Geochemical Database for Volcanic Rocks of the
Western Cascades, Washington, Oregon, and California

Data Series 155

U.S. Department of the Interior
U.S. Geological Survey
Geochemical Database for Volcanic Rocks of the Western Cascades, Washington, Oregon, and California

By Edward A. du Bray, David A. John, David R. Sherrod, Russell C. Evarts, Richard M. Conrey, and Jaroslav Lexa

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Introduction

The importance of the Cascade Range magmatic arc in understanding the geologic evolution of western North America is widely recognized, and these arc rocks have been extensively studied. Cenozoic volcanic rocks of the Cascade Range have been traditionally split into two physiographic provinces, the High Cascades and the Western Cascades (fig. 1) (Callaghan, 1933; Thayer, 1937; Peck and others, 1964). Active volcanoes of the modern Cascade magmatic arc form essentially undissected constructional landforms along the crest of the Cascade Range and form the High Cascades. Most of the modern arc rocks, including the prominent north-south chain of stratovolcanoes that extends from Mt. Garibaldi in the north to Lassen Peak in the south, are less than 4 million years old. The High Cascades have been the principal focus of research concerning the petrology and volcano hazards associated with ongoing magmatism in this region. However, these rocks rest on an older volcanic arc in the western part of the Cascade Range. These older rocks, which underlie a broad deeply dissected terrane, form the Western Cascades. Volcanic rocks of the Western Cascades represent the onset of subduction and arc magmatism in the Pacific Northwest, where volcanism has been ongoing for at least 35 m.y. between central Washington and northern California (fig. 1). Although many local studies have been conducted, including a large number of Masters and Doctoral theses completed at the University of Oregon, Oregon State University, Western Washington University, and Portland State University, volcanic rocks of the Western Cascades have not been as thoroughly studied as the products of modern arc volcanism nor has any synthesis of existing data been undertaken since the early interpretive compilations of McBirney (1978), White and McBirney (1978), and Priest (1990). The geochemical database presented here represents the first phase of an effort to synthesize and interpret the geochemistry of Western Cascades volcanic arc rocks.

Previous studies of Western Cascades rocks have been hindered by several factors. First, most of the Western Cascades arc is covered by dense stands of forest and under-story vegetation. Soil and colluvium are well developed and glacial deposits obscure bedrock in some places. Consequently, geologic bedrock exposures are obscured in all but the steepest terrain. Second, zeolite facies burial metamorphism and (or) local propylitic alteration have modified the primary geochemical, mineralogic, and textural characteristics of Western Cascades arc rocks in many places. Finally, the continental magmatic arc environment produced a series of coalescing and mutually overlapping volcanic centers; their intimately intermingled deposits have neither significant lateral persistence nor consistency. The conceptual framework of a continental arc presented by Smith (1993, fig. 3) illustrates the lack of stratigraphic coherency characteristic of deposits of this type. In sum, poor exposure, alteration, and stratigraphic complexity combine to render these rocks difficult to study and interpret. Nevertheless, through studies of small parts of the Western Cascades arc, knowledge and understanding of this arc have been incrementally enhanced. Using the large and synoptic body of information in the present database, it is possible to characterize the primary geochemical attributes of the Western Cascades rocks and begin interpretation of their petrologic, tectonic, and metallogenic significance.

Acknowledgments

We would like to thank several individuals who helped make this effort possible. The staff of the USGS Denver library were critical to the success of this compilation. In particular, the library staff used the interlibrary loan process to obtain many of the geologic reports on which this compilation is based. We thank Joan Luce for her tireless typing; data from many sources were available only in analog form and had to be painstakingly keyboarded. Many geologic researchers gave tirelessly of their time to track down missing bits of information that allow this database to be as complete as it is. These individuals include J.G. Smith, J.M. Curless, A.R. McBirney, C.W. Field, R.A. Duncan, C.M. White, C.G. Barnes, S.R. Munts, B.A. Carkin, S.M. Smith, and E.A. Bestland. Finally, we would like to gratefully acknowledge technical reviews by T.L. Klein and S.D. Ludington that helped
Figure 1 (above and following page). Index map (compiled from Wagner and Saucedo, 1987; Smith, 1993; and Sherrod and Smith, 2000) showing approximate distributions of Western Cascades (dark gray) and High Cascades (light gray) arc rocks. Intrusions colored pink. 

