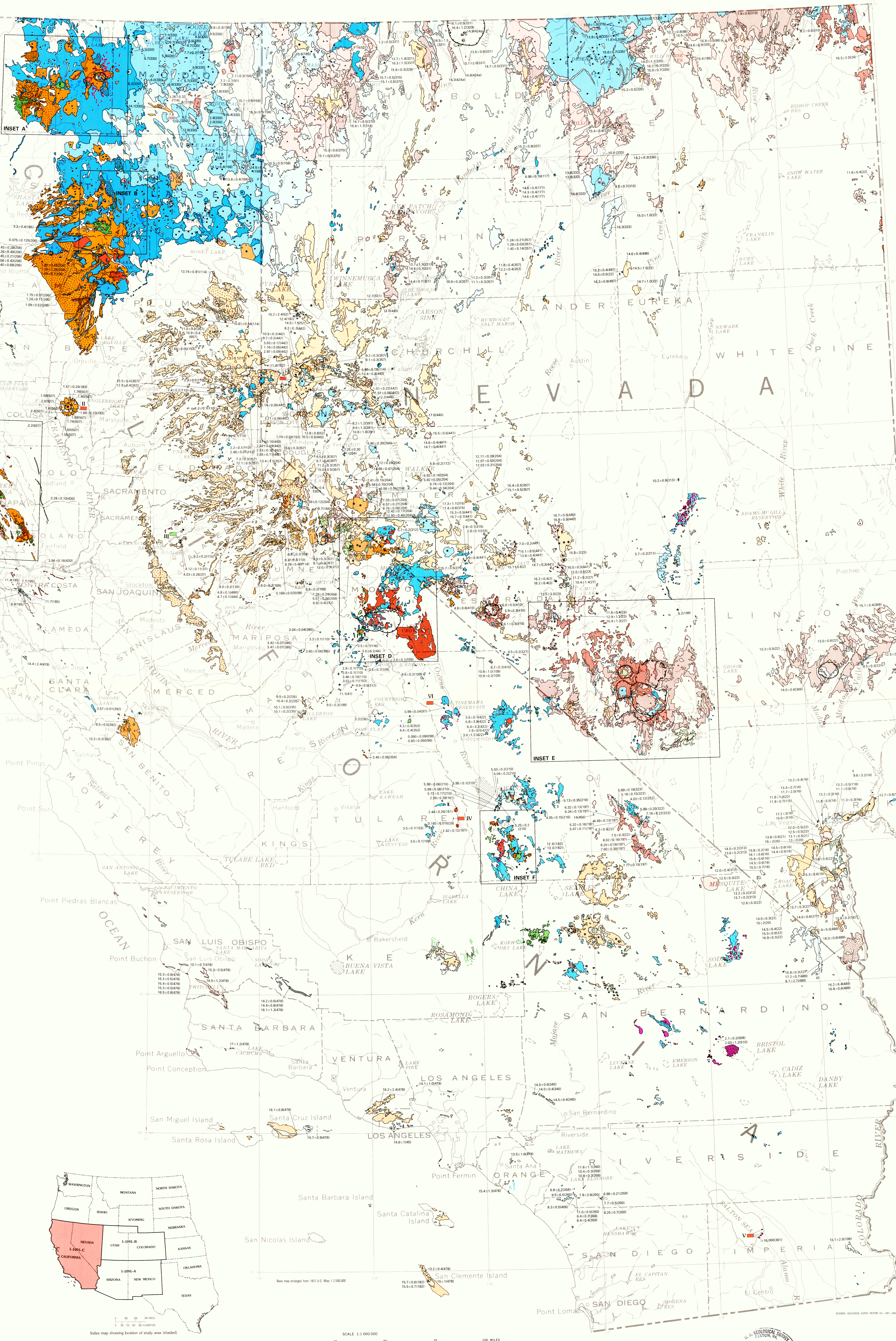

DISCUSSION

This map is the third of a series of maps showing the distribution, composition, and age of late Cenozoic volcanoes and volcanic rocks of the United States. Designed primarily as a guide for exploration and evaluation of igneous-related geothermal resources, this map series should also be useful as a base for evaluation of volcanic hazards, for studies of volcanology and volcano-tectonics, and for studies of the general geology of volcanic rocks. Because little or no reliable data are available for many areas, these maps are, to a considerable degree, our interpretation of the general age and composition of the volcanic rocks. Thus, current gaps in the data may be located by the combined use of the data source and reliability diagrams (figs. 1 and 2).

