	27	53	259
643	40	<5	4	15	16	13	23	3	33	400	113	28	59	253
659	37	<5	<2	15	13	12	32	3	37	388	121	27	52	256
589	41	2	12	20	17	10	22	0	36	398	105	26	73	202
600	40	2	9	18	19	10	21	0	37	398	96	26	73	207
623	39	1	9	19	22	11	21	0	38	401	95	26	72	211
602	36	2	10	18	18	11	18	0	38	401	96	26	72	206
592	42	2	8	18	19	11	20	0	37	390	89	25	74	207
621	34	3	8	19	20	10	17	0	36	394	96	25	76	209
649	35	12	20	17	17	8	16	5	50	319	76	20	56	195
600	44	3	7	19	20	11	22	0	37	401	95	27	75	208
567	39	2	11	18	18	10	22	0	34	412	111	26	73	200
610	42	6	11	19	23	12	24	2	36	444	111	28	80	209
Dacite east of Sink Creek														
617	33	1	8	20	15	8	17	0	38	401	53	19	58	181
Dacite north of Separation Creek														
660	49	<5	19	21	22	12	25	7	30	382	47	43	91	238
664	47	5	24	22	21	11	26	8	29	373	50	37	88	237
Dacite of Sister Spring														
636	44	<3	9	22	21	11	27	9	26	405	53	36	91	222
626	42	na	16	26	20	12	26	na	28	433	84	46	99	275
Dacite domes southwest of Middle Sister														
638	41	<5	6	24	18	12	31	8	27	293	21	41	95	281
644	40	<5	4	23	17	11	24	7	26	297	25	37	93	271
645	41	<5	7	24	16	12	29	9	26	297	21	37	96	275
639	38	6	6	23	17	11	26	8	27	292	19	40	93	277
Dacite of Todd Lake														
682	55	5	25	20	26	14	28	2	44	329	106	38	85	276
633	55	10	29	19	26	13	31	7	58	360	113	38	76	257
683	66	7	29	21	26	14	34	6	47	344	121	44	91	267
Dacite west of Lost Creek Glacier														
592	34	<5	22	21	17	10	19	7	37	394	96	28	69	214
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Dacite of Wickiup Plain														
612	37	<3	12	20	18	12	22	<2	39	401	91	25	71	219
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na

Table 1. Chemical data for Three Sisters volcanic cluster.—Continued

Sample	Unit label	Volcanic group	SiO_2	TiO_2	Al_2O_3	FeO*	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI	Original total
Dacite of Wickiup Plain—Continued														
TS-136	dwp	SS	64.00	1.00	16.48	5.12	0.11	1.58	4.01	4.96	2.04	0.30	0.26	99.14
TS-137	dwp	SS	64.21	0.99	16.25	5.02	0.11	1.58	4.10	5.00	2.04	0.30	0.16	98.66
TS-345	dwp	SS	64.49	0.98	16.17	5.03	0.11	1.50	3.84	5.06	2.10	0.32	0.11	99.16
Basaltic andesite of Black Crater														
TS-746	mbc	P	56.22	1.02	17.67	7.06	0.13	4.57	7.72	3.75	1.12	0.34	na	98.93
NS-07-197	mbc	P	55.11	1.00	18.50	6.98	0.12	4.52	8.27	3.85	0.96	0.27	na	100.03
NS-07-199	mbc	P	55.85	1.33	17.27	8.22	0.15	3.93	7.29	4.35	0.95	0.28	na	100.19
Basaltic andesite of Bare Lake														
TS-785	mbl	P	55.79	1.67	16.22	9.53	0.16	3.32	7.01	4.50	1.02	0.36	na	99.89
Basaltic andesite of Broken Top														
TS-165	mbt	BT	54.15	0.98	18.25	7.28	0.12	5.77	8.41	3.49	0.86	0.29	1.55	97.67
TS-322	mbt	BT	55.98	1.47	16.68	9.07	0.15	3.39	7.24	4.45	0.91	0.25	<0.01	99.10
TS-327	mbt	BT	54.69	0.97	18.70	6.93	0.12	4.99	8.42	3.82	0.73	0.23	0.30	99.07
TS-328	mbt	BT	56.02	1.53	16.40	9.37	0.15	3.37	7.15	4.43	0.90	0.28	<0.01	99.57
TS-329	mbt	BT	56.08	1.46	16.77	8.89	0.15	3.36	7.15	4.38	0.98	0.37	<0.01	98.57
TS-330	mbt	BT	56.71	1.19	18.20	6.91	0.13	3.30	7.58	4.24	0.99	0.34	<0.01	99.58
TS-333	mbt	BT	55.68	1.78	16.02	9.56	0.16	3.43	7.05	4.57	0.97	0.37	<0.01	99.45
TS-334	mbt	BT	56.30	1.44	16.95	8.00	0.15	3.50	7.61	4.42	0.96	0.27	na	100.09
TS-334R	mbt	BT	56.22	1.44	16.95	8.14	0.15	3.51	7.58	4.39	0.96	0.27	na	100.29
TS-341	mbt	BT	52.83	1.32	19.66	7.84	0.13	3.47	9.74	3.66	0.67	0.29	0.45	98.80
TS-342	mbt	BT	55.77	1.57	17.16	8.69	0.14	3.00	7.55	4.34	1.03	0.34	<0.01	99.82
TS-450	mbt	BT	52.54	1.16	20.51	7.40	0.12	3.62	9.98	3.39	0.62	0.25	0.06	99.53
TS-451	mbt	BT	57.79	1.68	16.03	8.75	0.16	2.87	6.06	4.56	1.29	0.41	<0.01	99.44
TS-454	mbt	BT	54.24	1.16	18.58	8.27	0.14	4.38	8.21	3.61	0.75	0.26	0.36	99.15
TS-501	mbt	BT	56.07	1.50	17.17	8.47	0.15	3.44	7.25	4.05	1.10	0.40	<0.01	100.37
TS-515	mbt	BT	56.49	1.42	16.85	9.12	0.15	3.39	7.01	4.03	0.90	0.24	0.32	98.74
TS-524	mbt	BT	54.11	1.31	18.47	8.64	0.14	4.33	7.80	3.84	0.67	0.29	0.14	98.67
TS-529	mbt	BT	57.28	1.80	15.92	8.91	0.18	2.95	6.19	4.80	1.24	0.33	<0.01	99.47
TS-568	mbt	BT	55.89	1.56	16.53	9.24	0.16	3.42	6.99	4.39	1.10	0.32	<0.01	99.43
TS-675	mbt	BT	55.50	1.51	17.42	8.26	0.15	3.44	7.39	4.53	1.07	0.34	na	99.25
TS-682	mbt	BT	55.82	1.74	16.40	9.06	0.16	3.40	6.94	4.51	1.13	0.44	na	100.20
TS-683	mbt	BT	55.72	1.74	16.51	9.10	0.16	3.41	6.96	4.44	1.12	0.44	na	100.20
TS-683R	mbt	BT	55.72	1.73	16.51	9.10	0.16	3.41	6.93	4.46	1.13	0.44	na	99.73
TS-684	mbt	BT	57.70	1.68	16.16	8.45	0.17	2.81	6.05	4.93	1.30	0.36	na	99.62
TS-685	mbt	BT	54.61	1.92	16.22	9.73	0.17	3.59	7.46	4.53	0.98	0.36	na	100.38
TS-686	mbt	BT	54.80	1.65	17.16	9.35	0.17	3.33	7.35	4.60	0.92	0.28	na	99.24
TS-715	mbt	BT	55.39	1.80	16.43	9.26	0.16	3.37	7.23	4.68	0.96	0.33	na	99.63
TS-717	mbt	BT	53.68	1.53	17.65	8.78	0.15	3.88	8.44	4.19	0.90	0.38	na	100.07
Basaltic andesite of Whychus Creek bridge														
TS-448	mbw	BT	52.90	1.32	18.00	8.62	0.14	5.34	8.68	3.51	0.78	0.31	0.11	99.60
TS-456	mbw	BT	52.93	1.32	18.14	8.49	0.14	5.28	8.74	3.43	0.80	0.32	0.07	99.36
TS-659	mbw	BT	52.91	1.35	17.99	8.17	0.15	5.39	8.72	3.85	0.80	0.27	na	99.96
Basaltic andesite of Camp Lake														
TS-1	mcl	MS	56.31	1.33	17.00	8.86	0.14	3.37	6.80	4.46	1.01	0.31	<0.01	99.58
TS-2	mcl	MS	56.78	1.32	17.06	8.60	0.14	3.24	6.63	4.48	1.04	0.31	<0.01	99.81
TS-22	mcl	MS	56.45	1.33	17.09	8.83	0.14	3.33	6.81	4.33	0.99	0.31	<0.01	99.68
TS-169	mcl	MS	56.34	1.34	17.10	8.90	0.14	3.33	6.88	4.27	1.02	0.28	0.01	98.99
TS-186	mcl	MS	56.79	1.31	16.99	8.64	0.14	3.28	6.79	4.36	1.04	0.27	0.12	99.09
TS-446	mcl	MS	56.59	1.32	17.14	8.73	0.14	3.42	6.79	4.14	1.03	0.31	<0.01	99.97

Ba	Ce	Cr	Cu	Ga	La	Nb	Nd	Ni	Rb	Sr	V	Y	Zn	Zr
Dacite of Wickiup Plain—Continued														
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
650	39	na	9	23	18	15	22	na	40	406	112	38	76	286
Basaltic andesite of Black Crater														
492	49	84	50	20	23	12	28	62	18	533	163	26	84	192
416	36	59	54	20	18	6	20	41	14	853	184	17	80	120
373	30	16	72	19	13	6	20	8	14	570	217	23	85	137
Basaltic andesite of Bare Lake														
407	32	4	62	21	13	10	22	6	18	498	282	30	96	144
Basaltic andesite of Broken Top														
289	28	111	91	21	13	7	17	100	11	735	155	18	73	123
318	29	na	71	23	10	8	13	na	16	527	321	31	85	150
288	22	63	68	15	8	4	<10	42	9	686	221	14	65	94
339	27	<5	77	17	8	5	<10	3	12	489	297	22	77	118
415	35	<5	74	16	11	7	15	3	14	530	228	24	81	140
357	25	25	49	16	7	6	22	3	17	510	198	23	66	130
325	30	na	76	22	11	12	19	na	15	486	325	37	96	187
337	25	38	64	19	14	7	19	6	16	472	239	26	84	135
333	29	38	63	20	14	6	17	5	16	473	239	27	86	136
263	22	19	54	16	9	6	<10	3	8	626	275	20	62	104
352	30	<5	41	16	12	6	<10	3	18	534	279	25	80	136
242	12	6	53	15	10	3	<10	3	8	745	204	13	49	76
437	40	<5	20	16	13	12	23	3	22	394	208	35	83	218
285	23	50	71	15	9	5	10	23	15	568	207	17	65	109
418	42	<5	22	17	12	9	11	3	14	583	196	26	74	163
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
427	40	<5	19	15	11	11	13	10	21	399	217	35	84	212
412	30	<5	38	15	8	7	<10	3	18	519	309	27	71	165
391	35	23	71	20	17	9	22	9	14	577	221	28	92	156
397	37	10	64	19	17	7	23	5	21	509	261	29	96	148
408	37	9	49	20	18	8	23	4	21	513	266	29	98	148
406	38	7	49	20	18	8	25	6	21	510	262	29	95	147
431	46	9	25	20	20	12	29	1	21	384	222	38	97	216
343	32	16	42	21	14	10	22	5	15	430	314	33	100	171
354	26	2	50	21	13	7	19	4	15	487	266	27	99	127
337	30	5	51	19	14	8	20	4	15	458	290	30	97	145
361	37	19	41	20	16	8	23	11	13	636	257	25	87	135
Basaltic andesite of Whychus Creek bridge														
315	25	42	71	16	8	5	<10	62	13	549	195	21	67	117
321	25	41	79	16	10	6	<10	53	13	549	203	21	72	120
313	27	69	80	18	14	6	19	78	14	532	215	24	88	120
Basaltic andesite of Camp Lake														
383	29	5	81	22	13	8	11	9	15	546	253	21	93	135
401	27	4	86	22	12	8	<7	6	16	540	220	22	88	139
386	28	<3	66	20	13	8	12	2	15	552	231	21	87	136
388	28	<5	89	20	11	8	<10	13	15	557	242	22	87	139
391	29	<5	89	19	14	8	11	6	17	550	223	22	88	137
419	35	<5	78	17	8	6	<10	3	15	558	226	20	76	134