A, Locations of principal Holocene to Pliocene stratovolcanoes of Cascades Mountains shown for reference. 

B, Sample locations for samples included in database, indicated by plus symbols; names of High Cascades volcanoes omitted.
Figure 1. Index map showing approximate distributions of Western Cascades and High Cascades arc rocks—Continued.
improve this report. Work conducted between 1971 and 1972 by Jaroslav Lexa and reported here was carried out at the Center for Volcanology of the University of Oregon under NASA grants in cooperation with Andrew Duncan.

### Western Cascades Arc—Geologic Constituents of the Database

There is no consensus definition of what constitutes the Western Cascades magmatic arc. The identity of rocks unequivocally part of this arc, as opposed to those that clearly pre- and post-date the arc, has not been well established. For the purposes of this compilation we used the following criteria:

1. In Oregon and northern California, the Western Cascades arc is composed only of Tertiary volcanic rocks exposed west of the present Cascade Range crest. Middle Tertiary volcanic rocks east of the Cascade crest are considered to represent magmatism related to the Challis volcanic field, back arc magmatism, or magmatism associated with the middle Tertiary geologic evolution of the Basin and Range province. Christiansen and Yeats (1992, fig. 20) suggested that the Western Cascades arc may have reached well south and east of Mt. Lassen, extending into northwest Nevada and nearly as far south as Lake Tahoe on the California-Nevada border. Because the geologic, and particularly tectonic, settings of this presumed Western Cascades arc southeast extension are quite different from those characteristic of the remainder of the Western Cascades arc, this southeast arc extension was not included in our data compilation. In southern Washington, rocks considered constituents of the Western Cascades arc do extend beneath stratovolcanoes of the modern arc and east of the Cascade crest; data for these rocks are included in the database. In Oregon and Washington, volcanic rocks west of the Puget-Willamette Lowland are not considered to be part of the Western Cascades arc; these rocks, widely distributed throughout the Oregon Coast Range, are not considered to be directly related to Western Cascades arc magmatism.

2. Volcanism associated with the Western Cascades arc may have begun as early as 45 Ma and may extend to ages as young as 5 Ma. This broad age range may allow inappropriate inclusion of some pre- and post-Western Cascades samples in the database. At the old end of this age range, earth scientists have struggled to identify (1) volcanic rocks (particularly in central Washington) that are demonstrably associated with the onset of arc magmatism and (2) which rocks may represent magmatism in some other tectonic regime. In many parts of the Cascade Range, no clear discontinuity between magmatism associated with the Western Cascades and High Cascades arcs has been identified. Callaghan (1933) suggested that a pronounced unconformity separates High Cascades from Western Cascades volcanic rocks. Abundant field work has shown since that such an unconformity is not a ubiquitous nor synchronous feature along the length of the Cascade Range. The onset of High Cascades volcanism has been variably denoted as between 10 and 2 Ma. Using local geologic relations and other criteria described here, we have included data for all Cascade Range volcanic rocks presumed older than approximately 5 Ma in the database.

3. Middle Miocene volcanic rocks of the voluminous Columbia River basalt are not related to Western Cascades arc magmatism and are not included in the database.

4. Undissected volcanic rocks that retain primary constructional morphology are considered to be part of the High Cascades.

5. Data for samples of lava flows, pyroclastic deposits, and intrusions were included in the database, whereas data for sedimentary rocks with a volcanic provenance were excluded.

Background information for some samples is incomplete and may be misleading or incorrect, and (or) invalid interpretations may have been made, any of which could cause inappropriate inclusion of data in the database. Every effort has been made to preclude inclusion of inappropriate samples; their number is probably limited and shouldn’t have a significant effect on data interpretations.

