MAPS SHOWING DISTRIBUTION, COMPOSITION, AND AGE OF EARLY AND MIDDLE CENOZOIC VOLCANIC CENTERS IN OREGON AND WASHINGTON

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DISCUSSION

This map is the fourth of a series showing the distribution, composition, and age of early and middle Cenozoic volcanic centers in the western conterminous United States. The maps are designed primarily as a data base of igneous systems, a major geologic environment related to and host to mineral deposits. The data shown provide the basic information necessary for derivative studies such as the identification and assessment of igneous-related mineral deposits and (or) mineralized systems. In addition, maps in this series show the temporal and spatial relationships of early and middle Cenozoic igneous rocks to their geochemical and age associations at a single common scale within the many different igneous centers in the western states. This map series can also be used as a base for studies of volcanology, volcanotectonics, and the general geology of volcanic and related rocks.

Regional compilations by others (for example, Sherrod and Smith, 1989; Smith, 1993; Walker and MacLeod, 1991; Walsh and others, 1987) are the principal source references, but the original sources used by them also were consulted whenever and wherever possible in the construction of these maps. However, in areas of meager data, the composition and age of the igneous rocks were arbitrarily interpreted. This procedure was necessary in order to resolve internal problems and to maintain a standard treatment for meaningful comparison of data throughout the map series.

In this map series, the early and middle Cenozoic time frame extends from about 58 Ma to 16 Ma. The 16 Ma age is the maximum age of rocks included in a compilation of late Cenozoic volcanic centers for a published map series designed as a guide for the evaluation of igneous-related geothermal resources (for the comparable Oregon and Washington region, see Luedke and Smith, 1982). Within this early and middle Cenozoic time frame, the ages of the volcanic rocks are arbitrarily divided into three time intervals: 58 to 37 Ma, 37 to 24 Ma, and 24 to 16 Ma. The ages of 58, 37, and 24 Ma, respectively, represent the approximate Paleocene-Eocene, Eocene-Oligocene, and Oligocene-Miocene boundaries (Berggren and others, 1985).

Igneous rocks of the early and middle Cenozoic are closely related to tectonism and magmatism occurring within this time span. Northeastern Washington is dominated probably as much by early Cenozoic rock units of subvolcanic or intrusive origin as by units of volcanic origin, and is a part of the Challis magmatic belt that represents continental-margin arc activity (Christiansen and Yeats, 1992, p. 295–296). Central to east-central Oregon also includes rock units of early Cenozoic age that are dominantly volcanic in origin, and represent earlier continental-margin arc and later volcanic arc activities (Christiansen and Yeats, 1992, p. 295, 300); this region also has been referred to as a back-arc downwind catchment basin (James G. Smith, 1993, written commun.).

Much of western Oregon and Washington is underlain dominantly by volcanic rocks and associated intrusive bodies with geologic ages inclusive and representative of the entire early and middle Cenozoic time span. From the northern Cascade Mountains in Washington, with mostly intrusive masses, southward through the western Cascade Mountains in southern Washington and western Oregon, the areal extent of the volcanic rocks appears to progressively increase. The ages of the igneous rocks in western Oregon and Washington appear to become gradually older from east to west, that is, from early Miocene and Oligocene to Eocene. Also, the compositions of the rocks progressively become more mafic from east to west, particularly in Oregon; these rocks represent a region of continental-arc volcanism that merges westward with a somewhat older mass of submarine mafic volcanics accreted to the continent and with slightly younger mostly mafic volcanics and associated intrusions in a forearc basin environment.

Most volcanic rock units shown on the map generally fit well within the selected time frames. Locally, a few rock units that are within about a million years of a boundary were included with the dominant younger or older unit of the region in order to maintain geologic, petrologic, and tectonic continuity. Parts of southwestern Washington particularly necessitated interpretation of unit assignments. In that area, the geology of Smith (1993) and Walsh and others (1987) was modified, with the assistance of Russell C. Evarts (U.S. Geological Survey, 1994, written and oral commun.), but the responsibility for the final interpretation shown is mine. On some parts of sheet 2, a specific rock unit or volcanic field may have an age listed that appears inconsistent with the majority of ages shown or with the time interval in which the age is included. For completeness, all known ages for a specific unit within the 58 to 16 Ma time span are shown. A few radiometric ages that are older or younger than the cutoff dates for this map series have been included; the older ages reported are found in northeastern Washington and the younger ages are in southeastern Oregon. In the Columbia Plateau region of both Oregon and Washington, a few 17 to 16 Ma ages are not reported, but those ages are for rocks that are mainly related to and are an integral part of the extensive volcanic field shown on the late Cenozoic maps (Luedke and Smith, 1982, 1984).