Table 1. Chemical data for Three Sisters volcanic cluster.—Continued

Sample	Unit label	Volcanic group	SiO_2	TiO_2	Al_2O_3	FeO*	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI	Original total
Basaltic andesite north and south of Demaris Lake														
TS-188	mdl	P	52.96	1.30	18.56	8.07	0.14	4.30	9.45	3.68	0.79	0.34	0.04	98.73
TS-463	mdl	P	53.63	1.19	17.61	8.02	0.14	6.26	8.43	3.11	0.88	0.33	<0.01	100.10
Basaltic andesite and basalt of "Egan Cone"														
TS-350	mec	P	54.08	1.31	17.98	8.62	0.15	4.63	7.94	3.83	0.74	0.31	na	99.54
TS-699	mec	P	53.58	1.36	18.11	8.75	0.16	4.77	8.06	3.75	0.72	0.35	na	99.59
TS-707	mec	P	52.91	1.51	17.83	9.18	0.16	4.93	8.09	3.81	0.73	0.45	na	99.76
TS-778	mec	P	51.94	1.72	17.37	10.11	0.17	5.15	8.17	3.68	0.72	0.57	na	99.59
TS-779	mec	P	51.59	1.70	17.45	10.04	0.17	5.39	8.32	3.72	0.68	0.53	na	100.25
TS-780	mec	P	52.17	1.70	17.49	9.99	0.18	5.11	8.03	3.66	0.71	0.56	na	99.38
Basaltic andesite east of Yapoah Lake														
TS-593	mey	NS	52.80	1.28	17.61	7.98	0.14	6.41	8.58	3.65	0.85	0.30	na	98.70
TS-599	mey	NS	52.94	1.28	17.67	7.80	0.14	6.40	8.54	3.67	0.86	0.30	na	98.37
NS-02-61	mey	NS	53.06	1.30	17.57	8.19	0.14	6.22	8.74	3.66	0.82	0.30	na	97.60
NS-02-96	mey	NS	53.21	1.30	17.91	7.96	0.14	5.84	8.81	3.68	0.85	0.30	na	98.96
Basaltic andesite of fissure vent south of Yapoah Lake														
TS-649	mfy	NS	57.49	1.55	16.68	8.20	0.14	3.03	6.21	4.71	1.25	0.32	na	99.96
TS-758	mfy	NS	56.62	1.48	16.93	8.70	0.15	3.20	6.50	4.59	1.12	0.32	na	98.61
Basaltic andesite of Hayden Glacier–Diller Glacier cleaver														
TS-178	mhd	MS	54.77	1.73	16.52	9.84	0.16	3.69	7.46	4.24	0.86	0.32	-0.35	99.47
TS-179	mhd	MS	54.66	1.73	16.58	9.87	0.16	3.73	7.45	4.23	0.87	0.32	-0.11	99.13
TS-180	mhd	MS	54.53	1.74	16.60	9.89	0.16	3.77	7.50	4.24	0.86	0.32	0.27	99.00
TS-477	mhd	MS	56.24	1.63	16.71	8.80	0.15	3.58	7.06	3.77	1.25	0.40	0.12	99.54
Basaltic andesite of headwaters of Linton Creek														
TS-270	mhl	MS	54.55	1.72	16.62	9.84	0.16	3.77	7.54	4.23	0.84	0.33	-0.21	99.51
TS-271	mhl	MS	55.68	1.71	16.46	9.53	0.16	3.36	6.99	4.39	0.98	0.34	-0.31	99.82
Basaltic andesite of The House Rock														
TS-150	mhr	P	53.36	1.08	18.52	7.81	0.13	5.57	8.45	3.66	0.72	0.30	-0.13	99.50
TS-702	mhr	P	53.44	1.10	18.52	7.62	0.13	5.50	8.57	3.66	0.77	0.27	na	100.05
TS-703	mhr	P	53.37	1.09	18.71	7.56	0.14	5.43	8.57	3.75	0.72	0.26	na	100.09
Basaltic andesite of Koosah Mountain														
TS-351	mkm	P	54.75	1.64	17.10	8.77	0.16	4.01	7.55	4.31	0.98	0.35	na	99.80
TS-352	mkm	P	53.86	1.23	17.87	7.88	0.14	5.17	8.24	3.85	0.94	0.43	na	100.13
TS-564	mkm	P	52.57	1.26	17.73	8.28	0.14	6.36	8.62	3.48	0.83	0.33	0.07	98.89
TS-701	mkm	P	52.80	1.22	17.53	8.06	0.14	6.51	8.63	3.53	0.85	0.32	na	99.79
TS-774	mkm	P	53.33	1.23	17.69	8.07	0.14	6.36	8.12	3.53	0.80	0.32	na	98.44
TS-775	mkm	P	53.08	1.19	17.35	7.95	0.14	6.75	8.54	3.45	0.83	0.31	na	99.48
Basaltic andesite of Little Brother														
TS-79	mlb	P	52.63	1.41	17.74	8.52	0.15	5.38	8.56	3.71	0.92	0.56	<0.01	99.35
TS-80	mlb	P	52.48	1.42	17.56	8.64	0.15	5.63	8.53	3.66	0.98	0.53	0.15	99.25
TS-81	mlb	P	52.89	1.41	17.56	8.49	0.15	5.26	8.48	3.77	1.01	0.57	<0.01	99.80
TS-383	mlb	P	53.05	1.41	17.48	8.45	0.15	5.09	8.59	3.82	1.00	0.55	<0.01	99.13
TS-385	mlb	P	52.74	1.41	17.45	8.62	0.15	5.49	8.56	3.71	0.95	0.51	0.08	99.33
TS-395	mlb	P	52.97	1.40	17.46	8.45	0.15	5.23	8.61	3.77	1.01	0.54	<0.01	99.28
TS-554	mlb	P	52.60	1.43	17.10	8.63	0.15	6.15	8.49	3.63	0.99	0.43	<0.01	99.60
TS-555	mlb	P	52.24	1.46	17.38	8.77	0.16	6.03	8.54	3.60	0.94	0.48	<0.01	99.14
TS-611	mlb	P	52.30	1.42	17.86	8.50	0.15	5.66	8.55	3.76	0.92	0.48	na	98.11
TS-612	mlb	P	52.89	1.42	17.52	8.39	0.15	5.48	8.54	3.79	0.96	0.47	na	100.42

Ba	Ce	Cr	Cu	Ga	La	Nb	Nd	Ni	Rb	Sr	V	Y	Zn	Zr
Basaltic andesite north and south of Demaris Lake														
322	36	36	130	19	16	9	<10	21	12	671	208	24	74	127
350	35	122	59	15	12	8	<10	109	11	614	180	19	67	135
Basaltic andesite and basalt of "Egan Cone"														
346	30	41	53	20	15	6	20	48	11	537	183	25	95	121
341	31	47	51	20	13	6	20	52	10	535	180	26	99	124
353	33	54	51	19	14	8	20	56	11	527	187	28	101	133
359	43	58	48	20	12	10	26	58	11	520	194	34	108	144
338	38	59	47	20	17	10	25	62	10	505	199	34	104	141
358	40	59	49	20	15	10	25	57	10	515	189	34	106	147
Basaltic andesite east of Yapoah Lake														
329	32	151	58	19	16	8	20	121	11	546	188	22	80	136
330	30	151	64	19	13	9	18	120	11	541	190	22	79	137
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Basaltic andesite of fissure vent south of Yapoah Lake														
436	41	3	50	20	15	8	24	5	20	465	224	27	93	181
411	39	1	47	21	15	8	21	5	18	536	233	27	93	154
Basaltic andesite of Hayden Glacier–Diller Glacier cleaver														
326	26	5	171	21	12	8	20	13	14	513	289	25	93	132
319	24	8	104	19	9	8	20	16	14	512	289	28	97	137
339	33	6	107	22	13	7	<10	16	13	516	282	26	93	132
429	34	26	89	17	9	8	<10	16	22	490	222	27	74	185
Basaltic andesite of headwaters of Linton Creek														
321	25	13	108	23	9	7	11	22	12	516	288	25	94	135
357	28	<5	71	22	13	8	19	20	16	503	260	27	91	146
Basaltic andesite of The House Rock														
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
321	26	94	48	18	12	7	18	93	12	597	186	20	80	118
323	29	94	72	18	12	7	18	87	11	598	193	20	82	118
Basaltic andesite of Koosah Mountain														
365	31	42	89	21	16	8	21	23	13	511	233	27	90	140
400	48	98	72	19	22	12	26	68	11	764	168	24	88	179
368	33	152	59	13	10	9	26	99	12	529	197	20	70	146
336	33	206	63	18	15	11	20	121	12	518	195	23	81	143
343	34	204	66	18	12	11	19	120	12	507	168	25	84	141
339	34	234	62	19	17	11	20	136	12	526	193	25	81	137
Basaltic andesite of Little Brother														
414	40	99	49	20	16	16	25	63	13	676	199	28	93	191
405	37	122	58	21	16	15	19	83	14	664	208	26	99	178
413	45	97	98	20	20	15	19	62	14	662	203	27	98	190
420	43	86	58	22	18	20	34	na	15	711	242	35	98	239
408	40	89	51	25	20	19	24	na	15	711	217	33	94	224
411	42	86	72	24	17	19	27	na	16	706	232	33	98	236
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
457	45	100	44	16	14	11	15	84	11	671	192	22	79	164
443	44	96	63	18	23	12	27	66	12	686	194	26	91	170
434	46	96	50	19	22	12	27	65	13	662	194	27	91	170

Table 1. Chemical data for Three Sisters volcanic cluster.—Continued

Sample	Unit label	Volcanic group	SiO_2	TiO_2	Al_2O_3	FeO*	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI	Original total
Basaltic andesite of Le Conte Crater														
TS-67	mlc	P	54.46	1.32	16.69	8.06	0.14	6.30	7.48	3.59	1.17	0.40	0.31	99.67
TS-247	mlc	P	54.50	1.31	16.46	8.12	0.14	6.39	7.53	3.61	1.17	0.36	0.17	99.24
TS-565	mlc	P	55.85	1.30	16.29	7.69	0.14	5.79	7.15	3.70	1.39	0.30	0.44	98.44
TS-628	mlc	P	54.48	1.33	16.51	7.96	0.14	6.40	7.55	3.74	1.16	0.33	na	100.50
Basaltic andesite of Linton Spring														
TS-292	mls	MS	55.09	1.43	17.02	9.23	0.15	3.81	7.34	4.25	0.98	0.29	0.24	98.89
Basaltic andesite of Millican Crater														
TS-745	mmc	P	53.59	1.10	18.52	7.64	0.13	5.40	8.50	3.73	0.73	0.24	na	99.60
TS-745R	mmc	P	53.54	1.10	18.51	7.76	0.13	5.40	8.47	3.72	0.74	0.24	na	100.60
Basaltic andesite intrusion of Middle Sister														
TS-181	mmi	MS	52.79	1.52	17.33	9.30	0.15	5.42	8.38	3.60	0.79	0.32	0.81	98.30
TS-474	mmi	MS	53.25	1.40	17.88	8.82	0.16	5.20	8.59	3.28	0.71	0.32	<0.01	99.70
Basaltic andesite of South Matthieu Lake														
TS-638	mml	NS	54.82	1.51	17.09	9.31	0.16	3.84	7.39	4.22	0.97	0.28	na	99.81
TS-731	mml	NS	54.42	1.48	17.26	9.26	0.15	3.96	7.68	4.14	0.97	0.27	na	99.48
TS-737	mml	NS	55.64	1.24	17.53	8.14	0.15	3.87	7.63	4.21	0.96	0.25	na	99.53
Basaltic andesite of Montague Memorial														
TS-106	mmm	MS	56.28	1.32	17.77	7.74	0.13	3.57	7.12	4.22	1.12	0.33	0.05	100.34
TS-384	mmm	MS	56.43	1.32	17.60	7.78	0.13	3.53	7.23	4.14	1.12	0.32	0.44	98.49
TS-428	mmm	MS	57.27	1.32	17.73	7.61	0.13	3.10	6.79	4.07	1.26	0.32	<0.01	100.01
TS-429	mmm	MS	56.62	1.34	17.43	7.79	0.13	3.42	7.08	4.33	1.16	0.30	0.11	98.86
Basaltic andesite of North Matthieu Lake														
TS-724	mmn	NS	54.58	1.51	17.08	9.33	0.15	3.89	7.59	4.25	0.94	0.28	na	100.34
TS-724R	mmn	NS	54.60	1.51	17.10	9.29	0.15	3.90	7.57	4.26	0.93	0.27	na	100.10
Basaltic andesite of Middle Sister														
TS-3	mms	MS	52.47	1.31	18.39	8.60	0.14	5.48	8.57	3.73	0.65	0.27	0.03	99.66
TS-4	mms	MS	52.16	1.35	18.42	8.79	0.14	5.52	8.69	3.59	0.62	0.31	0.09	100.05
TS-8	mms	MS	52.40	1.34	18.33	8.79	0.14	5.32	8.58	3.70	0.70	0.31	<0.01	99.99
TS-172	mms	MS	52.54	1.30	18.15	8.74	0.14	5.66	8.66	3.56	0.62	0.23	-0.25	99.34
TS-173	mms	MS	52.49	1.32	18.20	8.79	0.14	5.66	8.64	3.48	0.63	0.24	-0.04	99.04
TS-174	mms	MS	52.91	1.37	18.01	8.75	0.14	5.28	8.44	3.70	0.72	0.28	-0.23	99.02
TS-175	mms	MS	52.70	1.37	17.87	8.87	0.14	5.56	8.53	3.59	0.68	0.28	-0.05	99.21
TS-183	mms	MS	52.65	1.31	18.05	8.76	0.14	5.74	8.54	3.51	0.66	0.24	0.09	98.76
TS-184	mms	MS	52.62	1.32	18.01	8.83	0.14	5.65	8.60	3.55	0.64	0.24	-0.35	99.57
TS-192	mms	MS	52.76	1.37	18.42	8.57	0.14	4.92	8.77	3.67	0.70	0.28	-0.15	99.50
TS-218	mms	MS	52.50	1.33	18.06	8.83	0.14	5.68	8.61	3.57	0.64	0.24	-0.33	99.79
TS-226	mms	MS	52.52	1.38	18.14	8.79	0.14	5.41	8.69	3.58	0.68	0.27	0.03	99.38
TS-227	mms	MS	52.62	1.34	18.34	8.62	0.14	5.31	8.69	3.57	0.70	0.26	-0.04	99.37
TS-235	mms	MS	53.44	1.42	18.41	8.40	0.14	4.26	8.73	3.73	0.79	0.27	-0.11	99.53
TS-297	mms	MS	52.23	1.41	17.84	9.16	0.15	5.73	8.58	3.58	0.64	0.26	-0.04	99.35
TS-304B	mms	MS	52.56	1.88	16.85	10.32	0.17	4.61	8.07	3.84	0.89	0.40	0.03	99.30
TS-375	mms	MS	52.75	1.30	17.95	8.75	0.14	5.67	8.59	3.54	0.64	0.28	<0.01	99.89
TS-378	mms	MS	52.55	1.55	17.48	9.35	0.16	5.35	8.39	3.67	0.75	0.35	0.04	99.70
TS-382	mms	MS	52.64	1.54	17.28	9.35	0.15	5.44	8.45	3.68	0.75	0.33	<0.01	99.72
TS-398	mms	MS	52.75	1.29	17.95	8.69	0.14	5.73	8.62	3.52	0.63	0.27	<0.01	99.31
TS-403	mms	MS	52.60	1.28	18.20	8.46	0.14	5.50	8.92	3.58	0.62	0.29	<0.01	99.59
TS-404	mms	MS	52.41	1.27	18.37	8.52	0.14	5.76	8.90	3.34	0.61	0.28	<0.01	99.77
TS-406	mms	MS	52.51	1.28	18.40	8.52	0.14	5.66	8.87	3.32	0.62	0.28	0.16	99.59