### Data Compilation Methods

Several of us (Sherrod, Conrey, and Evarts) had already begun compilation of whole rock geochemical data for volcanic rocks from various parts of the Cascade Range. These compilations served as a starting point for the effort described here. Copies of original data source materials (subsequently referred to as sources), including published reports and Masters and Doctoral theses, were used to add data to the database. Reference lists contained in sources of data were examined and used to identify additional data sources. In this way, data for about 4,100 samples from 113 sources were identified and incorporated in the database. We believe that this process has probably resulted in identification and incorporation of most of the data that have been produced for samples of Western Cascades rocks. In order for a sample to be included in the database, at least a sample number and major oxide analysis were required. Samples for which only trace element data were available were not included in the database. Additional trace element (for instance, the rare earths) and (or) isotopic
data are available for some samples, but because the number of these samples is very small, these data were not included in the database. No effort was made in this compilation to identify altered samples; these evaluations will be made in the subsequent, interpretive phase of this work, and the contents of a derivative database will accordingly reflect this winnowing process. However, users of this database should be wary of samples with SiO₂ abundances greater than 77 percent, initial analytic totals less than 95 percent or greater than 103 percent, Al₂O₃ abundances less than 10 percent or greater than 20 percent, total volatile contents greater than 5 percent, or Na₂O/K₂O ratios less than 1 or greater than about 12; samples with any of these characteristics are apt to be altered and do not preserve primary igneous rock compositions. Data for samples explicitly identified as hydrothermally altered were not included in the database. Data presented in source materials were included in the database, without modification (with the exception of normalization of major oxide data, as described below), and all input subsequently verified.

Data were compiled using Microsoft Excel and can be accessed using software compatible with .xls files. The database release (file, WCascDB.xls) includes several worksheets that are accessed using tabs arrayed along the base of the spreadsheet screen display. The tab labeled “West Cascades database” is the primary data compilation. The tab labeled “db w censored data deleted” is a copy of the primary data compilation in which censored data (data coded as less than some specified value) were deleted prior to calculation of summary statistics and creation of histograms. The database release also includes a tab-delimited, text file version of the database (file, WCascDB.txt).

Data Fields

Data fields presented and described below represent those considered most critical to addressing questions concerning the tectonic, petrologic, and metallogenic evolution of the Western Cascades arc. Data for each of these fields constitute a column, or set of related columns, in the database. Data in these columns can be sorted, queried, and interpreted to address questions concerning the history, development, and implications of the Western Cascades arc. Sample number records are aggregated in blocks of data that share a primary geochemical data source.

Blank cells in the database indicate that no data are available for the corresponding column. Some sources report values of zero for some database fields. These values indicate that an abundance determination was attempted but that the constituent was not detected in the sample. Similarly, some sources present qualified data. In particular, records for some samples include less than (<) symbols. These data indicate that the constituent was detected but that its concentration was unquantifiable beyond the fact that its concentration is less than the indicated value. Actual analytical precision (number of significant figures) associated with each database entry is portrayed by each displayed onscreen value. Data in some cells appear to be more precise than displayed values, but this is a misleading artifact of computational processes (for instance, normalization to 100 percent volatile free), which may have been used to create data cell contents. Precision varies within individual columns in accordance with that associated with analytical determinations produced by specific analytical protocols and reported in individual sources. In most cases, the number of significant figures defined in data sources was retained. However, in some cases, the level of precision implied is implausible given either the analytical protocol or the corresponding analytical state of the art; accordingly, some numeric data contained in the database have been rounded to indicate a plausible level of analytical precision.

Identifiers for analyzed samples materials were compiled from sources and presented, without modification.