For the purposes of this map, the late Cenozoic extends from 16±1 million years (m.y.) ago to the present. This cutoff was chosen because it has meaning in a volcanological and tectonic sense; there was a widespread change in the style of volcanism at about this time over much of western United States (Christiansen and Lipman, 1972; McKee, Noble, and Silberman, 1970; Stewart, Moore, and Zietz, 1977). This change coincides, in a general way, with the onset of the tectonic extension and breakup that characterizes the Basin and Range Province but that is also reflected in bordering areas. This change may have occurred earlier or later than 16±1 m.y. ago in some areas, but this age seems an acceptable compromise for the general purposes of the maps.

The significance of this time cutoff for geothermal purposes is problematical. High-grade geothermal resources of the world are located in regions of late Cenozoic volcanic activity. The high-grade geothermal potential of an area declines rapidly with increasing age of volcanism; all high-grade geothermal resources from which energy has been extracted for power are associated with igneous systems active within the last 1 m.y. Lower grade (that is, lower temperature) geothermal resources may be related to the declining thermal stages of igneous systems or to other sources of thermal energy. However, the low-grade geothermal resource is not well defined, and at this time it is a largely unknown quantity. Hot or warm springs are known to be associated with volcanic areas older than 16±1 m.y. It is doubtful that these areas have significant geothermal resources although the utility of low-grade geothermal is currently uncertain. In any case, we suspect that the major thermal source for low-grade resources is very deep in the crust and that the hot-spring activity is related to very deep circulation of ground water. This same statement may apply to most large igneous systems older than a few million years and to many small systems older than a few tens of thousands of years.

Within this late Cenozoic time frame, the ages of the volcanic rocks are arbitrarily divided into three categories: present—5 m.y., 5–10 m.y., and 10–16±1 m.y. The time increment from the present to 1 m.y. is further subdivided by use of colored vent symbols; all vents older then 1 m.y. are shown in black.

The volcanic rocks, including some hypabyssal rocks, have been classified into five major types based primarily upon their known or assumed silica content:

1. Feldspathoidal basalts including basanite, limburgite, tephrite, and other rare alkalic rocks	Less than 46 percent SiO_2
2. Basalt including trachybasalt, hawaiite, etc.	46–54 percent SiO_2
3. Andesite including trachyandesite, etc.	54–62 percent SiO_2
4. Dacite including rhyodacite, quartz latite, trachyte, etc.	62–70 percent SiO_2
5. Rhyolite including pantellerite, etc.	Greater than 70 percent SiO_2

This rock classification is a compromise between the simple silicic-basic distinction that is considered to be significant for geothermal purposes (Smith and Shaw, 1975 and 1979), and a more detailed classification that would be desirable for purely volcanological purposes. In most areas the existing published data are inadequate for a systematic application of a more detailed classification. This classification also emphasizes dominant rock types. Unique and otherwise rare alkalic rocks are lumped together with the infrequently occurring feldspathoidal basalts unless, like trachyte, they represent the salic end of a rock series and may be interpreted, like dacite and rhyolite, as suggesting a high-level thermal source.

Considerable effort was made to accurately locate and represent the volcanic vents. The distribution, age, and morphology of vents must be known to interpret structure, type, and geothermal significance of volcanological systems. The type of vent is also a general indicator of rock chemistry and thus allows an interpretation of composition in the absence of other data.