Ba	Ce	Cr	Cu	Ga	La	Nb	Nd	Ni	Rb	Sr	V	Y	Zn	Zr
Basaltic andesite of Le Conte Crater														
375	33	204	55	17	16	14	15	128	20	444	180	24	77	165
374	34	193	56	17	16	13	16	110	21	448	171	23	70	165
441	33	150	43	13	11	11	28	102	26	417	163	22	62	165
389	30	205	63	16	18	11	19	124	21	453	172	24	74	159
Basaltic andesite of Linton Spring														
357	29	20	71	20	11	8	19	11	15	552	247	22	94	137
Basaltic andesite of Millican Crater														
312	23	85	65	17	12	7	15	90	12	599	184	20	82	108
323	26	87	65	19	11	7	14	91	13	605	188	20	80	109
Basaltic andesite intrusion of Middle Sister														
279	27	88	93	19	10	7	<10	73	12	515	216	25	82	131
292	26	78	36	16	13	4	<10	55	10	547	210	19	69	110
Basaltic andesite of South Matthieu Lake														
368	32	16	57	21	18	7	19	7	14	547	281	23	91	141
352	29	23	64	19	11	7	19	11	14	544	280	22	92	134
362	30	25	102	21	13	6	18	12	14	571	225	22	88	124
Basaltic andesite of Montague Memorial														
379	31	27	72	20	19	8	18	24	19	492	188	23	73	158
399	31	15	70	15	13	7	<10	13	17	496	206	22	69	158
452	34	8	65	17	13	7	11	6	21	492	194	22	66	167
383	29	22	78	24	12	11	18	na	20	521	252	30	76	203
Basaltic andesite of North Matthieu Lake														
358	33	17	60	21	16	8	21	9	14	548	293	22	92	138
352	30	18	60	20	13	7	18	9	13	539	290	22	93	137
Basaltic andesite of Middle Sister														
242	20	91	85	21	10	6	<7	72	10	550	208	21	83	100
248	21	100	85	19	10	6	8	76	10	552	208	23	84	110
252	23	93	87	20	7	6	12	70	10	544	204	22	81	111
234	19	98	97	19	6	5	11	80	10	577	203	20	77	94
244	17	103	96	19	7	5	13	82	9	566	208	20	82	97
266	20	77	88	19	7	7	<10	66	11	557	187	22	74	116
253	21	96	88	19	9	8	<10	75	12	548	214	24	82	112
245	21	100	95	21	10	6	<10	76	10	564	207	21	77	97
239	18	92	98	19	5	5	13	81	9	572	203	20	81	96
263	26	81	86	20	11	7	<10	59	11	552	196	22	73	114
237	25	95	102	22	8	5	<10	79	9	572	205	20	79	96
242	21	92	88	19	6	7	<10	69	11	546	194	23	76	114
243	22	90	73	19	7	7	<10	69	11	551	193	22	73	110
275	25	81	99	20	10	7	<10	40	13	551	217	24	73	119
244	21	84	120	20	9	6	11	77	10	565	212	22	77	105
338	29	67	115	21	12	10	21	42	14	489	277	34	103	173
250	22	86	78	13	7	4	<10	69	9	566	237	17	70	95
284	24	71	82	14	8	5	<10	53	13	526	242	22	74	135
289	25	71	91	16	10	5	<10	57	11	522	234	23	76	132
255	13	93	87	17	6	3	12	75	9	576	224	18	122	92
245	19	89	76	15	9	3	<10	58	10	574	217	17	73	94
242	13	81	76	16	<5	4	<10	62	8	578	207	17	61	94
249	23	90	75	14	10	4	<10	64	10	571	215	17	68	95

Table 1. Chemical data for Three Sisters volcanic cluster.—Continued

Sample	Unit label	Volcanic group	SiO_2	TiO_2	Al_2O_3	FeO*	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI	Original total
Basaltic andesite of Middle Sister—Continued														
TS-407	mms	MS	54.10	1.40	18.17	8.34	0.14	4.23	8.49	3.55	0.87	0.31	<0.01	99.23
TS-409	mms	MS	53.59	1.42	18.30	8.48	0.14	4.45	8.65	3.45	0.81	0.31	0.73	98.51
TS-422	mms	MS	52.76	1.73	17.25	9.76	0.16	4.81	8.32	3.54	0.86	0.40	<0.01	99.30
TS-465	mms	MS	52.50	1.33	18.24	8.94	0.14	5.79	8.69	3.12	0.58	0.27	<0.01	99.41
TS-469	mms	MS	52.77	1.32	18.09	8.85	0.14	5.70	8.64	3.18	0.64	0.28	<0.01	99.66
TS-551	mms	MS	52.30	1.46	17.37	8.73	0.16	5.96	8.50	3.72	0.95	0.45	<0.01	99.23
TS-304A	mms [dike]	MS	53.34	1.39	18.64	8.23	0.14	4.26	8.64	3.88	0.81	0.28	-0.09	99.90
Pyroxene-bearing variant of the basaltic andesite of Middle Sister														
TS-193	mms′	MS	54.53	1.76	16.63	9.91	0.16	3.71	7.51	4.19	0.88	0.31	0.19	98.81
TS-421	mms′	MS	54.56	1.73	16.51	9.89	0.16	3.73	7.50	4.32	0.85	0.34	<0.01	98.94
TS-423	mms′	MS	54.78	1.75	16.52	9.93	0.16	3.71	7.45	4.08	0.87	0.35	0.10	99.46
TS-424	mms′	MS	54.68	1.72	16.49	9.88	0.16	3.67	7.49	4.30	0.87	0.34	<0.01	99.09
TS-464	mms′	MS	54.91	1.74	16.63	9.94	0.16	3.73	7.41	3.85	0.87	0.35	<0.01	99.40
Basaltic andesite tuff of Middle Sister														
TS-266	mmt	MS	51.74	1.33	19.80	8.69	0.14	5.30	8.39	3.40	0.56	0.26	2.26	97.60
TS-288	mmt	MS	51.98	1.49	18.93	9.26	0.15	5.07	8.21	3.55	0.68	0.29	1.71	97.35
TS-289	mmt	MS	55.21	1.20	18.44	7.79	0.14	4.20	7.30	4.15	0.91	0.26	1.26	97.78
Basaltic andesite of North Fork Whychus Creek														
TS-185	mnf	MS	53.64	1.04	18.48	7.64	0.13	5.44	8.75	3.60	0.67	0.21	-0.13	99.16
TS-194	mnf	MS	54.35	1.03	19.09	7.23	0.12	4.62	8.52	3.73	0.70	0.21	0.23	99.14
TS-444	mnf	MS	54.23	1.07	18.58	7.45	0.13	5.03	8.58	3.48	0.76	0.29	0.17	99.72
TS-445	mnf	MS	53.78	1.10	18.26	7.64	0.13	5.56	8.71	3.35	0.76	0.30	0.11	99.26
TS-473	mnf	MS	54.38	0.99	19.15	7.18	0.12	5.03	8.61	3.20	0.68	0.26	0.01	100.37
Basaltic andesite north of Hayden Glacier														
TS-217	mnh	MS	57.13	1.30	17.02	8.60	0.14	3.06	6.51	4.49	1.07	0.28	-0.30	100.07
TS-470	mnh	MS	54.41	1.08	18.37	7.58	0.13	5.03	8.69	3.28	0.76	0.27	0.11	99.77
TS-471	mnh	MS	53.44	1.06	18.84	7.62	0.13	5.37	8.98	3.27	0.63	0.25	0.06	99.90
Basaltic andesite of North Sister														
TS-28A	mns	NS	54.25	1.07	18.52	7.40	0.13	4.90	8.49	3.77	0.77	0.29	0.36	99.51
TS-28B	mns	NS	53.46	1.06	18.75	7.43	0.13	5.01	8.87	3.86	0.77	0.27	0.10	99.86
TS-29	mns	NS	53.54	1.04	18.55	7.48	0.13	5.48	8.80	3.66	0.68	0.24	<0.01	99.89
TS-219	mns	NS	54.32	1.04	18.85	7.26	0.12	4.77	8.65	3.64	0.74	0.23	0.57	98.83
TS-220	mns	NS	53.42	1.08	18.04	7.74	0.13	6.39	8.71	3.32	0.51	0.25	1.54	97.70
TS-248	mns	NS	54.06	1.06	18.22	7.42	0.13	5.39	8.50	3.60	0.94	0.28	0.49	98.93
TS-249	mns	NS	54.00	1.05	18.37	7.42	0.13	5.41	8.55	3.55	0.83	0.28	0.29	99.24
TS-373	mns	NS	53.89	1.16	19.33	7.45	0.13	3.89	8.89	3.92	0.67	0.27	<0.01	99.42
TS-388	mns	NS	53.77	1.10	18.22	7.68	0.13	5.25	8.69	3.82	0.70	0.24	<0.01	98.92
TS-389	mns	NS	54.00	1.16	18.58	7.46	0.13	4.64	8.71	3.98	0.73	0.21	na	99.92
TS-390	mns	NS	53.61	1.11	19.00	7.38	0.13	4.72	8.94	3.85	0.67	0.19	na	100.55
TS-391	mns	NS	53.92	1.16	19.34	7.48	0.12	3.86	8.89	3.90	0.66	0.26	0.49	99.37
TS-594	mns	NS	53.61	1.11	18.56	7.70	0.13	5.17	8.52	3.86	0.72	0.23	na	98.59
TS-595	mns	NS	54.13	1.08	18.26	7.28	0.13	5.36	8.66	3.71	0.76	0.23	na	99.94
TS-596	mns	NS	53.41	1.03	18.58	7.27	0.13	5.83	8.87	3.64	0.66	0.19	na	100.35
TS-600	mns	NS	53.52	1.04	18.60	7.30	0.13	5.60	8.85	3.69	0.68	0.19	na	100.04
TS-602	mns	NS	52.51	1.21	18.44	7.96	0.14	5.78	8.85	3.81	0.65	0.26	na	100.15
TS-653	mns	NS	54.63	0.99	18.51	7.06	0.12	5.39	8.21	3.73	0.75	0.20	na	100.37
TS-654	mns	NS	54.39	0.98	18.36	7.19	0.12	5.69	8.19	3.74	0.74	0.21	na	99.00
TS-656	mns	NS	54.47	1.01	18.67	7.04	0.12	5.11	8.33	3.84	0.78	0.21	na	98.41

Ba	Ce	Cr	Cu	Ga	La	Nb	Nd	Ni	Rb	Sr	V	Y	Zn	Zr
Basaltic andesite of Middle Sister—Continued														
312	27	62	68	16	12	5	<10	26	14	545	228	20	67	122
289	24	<5	73	15	8	4	<10	31	12	547	<5	20	67	116
335	31	46	91	16	11	8	<10	35	13	510	264	26	89	154
264	17	71	82	14	6	4	<10	75	6	580	210	17	67	93
254	25	85	86	16	6	4	<10	77	9	571	229	17	78	90
447	44	104	51	14	11	11	26	74	12	679	179	22	73	163
286	25	82	92	21	12	6	17	41	13	555	211	24	82	126
Pyroxene-bearing variant of the basaltic andesite of Middle Sister														
329	30	6	103	20	10	7	13	16	13	511	287	25	98	134
344	29	na	108	23	9	10	21	na	13	544	357	31	96	170
345	25	<5	86	17	9	6	<10	3	15	517	5	9	88	9
332	27	<5	104	19	9	8	18	na	14	540	361	32	107	171
356	29	<5	148	15	12	4	11	4	13	519	44	22	82	128
Basaltic andesite tuff of Middle Sister														
243	21	98	95	19	8	6	17	70	8	550	192	20	75	99
404	25	97	92	18	10	8	19	58	11	515	210	24	85	126
390	25	77	71	17	10	8	12	49	14	506	155	24	86	142
Basaltic andesite of North Fork Whychus Creek														
270	25	75	78	20	8	6	15	65	8	578	153	18	68	101
267	27	45	70	20	11	7	13	60	9	603	147	19	75	114
309	28	57	67	14	7	5	<10	45	9	582	192	15	64	117
329	29	73	64	14	7	6	12	58	11	568	179	17	66	124
280	18	35	52	15	7	4	<10	81	9	614	173	15	59	104
Basaltic andesite north of Hayden Glacier														
408	32	10	65	22	13	8	19	10	17	549	209	23	92	144
325	27	60	64	14	11	5	19	41	9	566	185	17	62	112
288	26	33	88	21	30	9	17	94	11	616	228	27	75	106
Basaltic andesite of North Sister														
287	29	78	70	20	13	8	10	62	10	570	175	18	79	120
295	26	79	66	20	12	7	<7	54	9	588	176	19	74	119
268	22	91	76	20	10	6	7	67	8	577	176	18	72	104
274	25	63	74	20	10	7	<10	64	10	595	159	19	71	117
289	30	152	55	19	11	8	16	148	6	537	134	20	74	123
342	31	90	80	19	11	8	17	71	13	614	178	20	76	134
333	29	89	73	19	11	8	16	80	12	620	171	21	76	135
262	24	7	68	14	8	4	<10	22	6	623	213	17	62	103
268	24	69	94	21	7	8	<10	na	9	618	237	24	82	138
280	23	38	89	20	11	6	15	48	9	592	210	20	78	106
256	19	43	87	19	11	4	13	53	8	609	207	19	74	98
269	24	5	81	17	8	4	<10	23	6	624	209	16	67	99
319	21	42	68	19	11	5	16	74	11	595	190	19	78	99
321	31	98	55	17	13	6	16	66	11	567	190	20	75	119
274	19	104	70	19	13	5	13	97	8	580	192	18	72	99
280	22	97	79	19	10	5	17	85	8	583	194	19	73	101
285	26	46	84	20	12	6	17	92	8	594	199	20	77	117
299	25	100	33	19	15	6	16	95	9	618	176	18	73	111
288	32	122	62	18	13	5	17	102	9	607	170	17	70	107
299	25	68	59	18	13	4	14	83	10	617	176	17	73	109