In most cases, a lithologic description of analyzed samples was compiled from information contained in sources. Unless otherwise noted, samples are considered to represent lava of the designated composition; an entry of andesite indicates a sample of andesite lava. In some cases, source materials do not specify whether the sample represents lava, a pyroclastic deposit, or some form of intrusion; in these situations, lava is presumed. Many sources classify the composition of intrusions (dikes, sills, stocks, and so forth) using volcanic rock nomenclature. These designations suggest that these shallowly solidified, and therefore, fine-grained rocks were not evaluated by modal analysis and that subsequent name assignment using the nomenclature of Streckeisen (1973) for phaneritic igneous rocks was not possible. The form of intrusion (dike, sill, stock, and so forth) is given where known. All volcanic rock compositional names derived from the source were evaluated and updated as necessary, relative to the volcanic rock total alkalis versus silica nomenclature grid (LeBas and others, 1986). In cases for which the source provides no indication of rock type, an appropriate compositional name was established using composition data and the volcanic rock nomenclature grid; these samples are presumed to represent lava.

An effort was made to obtain location data for all samples. Most sources contain some form of location information. Missing sample location data were requested from authors, most of whom were able to provide the missing information. Accordingly, location data are available for all but a very few

long and lat

An effort was made to obtain location data for all samples. Most sources contain some form of location information. Missing sample location data were requested from authors, most of whom were able to provide the missing information. Accordingly, location data are available for all but a very few
samples. Location data are of variable quality as a consequence of the manner in which they were initially acquired and subsequently reported. However, location data contained in the database are probably accurate to within at least several hundred meters. Most location data are likely considerably more accurate and in all cases sufficient for regional-scale interpretation.

Some sources provide only very general information concerning sample locations. Fischer (1970) described sample collection sites relative to prominent topographic features. Murphy (1989) associated each sample with a geologic map unit. Power (1984) indicated only that four analyzed samples of the Spirit Lake pluton are from the Margaret porphyry copper prospect. In order to provide information concerning the geologic units represented by these samples and give the samples some geographic context, sample locations were approximated from available information. Fischer’s (1970) brief location descriptions were used to estimate sample locations. Locations for Murphy’s (1989) samples were assigned values near the center of the geologic units represented by each sample. Locations for Power’s (1984) four samples were assigned to a plausible site where a dirt road crosses the altered area coincident with the Margaret porphyry copper prospect. Locations for all of these samples are in italics in the database to denote their approximate nature.

Latitude and longitude data are reported as decimal degrees (relative to the 1927 North American Datum) to four decimal places, which corresponds to a location accuracy of about 10 m on the ground. Many of the sources report sample location in terms of township, range, and section values, usually to the closest 1/16 of a section. Township-range-section data were digitized to obtain decimal degree location, within the appropriate 1/16 section quadrilaterals; digitized points were usually selected to coincide with a road, trail, stream bottom, quarry, or natural cliff, any of which might represent a likely sampling location. Some sources do not include numerical sample location data but do contain sample maps. Location data for these samples were obtained by digitizing sample sites. A very few sources merely describe sample locations. For Western Cascades samples, longitude is reported as a negative value (western hemisphere) and latitude as a positive value (northern hemisphere).

\[
\begin{align*}
\text{SiO}_2, \text{TiO}_2, \text{Al}_2\text{O}_3, \text{FeO}^*, \text{MnO}, \text{MgO}, \text{CaO}, \\
\text{Na}_2\text{O}, \text{K}_2\text{O}, \text{and } \text{P}_2\text{O}_5
\end{align*}
\]

Sources report whole rock, major oxide data in a variety of formats. In addition, these data were produced by a wide array of analytical procedures, each with its associated analytical precision and accuracy. Compositions for many of the samples included in the database are presented in their sources already normalized to 100 percent volatile free. Some information loss occurs when data are reported solely in this fashion. Compiling analytical methods and associated estimates of precision and accuracy associated with the reported data was beyond the scope of this effort, but in most cases, each of these is documented in the source. The database includes columns for the abundances of SiO$_2$, TiO$_2$, Al$_2$O$_3$, FeO, MnO, MgO, CaO, Na$_2$O, K$_2$O, and P$_2$O$_5$. However, because diverse analytical protocols were used to analyze samples, not all sources contain data for each of these constituents.