Recent comprehensive reviews in the literature pertaining to Laramide time (Late Cretaceous to early Eocene) by Miller and others (1992) and Armstrong and Ward (1993), and to post-Laramide time by Christiansen and Yeats (1992), all particularly important to this series of maps, discuss magmatic events during the early to middle Tertiary geologic evolution of western North America. They show Laramide magmatism to be prevalent in both northern and northeastern Washington; this activity continued through the middle Eocene. The coastal region of Oregon and Washington at the same time was one of mostly accreted seamount-oceanic basalt terranes undergoing pronounced tectonism. In much of the Rocky Mountains region to the east, Late Cretaceous or Paleocene magmatic and tectonic events related to the Laramide orogeny also continued into the Eocene (Mutschler and others, 1987), and there served as precursors of similar events to follow later in the Cenozoic. Except for limited late Eccene to Oligocene magmatism in the Blue Mountains of eastcentral Oregon, the John Day region of central Oregon, and a few very local areas in the western coastal region, most magmatic activity within the time frame and geographic extent of this map occurred principally in the western Cascade Mountains. In general, volcanic activity in much of the western United States Cordillera resumed in the very latest Eocene to Oligocene and continued until the onset of mid-Miocene (about 16 Ma) bimodal basalt-rhyolite volcanism and associated basin-range extensional tectonism, typically characteristic of the Basin and Range province but reflected in some bordering regions (Lipman and others, 1972; Christiansen and Yeats, 1992).

The area of igneous rocks in the Colville or Okanogan region of northeastern Washington bears some relationship to known Laramide magmatic or tectonic belts within the United States Cordillera and contains geologic ages for slightly older rocks. Within the extensive metamorphic core complex-gneiss dome region in northeastern Washington (Holder and Holder, 1988; Carlson and others, 1991), a group of Paleocene and Eocene (61–51 Ma) plutonic rocks consisting mostly of leucocratic granitic rocks are shown on these maps as pre-58 Ma. Although the preponderance of reported ages (reset) for this group of rocks are Eocene, this group was distinguished from an assemblage of younger Eocene (53–46 Ma) silicic to intermediate intrusive rocks and associated volcanic rocks, the latter being largely confined to structural grabens.

The volcanic rocks and associated contemporaneous plutonic rocks have been classified with the use of a nongenetic system into five major types based primarily upon their known or inferred silica content:

- 1. Feldspathoidal basalts includ- Less than 46 percent SiO_2 ing basanite, tephrite, and other rare alkalic rocks
- 2. Basalt, including trachybasalt 46-54 percent SiO₂ and hawaiite
- 3. Andesite, including trachyandesite and phonolite 54–62 percent SiO₂
- Dacite, including rhyodacite, 62–70 percent SiO₂ quartz latite, and trachyte
- 5. Rhyolite More than 70 percent SiO₂

This simplistic rock classification, which is not desirable for detailed volcanological purposes, emphasizes the dominant rock type within a given region, although, in any specific area, several rock types may be intermixed. This rock classification is the same as that used in the map series for the late Cenozoic volcanic rocks (Luedke and Smith, 1982), thereby permitting easy comparison.

On sheet 2, the isotopically determined age data shown are referenced to the first or original source if reused in more than one reference. All older potassium-argon ages have been recalculated using the conversion tables of Dalrymple (1979) prepared for the decay constants and isotopic abundances adopted by the International Union of Geological Sciences (IUGS) Subcommission on Geochronology (Steiger and Jager, 1977). Most of the ages were determined by potassium-argon and fission-track methods, but a few ages determined by other methods are included. Multiple ages at a given locality are shown when cartographically possible. Some areas, such as in the Okanogan, Wenatchee, and other $1^{\circ} \times 2^{\circ}$ quadrangles (fig. 1), have many more ages than can be shown conveniently on sheet 2; these ages are listed separately and are keyed to the inset maps.

Cited references for geologic, age, and chemical information are indicated in figure 2. Several generalized but important references are cited separately at the end and are not numbered chronologically.

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*Geological, geochronological, and (or) geochemical data

**Geochronological and (or) geochemical data only [K-Ar, potassium-argon; Ar-Ar, argon-argon; Rb-Sr, rubidium-strontium; FT, fission track; Pb-α, lead-alpha; Pb-U, lead-uranium; Pb-Th-U, lead-thorium-uranium; C, chemistry]

No asterisk indicates geologic map data only

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