Table 1. Chemical data for Three Sisters volcanic cluster.—Continued

Sample	Unit label	Volcanic group	SiO_2	TiO_2	Al_2O_3	FeO*	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI	Original total
Basaltic andesite of North Sister—Continued														
TS-657	mns	NS	54.86	1.02	18.47	7.04	0.12	4.98	8.29	3.82	0.79	0.22	na	100.42
TS-658	mns	NS	54.17	1.03	18.49	7.14	0.13	5.42	8.54	3.63	0.81	0.24	na	99.68
TS-752	mns	NS	54.44	0.99	18.58	7.09	0.12	5.28	8.40	3.76	0.73	0.20	na	99.29
TS-753	mns	NS	54.51	1.01	18.68	7.09	0.12	5.05	8.40	3.78	0.74	0.21	na	98.89
TS-755	mns	NS	54.51	0.97	18.34	7.22	0.12	5.65	8.20	3.65	0.73	0.20	na	99.06
TS-761	mns	NS	54.46	1.00	18.56	7.16	0.12	5.24	8.36	3.75	0.74	0.21	na	98.91
TS-768	mns	NS	54.45	1.01	18.46	7.06	0.12	5.35	8.40	3.71	0.80	0.22	na	99.68
TS-768R	mns	NS	54.35	1.00	18.40	7.29	0.12	5.32	8.38	3.71	0.80	0.22	na	100.59
NS-07-201	mns	NS	54.10	1.10	18.36	7.51	0.13	5.35	8.27	3.72	0.80	0.25	na	99.97
NS-07-203	mns	NS	54.67	1.00	18.55	7.02	0.12	5.12	8.37	3.78	0.76	0.20	na	100.38
NS-07-204	mns	NS	53.73	1.11	18.53	7.69	0.13	5.16	8.50	3.84	0.68	0.22	na	100.71
TS-433	mns′	NS	54.75	1.31	17.48	7.52	0.13	5.45	8.05	3.48	1.07	0.36	0.26	99.15
TS-435	mns′	NS	54.40	1.27	17.73	7.64	0.13	5.37	8.26	3.49	0.99	0.33	0.05	99.97
TS-436	mns′	NS	54.61	1.32	17.30	7.56	0.13	5.45	8.32	3.50	1.06	0.35	<0.01	99.59
TS-437	mns′	NS	54.53	1.32	17.47	7.55	0.13	5.55	8.19	3.43	1.06	0.36	0.14	99.19
TS-443	mns′	NS	53.07	1.20	17.72	8.11	0.14	6.48	8.48	3.25	0.80	0.33	<0.01	99.46
TS-467	mns	NS	53.31	1.00	18.83	7.49	0.13	5.83	9.01	3.16	0.61	0.24	<0.01	99.96
TS-468	mns	NS	53.35	1.01	18.81	7.52	0.13	5.76	8.98	3.15	0.64	0.26	<0.01	100.08
TS-505	mns′	NS	55.09	1.31	17.14	7.46	0.13	5.50	8.20	3.31	1.10	0.37	<0.01	100.53
TS-561	mns′	NS	55.02	1.32	17.04	7.46	0.14	5.33	7.99	3.83	1.15	0.31	0.02	99.37
Basaltic andesite north of Trout Creek														
TS-637	mnt	NS	56.85	1.59	16.63	8.53	0.15	3.23	6.43	4.59	1.27	0.33	na	98.43
TS-663	mnt	NS	55.51	1.43	17.19	8.40	0.15	3.97	7.36	4.19	1.11	0.28	na	98.97
TS-664	mnt	NS	55.66	1.42	17.13	8.26	0.15	3.98	7.37	4.32	1.02	0.28	na	99.10
TS-670	mnt	NS	55.31	1.37	17.28	8.17	0.15	4.26	7.63	4.26	0.91	0.27	na	100.66
NS-07-200	mnt	NS	54.94	1.41	17.43	8.42	0.15	4.26	7.61	4.21	0.88	0.28	na	98.19
Basaltic andesite of Park Meadow														
TS-516	mpm	P	55.90	0.93	17.93	7.21	0.12	4.93	8.02	3.41	0.89	0.26	0.28	99.42
EMT-363	mpm	P	56.00	0.90	17.60	7.20	na	4.70	7.90	4.20	0.80	na	na	99.30
EMT-364	mpm	P	55.50	0.95	17.30	7.30	na	5.70	8.40	3.80	0.80	na	na	99.75
Basaltic andesite north of Scott Pass														
TS-639	mpn	NS	54.56	1.48	17.18	9.25	0.15	3.98	7.66	4.16	0.91	0.27	na	99.84
TS-725	mpn	NS	54.80	1.52	17.13	9.32	0.16	3.80	7.34	4.27	0.98	0.28	na	99.51
TS-726	mpn	NS	55.22	1.54	17.07	9.20	0.16	3.63	7.15	4.32	1.00	0.30	na	99.57
TS-728	mpn	NS	55.08	1.54	16.93	9.42	0.16	3.71	7.22	4.27	1.00	0.29	na	99.19
Basaltic andesite south of Scott Pass														
TS-82	mps	NS	55.97	1.25	17.29	8.35	0.14	3.76	7.33	4.24	0.96	0.33	<0.01	99.66
TS-83	mps	NS	57.59	1.42	17.03	8.08	0.14	2.94	6.05	4.71	1.23	0.41	0.10	99.44
TS-84A	mps	NS	58.69	1.37	16.91	7.56	0.14	2.68	5.64	4.86	1.32	0.42	<0.01	100.12
TS-84B	mps	NS	57.65	1.42	16.92	8.14	0.15	2.95	6.08	4.66	1.23	0.40	<0.01	99.51
TS-85	mps	NS	56.57	1.46	16.89	8.83	0.15	3.22	6.42	4.52	1.16	0.39	0.10	99.65
TS-86	mps	NS	56.14	1.49	16.98	9.01	0.15	3.33	6.59	4.43	1.10	0.38	<0.01	99.70
TS-87	mps	NS	56.44	1.47	16.95	8.87	0.15	3.25	6.50	4.49	1.11	0.38	<0.01	99.89
TS-88	mps	NS	56.37	1.48	16.99	8.89	0.15	3.26	6.47	4.50	1.11	0.38	<0.01	99.65
TS-640	mps	NS	56.25	1.50	16.85	8.88	0.15	3.34	6.69	4.54	1.09	0.31	na	99.83
TS-648	mps	NS	57.41	1.63	16.39	8.56	0.15	2.96	6.13	4.67	1.36	0.34	na	99.84
TS-732	mps	NS	56.06	1.49	16.99	8.87	0.15	3.34	6.73	4.58	1.09	0.30	na	99.71
TS-733	mps	NS	55.95	1.49	17.05	8.94	0.15	3.34	6.79	4.50	1.08	0.30	na	99.10
TS-738	mps	NS	56.29	1.54	16.88	8.59	0.15	3.43	6.74	4.51	1.16	0.32	na	99.84
TS-740	mps	NS	57.13	1.63	16.58	8.62	0.15	2.99	6.10	4.71	1.34	0.34	na	99.78

Ba	Ce	Cr	Cu	Ga	La	Nb	Nd	Ni	Rb	Sr	V	Y	Zn	Zr
Basaltic andesite of North Sister—Continued														
311	26	67	46	18	13	5	16	80	11	627	179	17	75	115
344	30	94	63	18	14	6	19	75	11	619	175	20	76	126
289	27	81	63	18	13	6	15	99	11	627	172	17	74	106
304	30	71	63	20	14	6	16	82	11	631	173	18	73	111
283	29	123	43	18	12	6	16	106	9	613	169	18	74	107
290	24	78	63	19	11	6	13	96	9	625	171	19	73	107
310	33	80	70	20	11	7	17	102	11	632	176	19	74	112
311	31	79	69	20	13	7	17	101	12	634	176	19	76	114
342	25	93	50	17	15	7	15	84	14	578	185	19	80	121
305	28	72	41	17	14	6	16	85	9	631	177	17	74	112
313	20	41	66	20	10	5	13	76	11	608	191	19	79	101
423	38	104	59	15	9	10	17	40	15	688	180	19	63	151
387	32	83	47	16	14	9	<10	43	14	679	179	17	63	127
414	33	86	26	15	10	10	22	37	16	684	187	17	59	135
419	36	97	42	14	12	10	<10	45	15	685	179	18	65	146
341	30	116	58	14	9	6	<10	107	10	604	169	17	65	128
271	22	74	65	15	7	3	<10	89	5	607	163	14	57	90
269	25	79	64	16	8	4	<10	90	7	598	195	14	62	92
408	40	92	44	14	16	11	<10	44	15	684	172	18	63	146
422	38	89	47	15	15	11	10	51	18	663	179	17	64	142
Basaltic andesite north of Trout Creek														
421	34	4	54	21	18	8	22	8	21	447	232	28	93	181
345	35	17	68	20	14	8	20	14	15	486	219	25	89	150
340	28	17	70	19	15	7	17	14	15	487	220	25	87	149
326	33	28	68	19	12	7	20	18	13	504	220	23	85	142
345	26	21	80	20	14	8	15	16	12	505	220	25	84	144
Basaltic andesite of Park Meadow														
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Basaltic andesite north of Scott Pass														
350	31	23	64	20	13	7	21	8	14	554	287	22	90	133
370	30	16	59	19	16	8	21	8	14	536	284	24	93	140
389	36	11	46	20	14	8	21	4	15	529	258	24	97	149
375	35	11	50	20	12	7	19	5	14	528	258	23	98	145
Basaltic andesite south of Scott Pass														
367	25	21	88	19	11	7	15	18	15	569	223	21	88	134
435	34	<3	33	18	15	8	17	11	19	527	191	26	98	178
456	33	<3	32	21	15	10	23	10	20	507	149	28	92	193
430	37	<3	36	25	17	9	22	12	18	527	184	26	97	179
406	33	<3	53	21	13	9	23	12	17	538	216	26	97	166
401	34	<3	68	22	16	9	17	12	17	544	232	25	95	159
399	30	<3	50	21	14	9	13	12	17	541	233	26	99	162
403	33	<3	52	24	14	9	20	12	17	538	241	26	93	159
415	34	2	56	21	17	7	19	2	16	539	261	24	91	150
457	40	1	54	21	18	9	24	5	23	440	230	30	94	195
402	29	2	54	20	14	7	19	3	15	533	257	24	94	150
401	39	3	61	20	15	7	22	4	16	533	259	24	93	148
399	35	7	52	20	16	9	22	12	18	465	228	28	93	174
450	38	1	49	21	18	10	25	8	21	431	227	29	101	196