Several different schemes are possible for reporting iron contents. In addition, reported abundances of ferrous versus ferric iron in these rocks are unlikely to represent primary magmatic values, because of oxidation during devitrification, zeolite facies metamorphism, and (or) postmagmatic hydrothermal alteration. Consequently, total iron abundances were recalculated as ferrous iron oxide and denoted as FeO*. Interaction with postmagmatic fluids caused compositions of many Western Cascades volcanic rocks to change in other ways as well. In particular, many of these rocks were hydrated (as indicated by secondary clay minerals, sericite, and (or) chlorite), and others were affected by fluids that precipitated calcite. Both processes caused volatile contents of the affected samples to increase, and correspondingly caused relative abundances of all other constituents to decrease. Therefore, to facilitate meaningful oxide abundance comparisons among samples, all analyses were normalized to 100 percent on a volatile-free basis. The resulting data are reported in columns identified by SiO$_2$, TiO$_2$, Al$_2$O$_3$, FeO*, MnO, MgO, CaO, Na$_2$O, K$_2$O, and P$_2$O$_5$. All data are reported as weight percent.

**total**

One measure of major oxide analytical accuracy is how nearly the sum of the determined constituents approaches 100 percent. Consequently, the database includes a column that reports initial analytical totals as reported by the source. Some sources do not include totals; totals for these samples were computed and added to the database. Initial analytical totals reported in the sources were spot checked for accuracy; discrepancies were noted and corrected in a number of cases. Many sources present abundances for the oxides listed above but include no abundance data for volatile constituents. Initial analytical totals for these samples tend to be several to 5 or 6 percent less than 100 percent. Unfortunately, it’s impossible to determine whether these low initial totals result from inaccurate analyses and (or) unreported volatile constituent abundances.

**vol_sum**

The volatile content of volcanic rocks provides some insight concerning whether abundances of other constituents accurately represent primary magmatic values. Samples with elevated volatile contents, for example greater than 3 weight percent, are apt to have experienced some fluid-mediated, postmagmatic chemical modification.

The use of diverse sample analysis protocols resulted in widely disparate reporting of data for the volatile constituents.
Data of Western Cascades volcanic rocks. Volatile constituents whose abundances are commonly determined include LOI (loss on ignition), H₂O⁺ (bound), H₂O⁻ (nonessential, moisture), CO₂, F, Cl, and SO₃. Of these, most sources contain no halogen abundance data, and data for SO₃ are presented for only a very few samples. Similarly, data for H₂O⁺, H₂O⁻, and CO₂ are so rarely and nonsystematically reported that separately compiling these data was not warranted. The best possible measure of the volatile contents of the analyzed samples is therefore total volatile content. For the purposes of the compilation, LOI data contained in source data compilations were defined as total volatile content. Alternatively, if the source includes data for H₂O⁺, H₂O⁻, and CO₂ (usually determined as a group), these data were summed to yield total volatile content.

Ba, La, Ce, Rb, Sr, Y, Zr, Nb, Co, Cr, Ni, Sc, V, Ag, Cu, Mo, Pb, Zn, and Au

The sources present data for inconsistent sets of trace elements. Of these, data for Ba, La, Ce, Rb, Sr, Y, Zr, Nb, Co, Cr, Ni, Sc, V, Cu, Pb, Zn, Mo, Ag, and Au were compiled; all data are in parts per million. These constituents are among those for which sources most often contain data and also are considered sufficient to address many petrologic, tectonic, and metallogenic questions.

chem_src

Data for each sample included in the database were compiled from primary data sources, in most cases a single source. For a few samples, data were culled from two or more sources; for example, major oxide data may have been compiled from one source and trace element data from another. Sources of geochemical information include publications of the U.S. Geological Survey, Masters theses, Doctoral dissertations, articles published in journals, and publications of the Oregon Department of Geology and Mineral Industries and the Washington Department of Natural Resources, Division of Geology and Earth Resources. Approximately one fourth of the geochemical information contained in the database is previously unpublished and was obtained by Russell Evarts in support of geologic mapping studies. A smaller amount of unpublished information was informally transmitted to us by earth scientists working in the Cascade Mountains.