Volcanic eruptions have occurred within the last 1 m.y. in approximately 17 different volcanic loci in California and Nevada. At least one eruption has occurred less than 100,000 years ago in 14 of the loci, less than 10,000 years ago in 9 loci, and less than 1,000 years ago possibly in 6 loci. Mount Shasta and Lassen Peak are considered active volcanoes with eruptions approximately 200 years ago and 62 years ago, respectively. Cinder Cone with eruption in 1851 is considered here as part of the Lassen volcanic thermal system.

There is no valid reason to think that any of the 17 loci are dead. Probably all of them reflect viable thermal anomalies at mantle depth today and have potential for future volcanic eruptions. At least 10 of the 17 loci show surface evidence, in the form of young silicic rocks, of high-level heat storage with potential geothermal significance. Six of the loci contain "Known Geothermal Resource Areas" (KGRA).

Fifteen of the 17 loci occur in a zone, generally less than 125 km wide, that includes the southern terminus of the Cascade Range (Lassen-Shasta regions) thence southeast along the crest of the Sierra Nevada and western margin of the Basin and Range Province to the Salton Trough and the Gulf of California to include the Pinacate volcanic field in Arizona and Mexico. The Pinacate field also marks the southwestern terminus of the Jemez Lineament as shown on Map I–1091–A of this series. The remaining two loci include the Clear Lake volcanic field and KGRA in western California, and the Lunar Crater volcanic field in south-central Nevada.

Approximately 50 volcanic loci in California and Nevada have been active in the last 5 million years and many of these, in addition to the 17 loci mentioned earlier, may represent viable thermal anomalies at mantle depth and have potential for future volcanic eruptions; several also have silicic nuclei and two such areas, Steamboat Springs, Nevada, and Lava Mountain, California, have been designated KGRA's.

In general the volcanic loci in Nevada that are less than 5 million years old are dominantly of basic composition. They are also smaller and more dispersed than those in California. The California loci are generally larger, more complex and have had a greater tendency to develop silicic nuclei than those in Nevada, at least as evidenced by surface volcanic expression. These generalizations hold for the 0–5 m.y. increment, but are largely reversed for the 10–16±1 m.y. increment.

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EXPLANATION

ROCK TYPE (silica range) / AGE (m.y.)	Feldspathoidal basalt and related rocks (<46 percent)	Basalt (46–54 percent)	Andesite (54–62 percent)	Dacite and related rocks (62–70 percent)	Rhyolite (>70 percent)
0–5					
5–10					
10–16±					

Ash-flow tuff—Rock type and age indicated by color

Dominantly volcaniclastic flows—Rock type and age indicated by color

Basic lava flow 0.01 m.y. in age (table 8, U.S.G.S. Circular 726)

Intrusive mass—Rock type and age indicated by color

Dike, sill—Rock type indicated by color

Buried lava flow

Caldera

10.0(333) Radiometric age in m.y.—Number in parentheses indicates data source. All data are radiometric (K-Ar) determinations unless otherwise noted

AGE (m.y.)	>1.0	1.0–0.1	0.1–0.01	0.01–0.001	0.001–0.0001	<0.0001

VENT TYPE

Cone, cinder, etc.

Dome

Shield

Stratovolcano

Maar

Dome cluster

Volcanic neck

INSET E Specific volcanic fields shown separately at scale of 1:500,000

IV Areas of small but potentially significant silicic (rhyolite or dacite) volcanoes <5 m.y. in age (may be obscured by vent symbol; rock type indicated by color)

I. Steamboat Springs, NV, domes-rhyolite
II. Sutter Buttes, CA, domes-rhyolite
III. Jackson, CA, domes-dacite
IV. Templeton, CA, domes-rhyolite
V. Salton Sea, CA, domes-rhyolite
VI. Big Pine, CA, dome-rhyolite

Note—Potassium-argon ages shown are from original sources and are not recalculated using decay constants and isotopic abundance adopted by the International Union of Geological Sciences on Geochronology, August 24, 1976

Index map showing location of study area (shaded)

SCALE 1:1 000 000

MAP SHOWING DISTRIBUTION, COMPOSITION, AND AGE OF LATE CENOZOIC VOLCANIC CENTERS IN CALIFORNIA AND NEVADA

By
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1981