Table 1. Chemical data for Three Sisters volcanic cluster.—Continued

Sample	Unit label	Volcanic group	SiO_2	TiO_2	Al_2O_3	FeO*	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI	Original total
Basaltic andesite south of Scott Pass—Continued														
TS-742	mps	NS	56.15	1.49	16.98	8.80	0.15	3.30	6.67	4.65	1.11	0.31	na	100.77
TS-762	mps	NS	57.34	1.64	16.55	8.50	0.15	2.97	6.11	4.67	1.32	0.35	na	99.35
Basaltic andesite of Renfrew Glacier														
TS-105	mrg	MS	54.55	1.73	16.69	9.82	0.16	3.75	7.40	4.27	0.86	0.38	<0.01	99.69
TS-379	mrg	MS	54.56	1.77	16.58	9.97	0.16	3.70	7.53	4.17	0.81	0.36	0.10	99.13
TS-381	mrg	MS	54.64	1.73	16.47	9.87	0.16	3.75	7.45	4.32	0.87	0.34	<0.01	99.17
TS-402	mrg	MS	54.71	1.72	16.36	9.86	0.16	3.83	7.49	4.24	0.87	0.36	<0.01	99.23
TS-417	mrg	MS	54.83	1.73	16.61	9.92	0.17	3.61	7.37	4.11	0.88	0.35	<0.01	99.54
Basaltic andesite of Sims Butte														
TS-634	msb	P	52.80	1.30	17.29	8.29	0.14	6.87	8.33	3.54	0.78	0.26	na	99.94
TS-667	msb	P	54.66	1.20	17.23	7.54	0.14	6.13	7.71	3.73	1.03	0.23	na	99.06
TS-747	msb	P	56.59	1.09	16.83	7.14	0.13	5.52	7.11	3.69	1.29	0.21	na	98.72
TS-748	msb	P	54.28	1.21	17.08	7.88	0.14	6.43	7.76	3.59	0.97	0.25	na	98.70
TS-749	msb	P	54.24	1.24	17.06	8.06	0.14	6.40	7.69	3.57	0.96	0.24	na	98.84
TS-750	msb	P	52.74	1.30	17.26	8.37	0.14	6.87	8.28	3.60	0.79	0.26	na	99.10
TS-751	msb	P	52.35	1.31	17.52	8.41	0.15	6.98	8.44	3.48	0.70	0.26	na	98.35
CR-111	msb	P	54.02	1.22	16.81	8.19	0.13	6.51	7.93	3.58	0.96	0.25	0.00	100.12
Basaltic andesite of Separation Creek														
TS-113	msc	P	57.10	1.22	17.36	7.47	0.13	3.80	6.73	4.34	1.15	0.29	-0.16	99.25
TS-114	msc	P	56.76	1.22	17.48	7.52	0.13	3.91	6.86	4.31	1.12	0.30	-0.17	99.15
TS-127	msc	P	57.05	1.26	17.23	7.58	0.13	3.78	6.82	4.30	1.16	0.30	0.33	98.29
TS-255	msc	P	57.27	1.23	17.58	7.50	0.13	3.66	6.68	4.17	1.10	0.28	0.41	99.12
TS-290	msc	P	56.92	1.22	17.43	7.55	0.13	3.81	6.78	4.35	1.14	0.28	0.47	98.87
TS-309	msc	P	57.16	1.21	17.39	7.44	0.13	3.73	6.77	4.35	1.15	0.28	-0.11	99.66
TS-310	msc	P	56.81	1.19	17.57	7.49	0.13	3.92	6.87	4.25	1.09	0.28	-0.07	99.76
TS-311	msc	P	56.74	1.19	17.61	7.48	0.13	3.96	6.89	4.23	1.09	0.28	0.56	98.99
TS-320	msc	P	56.91	1.22	17.53	7.60	0.13	3.74	6.78	4.27	1.12	0.29	0.20	99.40
TS-537	msc	P	57.09	1.23	17.38	7.48	0.13	3.76	6.82	4.26	1.17	0.27	0.42	98.58
Basaltic andesite of South Fork Whychus Creek														
TS-190	msf	P	53.69	0.99	18.74	7.69	0.13	5.39	8.57	3.67	0.58	0.15	0.45	98.88
TS-191	msf	P	53.97	1.02	18.63	7.66	0.13	5.10	8.56	3.78	0.60	0.15	-0.03	98.91
TS-459	msf	P	53.94	1.01	18.65	7.70	0.13	5.28	8.57	3.52	0.60	0.20	0.08	99.35
Basaltic andesite of Soap Creek–North Fork Whychus Creek confluence														
TS-466	msp	P	54.18	1.32	17.59	7.58	0.13	5.60	8.69	3.15	1.03	0.33	<0.01	99.09
TS-502	msp	P	54.77	1.26	17.60	7.56	0.13	5.30	8.29	3.37	0.99	0.33	<0.01	100.19
TS-504	msp	P	54.56	1.30	17.46	7.58	0.13	5.44	8.46	3.34	1.00	0.34	<0.01	99.85
Basaltic andesite of Middle Sister summit														
TS-234	mss	MS	56.11	1.32	17.60	7.76	0.13	3.75	7.60	3.73	1.33	0.27	0.44	99.04
Basaltic andesite south of Trout Creek														
NS-07-202	mst	NS	53.34	1.16	19.86	7.49	0.13	3.99	8.59	4.09	0.72	0.23	na	99.19
Basaltic andesite and basalt of Trout Creek Butte														
TS-660	mtb	P	51.94	1.14	17.65	8.21	0.15	6.01	10.57	3.15	0.57	0.21	na	100.09
TS-660R	mtb	P	51.89	1.14	17.65	8.30	0.15	5.99	10.55	3.15	0.56	0.21	na	100.38
TS-661	mtb	P	51.82	1.23	17.75	8.45	0.16	5.84	10.47	3.18	0.47	0.23	na	99.33
TS-662	mtb	P	52.14	1.29	17.51	8.45	0.16	5.65	10.32	3.27	0.57	0.25	na	100.46
CR-115	mtb	P	52.72	1.31	17.61	8.29	0.14	5.91	8.77	3.67	0.85	0.32	< 0.01	99.56

Ba	Ce	Cr	Cu	Ga	La	Nb	Nd	Ni	Rb	Sr	V	Y	Zn	Zr
Basaltic andesite south of Scott Pass—Continued														
413	35	3	59	20	15	7	21	4	16	540	256	25	94	152
450	46	3	52	21	19	11	25	11	22	443	228	32	96	196
Basaltic andesite of Renfrew Glacier														
324	28	7	87	23	13	8	19	19	13	515	257	26	90	133
363	26	<5	98	18	7	5	<10	3	11	526	303	23	86	136
324	28	na	91	20	13	11	12	na	15	545	371	35	97	173
345	29	<5	88	17	10	5	19	4	13	518	309	23	89	129
356	26	<5	97	17	11	6	<10	3	12	513	296	23	84	132
Basaltic andesite of Sims Butte														
272	29	215	59	18	16	6	16	121	14	459	188	23	76	128
315	26	156	45	16	14	6	15	106	19	423	168	22	75	131
351	29	131	44	17	12	6	16	95	27	403	152	23	67	128
305	28	190	52	18	10	8	16	120	18	435	170	24	75	131
307	23	188	55	17	13	8	13	121	18	430	170	24	74	132
268	26	209	64	18	10	7	15	128	13	456	191	23	78	124
261	29	212	59	16	8	8	17	130	11	462	189	24	78	125
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Basaltic andesite of Separation Creek														
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
397	29	42	63	22	12	7	24	31	16	491	164	23	79	162
375	26	43	58	20	11	7	17	27	19	498	165	23	76	155
376	26	39	62	19	10	7	17	23	19	501	163	21	79	153
369	27	47	62	20	15	8	18	24	18	503	160	22	79	146
359	28	43	42	21	11	7	16	31	18	508	163	21	75	145
372	27	42	64	22	11	7	20	27	19	504	171	22	86	153
422	26	27	52	14	13	6	<10	23	18	498	179	20	71	149
Basaltic andesite of South Fork Whychus Creek														
217	18	76	89	18	6	4	<10	40	8	589	176	16	75	73
209	16	68	79	17	<5	5	16	30	7	582	178	18	69	76
225	11	53	76	15	6	<2	<10	27	5	592	170	13	57	69
Basaltic andesite of Soap Creek–North Fork Whychus Creek confluence														
362	36	92	5	14	14	10	<10	44	17	702	196	17	65	128
382	33	82	40	14	13	7	<10	41	14	666	170	15	65	123
372	35	82	43	15	12	9	<10	38	15	687	190	16	61	128
Basaltic andesite of Middle Sister summit														
356	29	67	64	21	12	8	18	41	24	496	197	25	77	151
Basaltic andesite south of Trout Creek														
271	20	15	44	20	11	4	15	41	8	641	190	19	76	105
Basaltic andesite and basalt of Trout Creek Butte														
231	28	152	44	19	11	5	19	28	6	594	215	22	79	108
234	24	151	43	18	9	4	16	29	6	598	219	23	78	108
234	26	146	46	19	13	5	18	28	4	570	212	24	80	118
247	31	137	40	18	13	6	20	28	5	595	227	24	84	129
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na

Table 1. Chemical data for Three Sisters volcanic cluster.—Continued

Sample	Unit label	Volcanic group	SiO_2	TiO_2	Al_2O_3	FeO*	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI	Original total
Basaltic andesite of The Husband														
TS-112	mth	P	52.77	1.18	17.82	8.21	0.14	6.20	8.66	3.69	0.67	0.25	-0.25	99.47
TS-125	mth	P	55.87	0.95	17.72	7.04	0.12	5.09	7.75	3.59	1.14	0.33	0.51	98.94
TS-291	mth	P	55.77	0.90	18.19	6.79	0.12	4.87	8.06	3.71	0.94	0.26	-0.08	99.65
TS-536	mth	P	56.15	0.91	17.95	6.72	0.11	5.17	7.86	3.50	0.99	0.23	0.35	99.33
TS-550	mth	P	55.41	1.05	17.53	7.43	0.14	5.14	7.60	3.71	1.22	0.37	0.39	98.86
TS-558	mth	P	56.99	0.92	15.88	6.43	0.13	5.52	8.33	3.31	1.71	0.38	0.12	99.10
TS-633	mth	P	52.03	1.70	16.93	9.55	0.17	5.52	8.25	3.95	0.99	0.51	na	100.41
Basaltic andesite of Teardrop Pool														
TS-47	mtp	SS	53.82	1.33	18.08	8.65	0.14	4.56	8.13	3.97	0.67	0.25	0.70	98.64
TS-48	mtp	SS	56.13	1.28	17.31	8.02	0.14	3.90	7.24	4.26	1.04	0.26	<0.01	99.54
TS-50	mtp	SS	55.83	1.20	17.84	7.61	0.13	4.20	7.29	4.20	0.99	0.31	<0.01	99.37
TS-587	mtp	SS	54.23	1.32	17.94	8.45	0.14	4.35	8.14	3.98	0.78	0.26	0.40	98.81
Basaltic andesite southeast of "Todd Creek"														
TS-784	mts	P	56.10	1.27	17.32	8.37	0.15	3.60	7.04	4.47	0.99	0.29	na	99.26
Basaltic andesite of The Wife														
TS-66	mtw	P	53.03	1.09	18.28	7.81	0.13	5.87	8.76	3.53	0.77	0.33	0.06	99.72
TS-109	mtw	P	52.96	1.19	17.89	8.15	0.14	5.86	8.63	3.56	0.86	0.36	0.02	99.11
TS-128	mtw	P	52.42	1.21	18.04	8.22	0.14	6.12	8.85	3.49	0.77	0.34	0.24	98.81
TS-129	mtw	P	52.08	1.24	17.86	8.37	0.14	6.32	9.00	3.48	0.75	0.34	0.04	99.25
TS-147	mtw	P	53.59	1.07	18.20	7.60	0.13	5.46	8.83	3.53	0.92	0.28	0.34	99.06
TS-148	mtw	P	52.82	1.10	18.21	7.90	0.13	6.06	8.84	3.44	0.79	0.30	0.09	99.56
TS-149	mtw	P	53.46	1.09	18.35	7.89	0.13	5.55	8.43	3.63	0.75	0.31	0.19	99.31
Basaltic andesite west of upper Alder Creek														
TS-756	mwa	NS	53.25	1.14	19.99	7.46	0.13	4.13	8.60	3.99	0.69	0.22	na	99.03
TS-759	mwa	NS	53.60	1.38	18.34	7.70	0.14	4.59	8.85	3.83	0.86	0.30	na	98.00
TS-760	mwa	NS	54.96	1.54	17.70	8.71	0.15	3.51	7.31	4.61	0.84	0.27	na	99.34
TS-763	mwa	NS	55.42	1.29	18.43	7.88	0.14	3.67	6.92	4.63	0.91	0.32	na	99.90
TS-765	mwa	NS	54.21	1.18	19.21	7.32	0.13	3.95	8.60	4.05	0.73	0.22	na	100.06
TS-766	mwa	NS	56.12	1.24	18.37	7.60	0.14	3.36	6.72	4.76	0.96	0.33	na	100.26
Basaltic andesite of Whychus Creek														
TS-252	mwh	P	53.16	1.52	18.72	8.79	0.14	3.57	8.61	4.02	0.73	0.32	-0.12	99.48
TS-438	mwh	P	54.89	1.64	17.13	9.66	0.16	3.40	7.26	4.20	0.92	0.34	<0.01	99.43
TS-449	mwh	P	55.10	1.62	17.10	9.45	0.16	3.39	7.29	4.21	0.94	0.34	<0.01	99.61
TS-455	mwh	P	53.38	1.63	18.33	9.24	0.15	3.55	8.26	3.92	0.78	0.37	0.09	99.45
TS-457	mwh	P	53.73	1.65	17.91	9.37	0.16	3.54	8.05	3.98	0.83	0.38	<0.01	99.55
TS-613	mwh	P	55.08	1.63	17.06	9.31	0.17	3.28	7.31	4.56	0.92	0.28	na	100.05
TS-616	mwh	P	55.17	1.62	16.95	9.27	0.16	3.30	7.32	4.58	0.94	0.28	na	99.86
Basaltic andesite west of Snow Creek														
TS-254	mws	BT	54.61	1.93	16.06	10.14	0.17	3.63	7.36	4.35	0.95	0.39	-0.15	99.21
TS-525	mws	BT	53.74	1.92	16.11	10.39	0.18	3.90	7.90	4.25	0.88	0.33	<0.01	99.53
TS-567	mws	BT	53.56	1.99	16.25	10.41	0.17	3.97	7.84	4.25	0.81	0.34	<0.01	99.30
TS-669	mws	BT	54.97	1.89	16.17	9.60	0.17	3.54	7.34	4.55	1.02	0.36	na	99.57
Basaltic andesite scoria cone west of Yapoah Lake														
TS-643	mwy	NS	56.44	1.58	16.95	8.48	0.15	3.31	6.47	4.71	1.17	0.34	na	98.52
TS-643R	mwy	NS	56.48	1.58	16.98	8.44	0.15	3.29	6.49	4.69	1.16	0.34	na	98.75
TS-645	mwy	NS	56.56	1.59	16.90	8.49	0.15	3.29	6.46	4.65	1.16	0.33	na	99.75
Basaltic andesite of Yapoah Lake														
TS-597	myl	NS	54.16	1.10	18.29	7.51	0.13	5.34	8.25	3.76	0.80	0.25	na	100.67