Entries in the “chem_src” column of the database are keyed numerically to sources identified below:

1. Swanson (1994)
2. Swanson (1989)
4. Swanson (1992)
5. Swanson (1996a)
6. Swanson and others (1997)
7. Swanson (1996b)
8. Swanson (1993)
15. White (1980a)
17. Priest and Vogt (1982)
20. Barnes (1978)
22. Buddington and Callaghan (1936)
23. Peck and others (1964)
24. Callaghan (1933)
27. Dyhrman (1975)
29. Olson (1978)
30. Munts (1978)
32. Hladky (1998a)
33. Rollins (1975)
34. Schaubs (1978)
35. Sherrod (1986)
36. Thayer (1937)
38. Verplanck (1985)
40. Millhollen (1991)
41. Wise (1969)
42. Priest and Vogt (1983)
43. Wells and Waters (1935)
44. Storch (1978)
46. Wise (1970)
47. Hladky (1992)
49. Shepard (1979)
50. Millhollen (1989)
52. Schriener (1978)
53. Hladky (1998b)
55. Steinborn (1972)
56. White (1980b)
57. Wiley (1993)
58. Black, G.L., Oregon Department of Geology and Mineral Industries, unpublished data, 2005
59. Priest, G.R., Oregon Department of Geology and Mineral Industries, unpublished data, 2005
60. Murphy and Marsh (1993)
61. Madin, I.P., Oregon Department of Geology and Mineral Industries, unpublished data, 2005
63. Flaherty (1981)
64. Ritchie (1987)
65. Naslund (1977)
The ages of volcanic rocks that constitute the Cascade Range have been of keen interest and a large number of age determinations have been made. Principal contributions to the geochronologic knowledge of Western Cascades volcanic rocks in particular include those of Sutter (1978), Lux (1981), Priest and Vogt (1983), Tabor and others (1984), Verplanck (1985), Phillips and others (1986), and Evarts and others (1987). The compilation of Fiebelkorn and others (1983) is equally useful. Using these and other appropriate sources, all available radiometric age data were compiled for samples included in the database. The database column titled “rad_age” contains the age(s), in millions of years, determined for the associated sample. Multiple geochronologic age determinations have been obtained for a few samples included in the database. These replicate ages are listed in the “rad_age” column, in otherwise blank rows, below the row that contains geochemical data for the associated sample. If the source indicates that one of these ages is a preferred age, it is presented in italics.

The database column titled “uncert” contains data, in millions of years, for the analytical uncertainties associated with each of the age determinations reported in the “rad_age” column.

Radiometric age data for samples included in the database, although scarce, were compiled from primary data sources. In most cases, geochemical and geochronologic data were derived from the same source; the age source for each of these samples is numerically keyed to previously identified geochemistry sources. For the relatively small number of samples for which geochemical and geochronologic data have different sources, age sources data are keyed to alpha-coded citations listed below:

| A. | Keith and others (1985) |
| B. | Sutter (1978) |
| C. | Evans and Brown (1981) |
| D. | Mertzman, S.A., Franklin and Marshall College, unpublished data, 2005 |
| E. | Power and others (1981) |
| F. | Evarts and others (1987) |

Radiometric ages have not been determined for most samples included in the database. In order to enable study of time-space-composition relations among volcanic rocks of the West Cascades, ages of most samples included in the database were estimated. Entries in the geol_age column are in millions of years. In some cases, the radiometric age of samples that are not part of the database, but representative of the same unit as samples that are included in the database, was used to constrain the geologic age. Similarly, many of the sources include diagrams that correlate rock units with absolute age scales. By knowing the geologic map unit represented by individual samples and by interpolating geologic map unit age ranges from correlation of map units diagrams, approximate ages were estimated for many samples. In addition, the geologic ages of another large group of samples were
established by comparing individual sample localities to geology shown on the map of volcanic rocks of the Cascade Mountains in Oregon (Sherrod and Smith, 2000). This and a companion map for the Washington Cascade Range (Smith, 1993) denote the spatial and temporal distribution of Tertiary-age volcanic rocks. These rocks are assigned to one of five age intervals: 2–7 Ma, 7–17 Ma, 17–25 Ma, 25–35 Ma, and 35–45 Ma (Smith, 1993; Sherrod and Smith, 2000). The utility and rationale for definition of these particular intervals is described by Sherrod and Smith (2000).

**strat_name**

Some sources associate either formal or informal stratigraphic nomenclature with samples for which they include geochemical data. These names were compiled in the database field titled “strat_name” in order to facilitate sorting database contents by stratigraphic unit. Entries in this field are shortened from full stratigraphic designation (for instance, Sardine Formation) to entries that denote just the geographic feature included in the full stratigraphic designation (for instance, Sardine). Coding samples by assigned stratigraphic name allows grouping of samples from a particular stratigraphic unit. Grouped in this way, geochemical characteristics of units can be identified and interpreted and comparisons to other similar stratigraphic units can be made. Among the regionally most important stratigraphic designations of this sort are Sardine, Little Butte, Colestin, Goble, Northcraft, Scorpion Mountain, Breitenbush, Roxy, Heppsie, Wasson, Ohanapeosh, Fife’s Peak, Stevens Ridge, and Rhododendron. Unfortunately, many data sources do not assign specific formal or informal stratigraphic names; these source assigns sample names that are entirely lithologic, such as basalt, basaltic andesite, or andesite.

Several sources use the same geographic name for more than one rock unit. For instance, Priest and others (1988) used the name Blue River for an andesite unit and for a basalt unit. To distinguish these name assignments in the database, (and) is appended to the Blue River designation for andesite samples, whereas (bas) is appended for the basalt samples. Priest and others (1988) also assigned the name Frissell Point to an andesite and for a basalt; (and) is appended to the Frissell Point designation for andesite samples, and (bas) is appended for the basalt samples. Similarly, Cook (2002) used the name Moose Mountain for an andesite and a rhyolite. To distinguish these designations in the database, (and) is appended to the Moose Mountain designation for andesite samples, whereas (rhy) is appended for the rhyolite samples. Finally, Curless (1991) distinguished strata that compose upper and lower parts of the Elk Lake Formation; entries in the strat_name column for these samples are appended by (upper) and (lower) respectively.

Geologists have identified small- to intermediate-size intrusions that form an approximately north-trending array along the Western Cascades (fig. 1). These intrusions, for example the Spirit Lake pluton and the Detroit Dam, Nimrod, and Champion stocks, are especially significant because of their spatial and genetic association with mineral deposits in the Western Cascades. For each sample of an intrusion, the entry in the strat_name column identifies the name of the particular stock represented by that sample. These designations allow analytical data for individual stocks to be sorted and grouped, thereby enabling interpretation of their geochemistry.

**Histograms**

A series of histograms (fig. 2) is included in order to provide a basic graphical depiction of the compiled data. These histograms portray frequency distributions for the abundances of each geochemical constituent for which data were compiled. In order to prepare each histogram, a table of data abundance classes (bins) versus frequency within each class was computed (table 1). A set of descriptive statistical abundance parameters, including mean and standard deviation, median, minimum, maximum, and count (number of samples for which abundance data for the particular constituent are available), were computed for each database geochemical constituent and are included on the histograms. For the purpose of constructing the histograms and calculating statistics, all censored (less than) values were deleted. The worksheet tab labeled “db w censored data deleted” is a copy of the primary database with all censored data deleted.

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Geochemical Database for Volcanic Rocks of the Western Cascades, Washington, Oregon, and California


Wiley, T.J., 1993, Geology and mineral resources map of the Cleveland Ridge quadrangle, Jackson County, Oregon: Oregon Department of Geology and Mineral Industries Geologic Map Series GMS-73, scale 1:24,000.