Ba	Ce	Cr	Cu	Ga	La	Nb	Nd	Ni	Rb	Sr	V	Y	Zn	Zr
Basaltic andesite of The Husband														
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
382	34	83	58	20	12	6	20	62	15	686	129	17	63	137
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
774	62	117	39	13	24	8	35	50	41	849	152	20	66	153
481	51	98	64	20	25	12	28	66	14	799	230	28	105	177
Basaltic andesite of Teardrop Pool														
290	21	65	55	21	8	6	<7	24	9	518	212	21	84	109
347	24	50	57	20	10	6	17	17	18	476	192	22	82	127
337	27	53	59	19	12	8	18	27	15	522	170	21	79	139
310	25	43	54	16	8	5	<10	12	12	525	213	19	73	106
Basaltic andesite southeast of "Todd Creek"														
400	37	30	67	21	10	7	22	17	16	599	230	24	94	133
Basaltic andesite of The Wife														
352	27	108	65	21	16	8	14	75	11	645	168	21	71	123
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Basaltic andesite west of upper Alder Creek														
261	23	13	59	20	9	7	17	54	8	649	187	20	77	102
338	30	86	67	17	14	11	21	54	10	570	191	25	78	146
319	33	1	62	23	10	7	20	8	9	572	265	26	93	125
347	34	5	62	21	12	8	21	30	10	585	175	26	92	143
271	27	19	79	20	12	6	16	37	9	620	197	22	79	106
359	31	3	29	20	13	8	19	26	10	584	162	26	88	148
Basaltic andesite of Whychus Creek														
299	26	13	64	22	9	9	17	22	10	567	213	25	87	117
373	32	<5	35	18	11	6	<10	8	14	499	238	25	78	127
369	29	<5	44	18	7	6	<10	3	16	501	235	25	83	132
350	30	<5	46	18	8	7	<10	4	9	550	213	23	75	122
352	32	<5	53	18	10	6	<10	3	12	537	216	22	71	122
362	23	4	51	20	14	7	19	3	15	495	268	28	100	131
362	30	2	46	20	18	7	20	3	15	491	272	26	98	128
Basaltic andesite west of Snow Creek														
321	31	13	46	22	13	11	20	10	15	435	297	36	94	176
318	32	14	29	18	11	8	<10	27	13	462	300	28	72	147
308	30	6	44	16	12	10	<10	4	9	447	359	31	77	170
340	32	14	48	21	15	11	23	5	16	423	281	33	102	174
Basaltic andesite scoria cone west of Yapoah Lake														
418	36	6	58	21	16	8	24	10	17	473	210	28	94	172
416	34	6	58	20	15	8	21	11	17	475	215	28	93	173
426	34	5	63	20	18	7	22	11	18	480	217	28	90	173
Basaltic andesite of Yapoah Lake														
346	27	94	69	19	12	6	16	83	13	579	186	19	78	122

Table 1. Chemical data for Three Sisters volcanic cluster.—Continued

Sample	Unit label	Volcanic group	SiO_2	TiO_2	Al_2O_3	FeO*	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI	Original total
Basaltic andesite of Yapoah Lake—Continued														
TS-598	myl	NS	53.48	1.11	18.58	7.75	0.13	5.19	8.54	3.87	0.71	0.23	na	98.54
TS-636	myl	NS	53.42	1.10	18.70	7.72	0.13	5.27	8.51	3.86	0.67	0.22	na	98.82
TS-650	myl	NS	53.62	1.09	18.68	7.66	0.13	5.20	8.44	3.86	0.69	0.22	na	98.85
TS-651	myl	NS	53.56	1.10	18.63	7.71	0.13	5.20	8.49	3.86	0.69	0.22	na	99.04
TS-665	myl	NS	53.49	1.10	18.72	7.55	0.14	5.35	8.53	3.73	0.75	0.24	na	99.93
TS-666	myl	NS	53.65	1.11	18.68	7.58	0.13	5.12	8.54	3.86	0.71	0.23	na	100.28
TS-757	myl	NS	53.73	1.09	18.54	7.62	0.13	5.24	8.51	3.84	0.67	0.22	na	99.51
TS-767	myl	NS	53.61	1.10	18.64	7.77	0.13	5.18	8.45	3.82	0.67	0.22	na	99.85
NS-07-205	myl	NS	53.78	1.10	18.56	7.70	0.13	5.42	8.22	3.68	0.76	0.24	na	99.78
Basaltic andesite southwest of Yapoah Lake														
TS-646	mys	NS	53.08	1.49	18.07	9.35	0.16	4.50	7.60	4.33	0.76	0.26	na	100.70
TS-647	mys	NS	52.50	1.43	17.88	9.57	0.16	5.37	7.57	4.17	0.70	0.25	na	100.48
TS-647R	mys	NS	52.49	1.42	17.86	9.56	0.16	5.37	7.60	4.18	0.70	0.25	na	100.36
TS-739	mys	NS	53.21	1.48	18.19	9.09	0.16	4.40	7.68	4.39	0.76	0.26	na	100.00
TS-741	mys	NS	53.11	1.48	18.23	9.27	0.16	4.34	7.64	4.36	0.77	0.26	na	100.11
TS-776	mys	NS	53.13	1.47	18.06	9.19	0.15	4.60	7.66	4.33	0.74	0.26	na	99.71
Basaltic andesite window west of Yapoah Lake														
TS-644	myw	NS	53.04	1.03	19.21	7.25	0.13	5.37	9.07	3.69	0.63	0.19	na	100.11
Rhyolite of South Sister climbers trail														
TS-51	rct	SS	72.87	0.31	14.33	2.03	0.06	0.41	1.59	4.74	3.14	0.12	0.21	99.37
TS-52	rct	SS	72.94	0.30	14.29	2.00	0.05	0.40	1.60	4.75	3.15	0.13	0.36	99.00
TS-157	rct	SS	72.79	0.31	14.38	1.99	0.06	0.42	1.63	4.79	3.14	0.10	0.14	99.06
TS-157A	rct	SS	72.70	0.30	14.40	1.97	0.05	0.41	1.62	4.43	3.61	0.10	0.46	98.92
TS-164	rct	SS	73.05	0.30	14.27	1.98	0.06	0.40	1.63	4.67	3.15	0.09	0.44	98.45
TS-489	rct	SS	73.41	0.31	14.22	2.01	0.06	0.40	1.66	4.24	3.15	0.14	0.60	100.13
Rhyolite of "Devils chain"														
TS-13	rdc	SS	72.46	0.33	14.31	2.13	0.05	0.58	1.91	4.52	3.17	0.13	0.24	99.52
TS-95	rdc	SS	72.43	0.34	14.41	2.12	0.05	0.57	1.93	4.45	3.14	0.16	0.46	99.56
TS-199	rdc	SS	72.56	0.34	14.35	2.14	0.05	0.56	1.94	4.40	3.16	0.10	0.50	98.55
TS-206	rdc	SS	72.57	0.34	14.31	2.16	0.06	0.56	1.93	4.40	3.16	0.10	0.61	98.82
TS-207	rdc	SS	72.63	0.33	14.32	2.14	0.05	0.55	1.94	4.37	3.16	0.10	0.82	98.73
TS-240	rdc	SS	72.61	0.34	14.36	2.13	0.05	0.53	1.95	4.36	3.15	0.11	0.35	99.17
TS-241	rdc	SS	72.55	0.33	14.31	2.14	0.05	0.59	1.93	4.40	3.17	0.11	0.53	98.84
TS-245	rdc	SS	72.57	0.34	14.35	2.16	0.05	0.57	1.95	4.36	3.14	0.10	0.74	98.54
TS-358	rdc	SS	72.63	0.33	14.27	2.08	0.05	0.54	1.95	4.53	3.14	0.08	na	99.44
TS-365	rdc	SS	72.65	0.33	14.19	2.12	0.05	0.53	1.92	4.50	3.19	0.12	0.32	98.98
TS-591	rdc	SS	72.54	0.34	14.31	2.13	0.05	0.52	1.94	4.44	3.14	0.18	0.35	99.54
TS-590	rdc	SS	72.49	0.34	14.34	2.14	0.06	0.52	1.96	4.46	3.12	0.18	0.24	100.03
Rhyolite of Devils Hill														
TS-93	rdh	SS	73.35	0.28	14.21	1.86	0.05	0.38	1.49	4.66	3.17	0.14	0.46	99.53
TS-242	rdh	SS	73.66	0.27	14.05	1.85	0.05	0.37	1.48	4.62	3.18	0.08	0.51	99.25
TS-243	rdh	SS	73.69	0.28	14.04	1.84	0.05	0.36	1.46	4.63	3.17	0.08	0.13	99.35
TS-244	rdh	SS	73.67	0.27	14.03	1.85	0.05	0.37	1.46	4.63	3.18	0.08	0.25	98.70
TS-338	rdh	SS	74.05	0.26	13.85	1.73	0.05	0.30	1.40	4.58	3.24	0.14	0.40	99.26
TS-339	rdh	SS	74.01	0.26	13.91	1.74	0.05	0.31	1.36	4.61	3.26	0.09	0.26	98.78
Rhyolite of Green Lakes														
TS-507	rgl	SS	72.92	0.33	14.46	2.09	0.06	0.44	1.73	4.31	3.11	0.15	0.79	99.85
TS-569	rgl	SS	72.18	0.33	14.54	2.12	0.06	0.47	1.73	4.72	3.38	0.09	0.41	97.98

Ba	Ce	Cr	Cu	Ga	La	Nb	Nd	Ni	Rb	Sr	V	Y	Zn	Zr
Basaltic andesite of Yapoah Lake—Continued														
303	18	39	72	20	11	5	13	74	10	595	192	19	78	99
306	22	41	59	18	11	5	15	76	10	593	190	18	78	96
311	26	39	60	20	11	5	15	74	9	592	183	18	77	100
309	16	40	71	19	13	5	13	74	10	596	186	18	79	98
324	28	86	60	19	15	5	15	86	11	588	187	19	82	112
308	24	41	78	18	10	5	14	77	11	596	187	19	80	102
301	23	39	71	20	10	6	13	85	10	604	188	20	77	97
305	25	41	48	19	8	6	15	81	10	603	191	20	79	97
338	27	95	70	19	12	6	17	84	12	573	176	20	80	121
Basaltic andesite southwest of Yapoah Lake														
335	26	3	56	20	14	5	16	42	8	608	232	21	96	102
312	25	4	39	20	12	5	18	72	7	601	221	20	95	95
311	25	5	40	19	14	4	17	72	6	602	220	21	94	94
324	23	3	56	20	11	5	15	42	7	594	227	22	94	102
335	29	4	63	21	13	5	20	40	8	591	220	22	96	103
321	27	5	67	20	10	6	17	50	7	607	227	24	95	99
Basaltic andesite window west of Yapoah Lake														
267	21	51	79	19	10	4	16	94	6	614	190	18	72	96
Rhyolite of South Sister climbers trail														
901	45	5	6	18	28	10	24	3	66	188	16	15	35	236
913	45	6	3	17	30	10	20	3	68	184	17	16	40	237
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
915	50	7	5	17	29	10	30	5	67	188	19	16	45	238
977	40	<5	<2	11	20	9	11	2	65	189	6	14	31	233
Rhyolite of "Devils chain"														
855	46	5	6	17	33	11	27	4	73	221	21	16	39	194
847	42	5	7	17	26	10	27	9	75	225	23	16	37	198
853	44	7	9	17	28	10	23	3	74	226	26	16	40	196
851	44	6	9	17	28	10	31	<2	73	222	22	16	39	195
852	45	6	6	17	29	9	29	3	73	221	23	16	39	195
864	42	8	8	17	27	11	21	8	74	225	21	17	40	196
861	47	8	9	17	28	10	25	9	74	226	24	17	39	196
850	45	7	7	17	28	10	25	7	74	225	25	16	38	197
794	40	3	5	16	23	8	16	0	72	233	20	18	40	181
852	43	<5	9	19	24	13	26	na	79	234	31	22	41	247
938	36	<5	<2	10	16	9	11	2	71	223	6	15	31	196
926	37	<5	<2	10	18	8	28	2	68	226	6	14	30	194
Rhyolite of Devils Hill														
900	51	6	5	16	33	10	18	7	69	174	16	15	42	229
899	45	7	5	16	28	9	25	6	67	171	16	16	37	225
912	48	7	6	17	30	10	24	6	68	173	13	15	39	225
905	43	7	6	16	27	11	17	5	71	172	17	15	40	228
976	39	<5	<2	10	20	8	14	2	67	156	6	13	29	212
913	39	7	5	19	25	13	18	na	73	164	22	18	38	264
Rhyolite of Green Lakes														
960	39	<5	<2	12	19	9	19	2	62	191	6	17	34	252
939	39	<5	<2	11	19	13	14	2	60	193	7	20	27	301

Table 1. Chemical data for Three Sisters volcanic cluster.—Continued

Sample	Unit label	Volcanic group	SiO_2	TiO_2	Al_2O_3	FeO*	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI	Original total
							Rhyolite of Kaleetan Butte							
TS-73A	rkb	SS	73.53	0.28	14.04	1.89	0.05	0.36	1.49	4.59	3.24	0.12	0.39	99.29
TS-94	rkb	SS	73.60	0.28	14.06	1.89	0.05	0.37	1.50	4.63	3.10	0.13	0.30	99.87
TS-138	rkb	SS	73.52	0.27	14.12	1.83	0.05	0.38	1.46	4.68	3.20	0.09	1.27	98.08
							Rhyolite of Mesa Creek							
TS-69	rmc	SS	72.32	0.33	14.56	2.13	0.06	0.44	1.71	4.84	3.06	0.14	0.40	99.16
TS-70	rmc	SS	72.38	0.33	14.64	2.09	0.06	0.43	1.68	4.77	3.08	0.14	0.25	99.36
TS-141	rmc	SS	72.59	0.32	14.46	2.05	0.06	0.43	1.67	4.80	3.10	0.10	0.91	98.51
							Rhyolite of Obsidian Cliffs							
TS-102A	roc	MS	76.54	0.11	13.04	1.00	0.04	0.15	0.86	4.34	3.42	0.11	0.38	100.07
TS-107	roc	MS	76.37	0.13	13.21	1.06	0.04	0.16	0.87	4.26	3.40	0.11	0.25	100.30
TS-430	roc	MS	76.69	0.11	13.00	1.02	0.04	0.11	0.91	4.10	3.52	0.09	0.46	96.50
							Rhyolite of Park Creek							
TS-777	rpc	SS	72.54	0.32	14.44	2.07	0.06	0.42	1.69	4.86	3.13	0.07	na	99.13
EMT-209	rpc	SS	72.50	0.35	14.60	2.20	<0.1	0.30	1.50	5.10	2.95	~0.1	na	99.50
							Rhyodacite of Prouty Glacier							
TS-201	rpg	SS	68.44	0.67	15.22	3.72	0.07	1.08	3.04	4.62	2.57	0.18	0.18	98.82
TS-572	rpg	SS	68.11	0.65	15.17	3.85	0.08	1.35	3.16	4.66	2.43	0.14	0.25	99.15
							Rhyolite of Rock Mesa							
TS-65	rrm	SS	73.47	0.30	13.98	1.88	0.05	0.48	1.68	4.26	3.35	0.15	0.44	99.77
TS-159	rrm	SS	73.43	0.30	14.02	1.87	0.05	0.48	1.70	4.27	3.37	0.10	0.55	98.74
TS-160	rrm	SS	73.53	0.29	13.94	1.85	0.05	0.47	1.70	4.27	3.39	0.10	0.65	98.62
							Rhyolite of Separation Creek							
TS-209	rsc	SS	73.85	0.26	13.87	1.76	0.05	0.48	1.51	4.40	3.36	0.07	0.41	99.13
TS-210	rsc	SS	69.63	0.49	15.15	3.05	0.07	1.07	2.60	4.71	2.69	0.14	0.14	99.27
TS-321	rsc	SS	73.33	0.29	14.04	1.89	0.05	0.53	1.60	4.53	3.26	0.07	0.30	99.28
TS-231	rsc′	SS	72.30	0.34	14.48	2.19	0.06	0.65	1.86	4.51	3.12	0.09	0.20	99.74
							Rhyolite southeast of Lewis Glacier							
TS-364	rse	SS	73.81	0.28	13.90	1.90	0.05	0.33	1.54	4.53	3.11	0.14	0.14	99.58
TS-366	rse	SS	73.68	0.28	14.01	1.91	0.05	0.36	1.49	4.55	3.17	0.10	0.29	98.81
TS-486	rse	SS	73.98	0.30	14.04	1.95	0.05	0.35	1.56	4.10	3.13	0.15	0.16	100.04
TS-487	rse	SS	73.92	0.28	14.07	1.92	0.05	0.34	1.56	4.19	3.12	0.15	0.04	99.84
TS-490	rse	SS	73.69	0.29	14.30	1.95	0.06	0.36	1.58	4.14	3.08	0.16	0.66	99.62
TS-521	rse	SS	74.02	0.28	13.94	1.91	0.05	0.37	1.55	4.22	3.13	0.12	0.34	99.30
TS-522A	rse	SS	73.59	0.28	13.99	1.88	0.05	0.38	1.57	4.69	3.10	0.07	na	98.45
TS-522B	rse	SS	73.64	0.28	13.98	1.89	0.05	0.37	1.54	4.68	3.10	0.06	na	99.81
TS-522C	rse	SS	73.98	0.29	13.91	1.93	0.05	0.36	1.57	4.24	3.12	0.13	0.95	98.82
TS-523	rse	SS	74.01	0.29	13.90	1.93	0.05	0.35	1.54	4.26	3.14	0.13	0.14	99.59
							Rhyolite of South Fork Whychus Creek							
TS-9	rsf	SS	73.97	0.26	13.83	1.77	0.05	0.34	1.42	4.65	3.18	0.12	0.15	99.37
TS-15	rsf	SS	73.94	0.26	13.89	1.77	0.05	0.35	1.42	4.65	3.16	0.12	0.16	99.68
TS-16	rsf	SS	73.85	0.26	13.92	1.85	0.06	0.36	1.43	4.58	3.14	0.15	0.24	100.20
TS-17	rsf	SS	73.84	0.26	14.05	1.79	0.05	0.35	1.40	4.56	3.16	0.14	0.25	99.95
TS-18	rsf	SS	74.00	0.25	13.92	1.79	0.05	0.32	1.41	4.60	3.15	0.11	0.16	99.47
TS-166	rsf	SS	74.03	0.26	13.94	1.79	0.05	0.33	1.43	4.50	3.17	0.08	0.38	99.29
TS-167	rsf	SS	74.00	0.26	14.03	1.79	0.05	0.33	1.41	4.46	3.18	0.08	0.26	98.66
TS-168	rsf	SS	74.26	0.25	13.79	1.76	0.05	0.31	1.42	4.50	3.19	0.07	0.19	98.98
TS-512	rsf	SS	74.42	0.27	13.82	1.79	0.05	0.32	1.45	4.18	3.17	0.13	0.19	99.44
TS-722	rsf	SS	73.95	0.25	14.00	1.75	0.05	0.32	1.42	4.63	3.17	0.06	na	99.61

Ba	Ce	Cr	Cu	Ga	La	Nb	Nd	Ni	Rb	Sr	V	Y	Zn	Zr
Rhyolite of Kaleetan Butte														
902	42	4	4	16	28	10	18	<2	67	171	17	16	44	194
891	47	5	5	17	30	11	30	8	68	174	19	17	41	201
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Rhyolite of Mesa Creek														
901	50	6	4	17	29	12	26	3	63	195	17	18	40	253
909	46	6	7	18	26	10	18	9	62	201	16	17	38	258
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Rhyolite of Obsidian Cliffs														
987	46	6	2	15	31	8	12	7	76	104	8	13	33	92
1000	59	6	3	15	41	9	51	7	73	107	9	13	31	96
1070	33	<5	<2	10	24	8	12	2	75	104	6	13	25	94
Rhyolite of Park Creek														
835	42	2	5	17	22	10	16	2	63	205	15	19	43	251
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Rhyodacite of Prouty Glacier														
744	38	6	11	18	20	9	26	4	53	287	60	19	48	227
758	32	<5	10	10	10	10	22	2	46	281	71	20	41	269
Rhyolite of Rock Mesa														
888	43	6	7	16	28	10	21	7	80	190	19	16	35	183
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Rhyolite of Separation Creek														
846	49	7	10	17	28	9	29	2	74	162	21	15	37	156
760	47	12	17	18	33	9	38	9	56	261	43	20	44	216
849	43	9	7	17	28	9	18	4	71	167	23	16	31	157
832	48	9	12	17	31	9	23	8	66	197	29	17	41	177
Rhyolite southeast of Lewis Glacier														
898	36	6	7	20	25	13	18	na	69	184	28	19	39	247
927	35	<5	9	19	22	12	20	na	73	186	32	16	39	250
981	44	<5	3	12	24	9	22	2	63	177	7	17	30	199
981	37	<5	<2	11	18	9	10	2	64	176	6	16	31	196
994	38	<5	<2	11	20	9	15	2	58	181	6	17	34	197
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
815	40	2	5	16	20	9	16	0	66	183	11	18	39	181
826	37	3	5	16	20	9	15	0	65	183	10	18	38	182
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Rhyolite of South Fork Whychus Creek														
903	42	6	3	16	27	11	29	4	69	165	14	16	40	190
907	49	7	7	17	32	11	32	4	68	164	14	16	41	189
901	41	6	5	15	28	10	27	8	67	166	16	16	40	191
926	44	7	3	17	27	10	21	5	67	164	15	14	38	188
915	41	6	4	17	27	10	25	<2	66	165	13	16	38	190
911	45	7	7	17	31	11	33	4	68	167	14	16	38	193
922	45	6	7	16	32	11	32	3	68	168	18	16	40	193
908	45	8	7	16	30	10	26	4	70	166	16	16	41	194
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
827	39	1	2	15	21	9	14	0	67	171	9	17	36	177

Table 1. Chemical data for Three Sisters volcanic cluster.—Continued

Sample	Unit label	Volcanic group	SiO_2	TiO_2	Al_2O_3	FeO*	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI	Original total
Rhyodacite southwest of Golden Lake														
TS-514	rsg	BT	70.07	0.64	14.90	3.19	0.09	0.60	1.86	5.47	2.58	0.19	0.13	98.93
Rhyolite southwest of Lewis Glacier														
TS-144	rsw	SS	73.64	0.28	13.96	1.91	0.05	0.38	1.52	4.61	3.13	0.11	0.29	99.14
TS-156	rsw	SS	73.30	0.29	14.11	1.98	0.05	0.43	1.59	4.62	3.13	0.10	0.55	98.11
Rhyodacite of Upper Chush Falls														
TS-91	ruc	BT	69.07	0.50	15.39	3.52	0.10	0.55	1.94	6.05	2.30	0.18	0.06	99.64
TS-499	ruc	BT	69.68	0.50	15.52	3.42	0.09	0.46	1.90	5.54	2.31	0.18	0.19	99.48
TS-624	ruc	BT	69.21	0.49	15.41	3.49	0.09	0.49	1.88	6.12	2.31	0.10	na	99.44
Rhyolite of Dome 5803														
TS-735	r58	P	73.96	0.20	14.21	1.64	0.05	0.29	1.44	4.67	3.08	0.06	na	99.63

Ba	Ce	Cr	Cu	Ga	La	Nb	Nd	Ni	Rb	Sr	V	Y	Zn	Zr
Rhyodacite southwest of Golden Lake														
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Rhyolite southwest of Lewis Glacier														
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Rhyodacite of Upper Chush Falls														
669	41	5	7	22	22	12	25	10	45	219	18	38	79	271
729	40	<5	<2	15	18	10	22	2	42	217	7	27	62	265
639	37	0	4	21	20	10	23	0	43	221	7	35	75	253
Rhyolite of Dome 5803														
844	37	3	3	17	20	8	13	0	65	186	7	16	42	160

Table 2. $^{40}Ar/^{39}Ar$ ages for Three Sisters volcanic cluster.

[Samples irradiated at USGS reactor, using 27.87-Ma Taylor Creek sanidine as neutron flux monitor. Abbreviations: GM, groundmass concentrate; PL, plagioclase; MSWD, mean square weighted deviation; --, not determined. Whole-rock weight-percent SiO_2 values are from table 1. $^{40}Ar/^{39}Ar$ ages determined by incremental-heating analysis; weighted-mean plateau ages calculated from apparent ages on increments released within analytical error; samples without listed plateau ages yielded discordant $^{40}Ar/^{39}Ar$ age spectra, but acceptable isochron or total-gas ages. Interpreted eruption ages are highlighted in **bold**]

Sample	Unit label	Whole-rock SiO_2	Material	$^{40}Ar/^{39}Ar$ weighted-mean plateau age		$^{40}Ar/^{39}Ar$ isotope-correlation (isochron) age				$^{40}Ar/^{39}Ar$ total-gas age (ka)
				Age (ka)	%^{39}Ar[steps, °C]	Age (ka)	%^{39}Ar[steps, °C]	MSWD	$^{40}Ar/^{36}Ar_i$	
TS-324	abt	63.6	GM	**177.9±1.1**	95[600–1100]	176.9±2.1	95[600–1100]	0.44	296.6±3.3	176.9±1.1
TS-562	adl	61.3	GM	**24.2±1.1**	83[600–800]	29.8±6.0	83[600–800]	1.48	290.4±12.3	19.9±1.2
TS-202	aeg	56.5	GM	**27.0±3.2**	77[650–925]	24.4±4.8	95[600–1100]	0.79	296.9±2.3	28.5±3.6
TS-577	aeg	59.2	GM	**26.7±1.7**	73[600–750]	28.5±3.6	73[600–750]	2.16	295.2±3.5	27.6±1.8
TS-584	aeg	56.7	GM	**28.5±2.1**	77[640–850]	29.0±6.3	77[640–850]	0.42	295.3±2.7	19.8±2.7
TS-44	ahi	60.5	GM	16.8±2.1	78[640–940]	**23.3±6.3**	78[640–940]	0.62	291.5±2.3	13.1±2.4
TS-283	ahl	57.9	GM	44.5±3.6	58[550–740]	33.7±10.5	58[550–740]	0.15	298.3±2.3	**20.8±3.3**
TS-298A	alc	61.9	GM	**27.2±1.0**	96[600–1100]	25.5±1.9	96[600–1100]	1.24	297.4±3.6	27.6±1.1
TS-557	alc	61.9	GM	**26.8±1.2**	74[550–750]	30.9±7.0	74[550–750]	0.91	292.0±12.9	21.9±1.2
TS-256	alg	62.2	GM	**27.1±1.1**	100[550–1150]	25.4±2.2	100[550–1150]	1.02	296.5±2.8	27.6±1.2
TS-580	alh	62.0	GM	**30.4±1.3**	89[550–850]	29.5±5.6	89[550–850]	2.64	296.0±9.4	28.7±1.3
TS-472	anh	58.0	GM	17.9±2.5	93[550–925]	**21.0±6.3**	93[550–925]	1.44	294.6±4.8	15.4±2.7
TS-386	aoc	58.6	GM	**47.9±2.2**	67[550–700]	52.0±11.9	67[550–700]	0.29	293.2±7.9	41.7±2.3
TS-426	aoc	61.8	GM	29.2±2.3	74[650–830]	**48.9±3.7**	74[650–1050]	1.14	285.0±2.9	-75.7±3.9
TS-559	aoc	60.1	GM	**44.6±1.8**	74[600–750]	45.2±12.7	74[600–750]	0.15	295.1±7.5	41.7±2.0
TS-622	apc	61.6	GM	8.4±3.3	48[650–725]	**31.4±8.7**	82[600–850]	0.30	290.2±1.9	2.9±2.5
TS-225	asw	61.5	GM	**24.5±4.2**	58[600–800]	36.7±15.4	58[600–800]	0.38	292.6±3.5	6.6±4.0
TS-655	awa	57.5	GM	**25.2±2.2**	83[550–750]	18.1±8.5	83[550–750]	0.52	298.8±6.6	20.2±2.1
TS-372	awc	62.1	GM	**21.9±1.7**	90[600–1250]	24.8±9.6	90[600–1250]	2.20	293.9±2.0	19.0±1.7
TS-392	awc	62.1	GM	**24.5±1.5**	92[600–1100]	27.4±4.4	92[600–1100]	2.20	294.0±1.8	21.2±1.7
TS-510	awf	60.0	GM	**23.7±1.3**	87[600–850]	24.9±4.0	87[600–850]	0.30	294.6±3.4	23.2±1.4
TS-453	awy	61.3	GM	**298.7±1.4**	79[650–830]	292.7±8.1	79[650–830]	0.46	302.5±14.0	296.9±1.3
TS-652A	bac	53.1	GM	**127.9±6.6**	73[780–1150]	94.6±21.5	73[780–1150]	0.80	300.7±7.2	162.2±11.1
TS-119	bjc	51.6	GM	**147.9±4.3**	88[650–975]	140.9±8.6	88[650–975]	1.03	297.8±1.9	151.2±4.8
TS-131	bsb	51.5	GM	**278.9±5.5**	88[700–1100]	284.9±5.4	88[700–1100]	0.31	295.2±1.5	280.2±6.7
TS-100	dbh	64.0	GM	**17.9±2.2**	99[650–1100]	20.1±6.8	99[650–1100]	1.50	294.5±4.7	12.9±3.2
TS-216	dbh	64.4	GM	27.1±1.8	92[550–925]	**23.0±6.8**	100[550–1200]	0.32	298.2±3.5	29.0±2.0
TS-117	dcg	63.3	GM	25.9±1.2	69[650–800]	**30.7±2.6**	69[650–800]	0.57	290.5±1.7	11.6±1.5