Figure 2 (above and following pages). Frequency distribution histograms showing compositions of Western Cascades igneous rock samples. Height of each histogram bar indicates number of samples whose abundances of indicated component are as much as numeric label beneath bar but greater than value associated with next lower abundance bar (for instance, if two adjacent bars are labeled 90 and 100 and if associated data are reported as whole numbers, the height bar labeled 100 depicts the number of samples with abundances of 91 to 100). Also presented are basic descriptive statistics, including mean and standard deviation, median, minimum, maximum, and count, for each distribution. A, SiO$_2$; B, TiO$_2$; C, Al$_2$O$_3$; D, FeO$^*$; E, MnO; F, MgO; G, CaO; H, Na$_2$O; I, K$_2$O; J, P$_2$O$_5$; K, initial analytical total; L, total volatile content; M, Ba; N, La; O, Ce; P, Rb; Q, Sr; R, Y; S, Zr; T, Nb; U, Co; V, Cr; W, Ni; X, Sc; Y, V; Z, Ag; AA, Cu; BB, Mo; CC, Pb; DD, Zn; EE, Au.

Mean 58.60 ± 6.92
Median 56.99
Minimum 45.42
Maximum 83.73
Count 4135
Figure 2. Frequency distribution histograms showing compositions of Western Cascades igneous rock samples—Continued.
Figure 2. Frequency distribution histograms showing compositions of Western Cascades igneous rock samples—Continued.

Mean 16.80 ± 1.59
Median 16.83
Minimum 3.23
Maximum 25.04
Count 4135
Figure 2. Frequency distribution histograms showing compositions of Western Cascades igneous rock samples—Continued.
Figure 2. Frequency distribution histograms showing compositions of Western Cascades igneous rock samples—Continued.

Mean 0.14 ± 0.14
Median 0.14
Minimum 0
Maximum 6.15
Count 3980
Figure 2. Frequency distribution histograms showing compositions of Western Cascades igneous rock samples—Continued.

Mean 3.68 ± 2.11
Median 3.57
Minimum 0
Maximum 16.68
Count 4135
Figure 2. Frequency distribution histograms showing compositions of Western Cascades igneous rock samples—Continued.
Figure 2. Frequency distribution histograms showing compositions of Western Cascades igneous rock samples—Continued.
Figure 2. Frequency distribution histograms showing compositions of Western Cascades igneous rock samples—Continued.

Mean 1.30 ± 0.95
Median 1.03
Minimum 0
Maximum 9.58
Count 4135
Figure 2. Frequency distribution histograms showing compositions of Western Cascades igneous rock samples—Continued.
Figure 2. Frequency distribution histograms showing compositions of Western Cascades igneous rock samples—Continued.

Mean 99.73 ± 0.85
Median 99.87
Minimum 90.95
Maximum 103.75
Count 4135
Figure 2. Frequency distribution histograms showing compositions of Western Cascades igneous rock samples—Continued.
Figure 2. Frequency distribution histograms showing compositions of Western Cascades igneous rock samples—Continued.
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Mean 44 ± 21
Median 42
Minimum 0
Maximum 245
Count 1190
Figure 2. Frequency distribution histograms showing compositions of Western Cascades igneous rock samples—Continued.
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Figure 2. Frequency distribution histograms showing compositions of Western Cascades igneous rock samples—Continued.

- Mean: 181 ± 108
- Median: 190
- Minimum: 0
- Maximum: 510
- Count: 848
Figure 2. Frequency distribution histograms showing compositions of Western Cascades igneous rock samples—Continued.
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Figure 2. Frequency distribution histograms showing compositions of Western Cascades igneous rock samples—Continued.

Mean 0.03 ± 0.08
Median 0.005
Minimum 0.001
Maximum 0.343
Count 17
Table 1. Number of observations (Freq) within each composition range (Bin) for Western Cascades database.

[Each bin denotes an abundance less than or equal to the indicated value but greater than that specified by the bin with the next lowest abundance. Bins for SiO$_2$, TiO$_2$, Al$_2$O$_3$, FeO*, MnO, MgO, CaO, Na$_2$O, K$_2$O, P$_2$O$_5$, initial analytical total (total I), and total volatile content (vol_sum) are in weight percent; all others in parts per million]

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Table 1. Number of observations (Freq) within each composition range (Bin) for Western Cascades database—Continued.

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Table 1. Number of observations (Freq) within each composition range (Bin) for Western Cascades database—Continued.

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