Table 2. $^{40}Ar/^{39}Ar$ ages for Three Sisters volcanic cluster.—Continued

Sample	Unit label	Whole-rock SiO_2	Material	$^{40}Ar/^{39}Ar$ weighted-mean plateau age		$^{40}Ar/^{39}Ar$ isotope-correlation (isochron) age				$^{40}Ar/^{39}Ar$ total-gas age (ka)
				Age (ka)	%^{39}Ar[steps, °C]	Age (ka)	%^{39}Ar[steps, °C]	MSWD	$^{40}Ar/^{36}Ar_i$	
TS-19	dcl	65.4	GM	19.8±1.6	87[600–850]	**26.0±2.1**	100[550–1250]	0.47	290.3±0.9	14.1±1.7
TS-115	ddl	64.3	GM	**32.3±1.8**	99[600–1100]	34.1±2.7	99[600–1100]	1.16	294.7±0.9	31.2±2.1
TS-706	dgc	65.2	GM	**31.6±2.0**	100[550–1100]	31.1±4.4	100[550–1100]	1.15	295.8±7.4	31.3±2.2
TS-412	dhr	63.6	GM	**19.1±1.7**	76[630–900]	18.8±3.8	76[630–900]	0.75	295.6±2.0	14.2±1.9
TS-5	dig	64.2	GM	**14.4±2.7**	77[700–1000]	22.9±11	77[700–1000]	0.91	296.6±8.4	14.7±2.5
TSAC1	dkb	~62.5	GM	**27.3±2.6**	85[600–950]	26.5±4.5	85[600–950]	1.99	295.8±2.5	32.1±2.9
TS-581	dlg	63.6	GM	**25.3±1.4**	70[620–780]	26.4±4.4	70[620–780]	3.50	291.4±3.9	18.8±1.5
TS-631	dlg	63.8	GM	**22.3±1.6**	78[600–850]	23.2±5.0	78[600–850]	0.14	295.0±2.3	22.9±1.5
TS-103	dlp	65.3	GM	**21.4±1.9**	81[700–1250]	20.4±7.5	81[700–1250]	2.80	294.2±1.8	19.0±1.9
TS-705	dml	64.0	GM	**33.6±1.2**	79[550–750]	37.5±6.2	79[550–750]	0.95	291.8±13.3	38.8±1.4
TS-492	dmn	65.7	GM	**27.7±1.0**	82[600–1015]	27.8±2.5	82[600–1015]	1.70	294.6±5.2	19.5±1.1
TS-491	dmn	66.1	GM	**25.2±0.8**	95[590–1000]	27.7±2.4	95[590–1000]	0.97	292.9±2.3	22.6±0.9
TS-629A	dnt	63.1	GM	**23.5±1.1**	83[550–850]	27.9±6.3	83[550–850]	0.39	291.3±7.7	23.9±1.0
TS-511	drm	64.3	GM	**28.7±0.8**	78[700–1250]	28.9±1.8	78[700–1250]	0.89	295.1±1.6	24.2±0.9
TS-257	dsn	64.4	GM	26.0±1.5	93[630–1150]	**19.1±3.7**	93[630–1150]	0.67	299.3±1.8	26.2±1.6
TS-387	dss	63.7	GM	18.5±1.5	94[600–1000]	**24.5±3.1**	100[550–1150]	1.20	292.4±1.4	17.0±1.5
TS-223	dsw	65.4	GM	28.2±2.4	77[650–925]	**16.8±15.3**	71[650–850]	0.72	300.2±6.2	-3.9±6.0
TS-345	dwp	64.5	GM	25.6±1.7	72[550–770]	**33.6±3.3**	82[550–875]	0.31	290.2±1.7	17.7±2.0
TS-22	mcl	56.5	GM	**16.1±10.4**	73[640–850]	65.9±14.7	100[550–1250]	8.28	291.5±4.7	-60.9±13.0
TS-169	mcl	56.4	GM	35.1±9.0	63[650–1000]	**23.3±15.8**	63[650–1000]	0.36	297.6±2.2	31.6±8.1
TS-188	mdl	53.0	GM	205.5±7.1	79[550–850]	**180.8±20.7**	79[550–850]	0.86	299.6±3.3	257.1±8.1
TS-178	mhd	54.8	GM	**36.8±8.9**	92[550–925]	44.0±18.0	92[550–925]	0.52	293.8±3.4	11.3±11.3
TS-150	mhr	53.4	GM	**67.0±4.1**	100[600–1250]	67.3±1.2	100[600–1250]	0.16	295.4±1.7	59.8±5.4
TS-383	mlb	53.1	GM	**47.2±5.8**	50[700–750]	3.8±44.2	50[700–750]	0.33	302.3±9.0	29.6±4.6
TS-554	mlb	52.6	GM	**48.4±3.6**	74[550–800]	43.0±16.8	74[550–800]	0.18	296.7±3.6	34.0±3.8
TS-474	mmi	53.3	GM	--	--	**18.1±3.9**	88[550–925]	0.98	303.9±2.5	31.0±2.1
TS-429	mmm	56.6	GM	**19.2±6.9**	50[650–790]	19.6±5.4	100[550–1075]	1.40	293.8±1.2	9.1±3.2
TS-235	mms	53.4	GM	**16.4±11.7**	83[580–1250]	34.6±29.5	83[580–1250]	0.96	294.2±1.9	-25.3±12.3
TS-444	mnf	54.2	GM	**47.7±9.5**	99[550–1075]	92±43	99[550–1075]	1.80	291.6±2.2	39.1±9.3
TS-217	mnh	57.1	GM	**20.9±5.5**	86[550–900]	16.2±17.2	86[550–900]	0.84	296.6±3.5	17.0±5.8
TS-505	mns	55.1	GM	**119.3±5.6**	76[600–900]	136.0±9.4	100[550–1150]	2.70	292.9±0.8	99.8±5.5

Table 2. $^{40}Ar/^{39}Ar$ ages for Three Sisters volcanic cluster.—Continued

Sample	Unit label	Whole-rock SiO_2	Material	$^{40}Ar/^{39}Ar$ weighted-mean plateau age		$^{40}Ar/^{39}Ar$ isotope-correlation (isochron) age				$^{40}Ar/^{39}Ar$ total-gas age (ka)
				Age (ka)	%^{39}Ar[steps, °C]	Age (ka)	%^{39}Ar[steps, °C]	MSWD	$^{40}Ar/^{36}Ar_i$	
NS-02-79	mns	53.9	GM	--	--	**83.1±24.5**	100[550–1150]	2.99	294.4±5.6	71.3±7.0
NS-02-160	mns	54.8	GM	**70.5±3.2**	80[550–800]	73.7±15.3	80[550–800]	0.81	294.1±12.8	63.3±3.6
NS-02-183	mns	~54	GM	**55.0±5.3**	60[600–750]	37.6±47.0	60[600–750]	0.23	299.7±12.6	47.4±6.1
TS-388	mns	53.8	GM	**46.2±5.6**	91[600–1250]	52.8±12.0	100[550–1250]	0.77	294.2±1.3	39.8±5.2
TS-670	mnt	55.3	GM	**20.3±4.6**	79[600–900]	-1.5±18.4	79[600–900]	0.47	299.4±4.7	4.0±4.4
TS-381	mrg	54.6	GM	--	--	**19.6±6.1**	83[650–1060]	1.17	289.4±0.6	-78.9±6.9
TS-114	msc	56.8	GM	17.6±2.4	100[550–1150]	**21.4±5.5**	89[550–975]	0.58	294.3±1.3	17.6±2.9
TS-191	msf	54.0	GM	**166.2±16.0**	94[600–1100]	162.6±43.0	94[600–1100]	0.13	295.8±3.7	158.2±16.7
TS-466	msp	54.2	GM	116.3±2.9	96[550–1000]	**129.1±5.8**	96[550–1000]	0.57	291.8±1.3	110.2±3.3
TS-662	mtb	52.1	GM	**531.7±7.3**	63[550–725]	539.5±17.3	63[550–725]	0.62	294.1±5.4	506.3±7.4
TS-112	mth′	52.8	GM	**148.9±4.8**	76[600–850]	157.7±9.6	100[600–1150]	1.44	294.3±1.6	147.1±6.0
TS-47	mtp	53.8	GM	**22.3±12.9**	100[550–1150]	18.1±32.5	100[550–1150]	0.84	295.7±1.6	25.2±13.2
TS-147	mtw	53.6	GM	**373.7±6.0**	82[550–850]	361.5±10.0	82[550–850]	1.30	299.6±6.3	384.7±6.8
NS-02-93	mwa	54.9	GM	**58.8±3.6**	63[550–700]	57.1±18.5	63[550–700]	0.96	295.9±10.4	69.2±6.0
TS-252	mwh	53.2	GM	**194.6±5.0**	69[600–750]	206.6±19.2	69[600–750]	0.63	293.2±6.0	174.5±7.9
TS-254	mws	54.6	GM	**174.5±2.9**	80[550–800]	182.0±12.3	80[550–800]	0.51	292.0±8.5	158.0±3.5
TS-51	rct	72.9	PL	**24.0±5.4**	55[900–1050]	29.7±14.5	55[900–1050]	4.05	295.3±4.1	30.5±5.3
TS-157	rct	72.8	PL	**30.4±7.7**	56[900–1075]	69.6±6.1	100[550–1300]	7.23	286.4±8.2	43.1±7.0
TS-339-1	rdh	74.0	GM	27.2±1.1	76[550–680]	**34.8±1.5**	76[550–680]	0.76	285.2±1.5	8.8±2.2
TS-569	rgl	72.2	GM	**31.9±0.7**	79[600–820]	33.7±2.6	79[600–820]	1.30	292.3±4.5	26.1±0.8
TS-70	rmc	72.4	PL	**47.4±8.2**	88[700–1150]	40.9±21.0	88[700–1150]	2.09	296.7±2.5	69.6±9.2
TS-141	rmc	72.6	GM	-39.7±5.1	76[690–1150]	**45.2±15.0**	91[580–975]	1.84	288.9±2.0	- 59.1±5.1
TS-102	roc	76.5	GM	**37.8±1.8**	59[650–800]	37.6±17.9	100[500–1200]	5.70	295.4±10.8	38.2±1.6
TS-201	rpg	68.4	GM	**32.8±1.5**	88[550–800]	30.6±2.6	100[550–1200]	0.99	297.4±1.8	34.4±1.7
TS-321	rsc	73.3	GM	**25.4±1.3**	91[580–1100]	23.7±3.6	91[580–1100]	0.28	297.1±3.7	23.9±1.3
TS-364	rse	73.8	GM	31.4±1.1	53[720–800]	**35.0±2.7**	97[600–1150]	2.70	286.1±2.0	5.5±1.1
TS-487	rse	73.9	GM	**33.6±0.5**	100[550–1100]	34.0±1.6	100[550–1100]	0.98	295.0±2.3	33.7±0.7
TS-18	rsf	74.0	GM	**35.8±2.0**	76[700–890]	46.5±6.2	97[600–1020]	1.76	282.6±5.3	33.2±2.0
TS-156	rsw	73.3	PL	**50.5±9.5**	77[850–1150]	55.3±20.7	77[850–1150]	2.21	293.7±11.3	101.8±9.5
TS-91	ruc	69.1	GM	**169.3±2.1**	87[600–850]	172.6±6.0	87[600–850]	1.20	295.1±2.8	167.7±2.2
TS-735	r58	74.0	GM	**40.4±1.4**	93[650–1150]	43.1±2.9	93[650–1150]	1.02	292.9±5.2	41.1±1.7

Table 3. K-Ar ages for Three Sisters volcanic cluster.

[Abbreviations: GM, groundmass concentrate; $^{40}Ar^*$, radiogenic argon; wt.av., weighted average of two K-Ar experiments. Whole-rock weight-percent SiO_2 values from table 1; weight percent K_2O values by flame photometry at U.S. Geological Survey laboratory in Lakewood, Colo., Dave Siems analyst. Interpreted eruption age is highlighted in **bold**]

Sample	Unit label	Whole-rock SiO_2	Material	K_2O	$^{40}Ar^*$ (moles/g)	Radiogenic Ar (%)	K-Ar age (ka)
TS-100	dbh	64.0	GM	1.731±0.005	6.04E-14	1.27	24.1±11.3
TS-19	dcl	65.4	GM	2.339±0.002	1.08E-13	3.01	31.9±8.5
					8.12E-14	1.52	23.9±7.3
						(wt.av.)	27.3±5.5
TS-5	dig	64.2	GM	1.770±0.000	5.25E-14	0.768	20.4±12.2
TS-94	rkb	73.6	GM	3.187±0.055	1.39E-13	5.825	**30.3±5.3**
TS-18	rsf	74.0	GM	3.115±0.003	1.42E-13	5.896	31.5±5.1
TS-91	ruc	69.1	GM	2.304±0.006	6.25E-13	13.8	188.3±6.7