DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

MISCELLANEOUS INVESTIGATIONS SERIES
MAP I–1091–B

DISCUSSION

This map is the second 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 also should be useful as a base for evaluation of volcanic hazards, for studies of volcanology and volcanotectonics, 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 reliability and data source 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 m.y. 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 than 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. Basalts 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 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 at least 3 volcanic loci in Colorado, Utah, and southwestern Wyoming; in each, an eruption has occurred less than 10,000 years ago. The most recent eruption was probably the "Santa Clara" basalt flow near St. George, Utah, about 1,000 years ago.

Approximately 15 volcanic loci that can be recognized as more or less independent entities have been volcanically active in the last 5 m.y., and most have had a history of volcanic activity extending back in time for more than 10 m.y. Because of this long time range of volcanic activity in the same general areas and by analogy with conclusions drawn for similiar volcanic loci in Arizona and New Mexico (map A of this series), most of the 15 loci in Colorado, Utah, and the Leucite Hills in southwestern Wyoming may be associated with viable mantle anomalies today.

Rhyolitic domes presumed to be indicative of heat storage at high crustal level have formed at 4 of the 15 loci within the last 5 m.y., and at 2 of 3 loci within the Mineral Mountains-Black Rock Desert locus (see inset map) within the last 500,000 years. The Mineral Mountains area is considered to be a known geothermal resource area (KGRA)—also referred to as the Roosevelt KGRA, Godwin and others (1971).

The areas of most recent volcanic activity in Utah are localized along the join between the Basin and Range Province and the Colorado Plateau. Here there seems to be, as in Arizona, a general migration (eastward) of volcanism toward and onto the Colorado Plateau especially in the southern part of the map area. However, the long history of volcanism in this same region and the extensive information gaps preclude meaningful interpretation at the present time.

In Colorado, intermittent late Cenozoic volcanic activity centered near Eagle spans more than 13 m.y. with the most recent event, a small basaltic lava flow, about 4,000 years ago.

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[Keyed to fig. 2]

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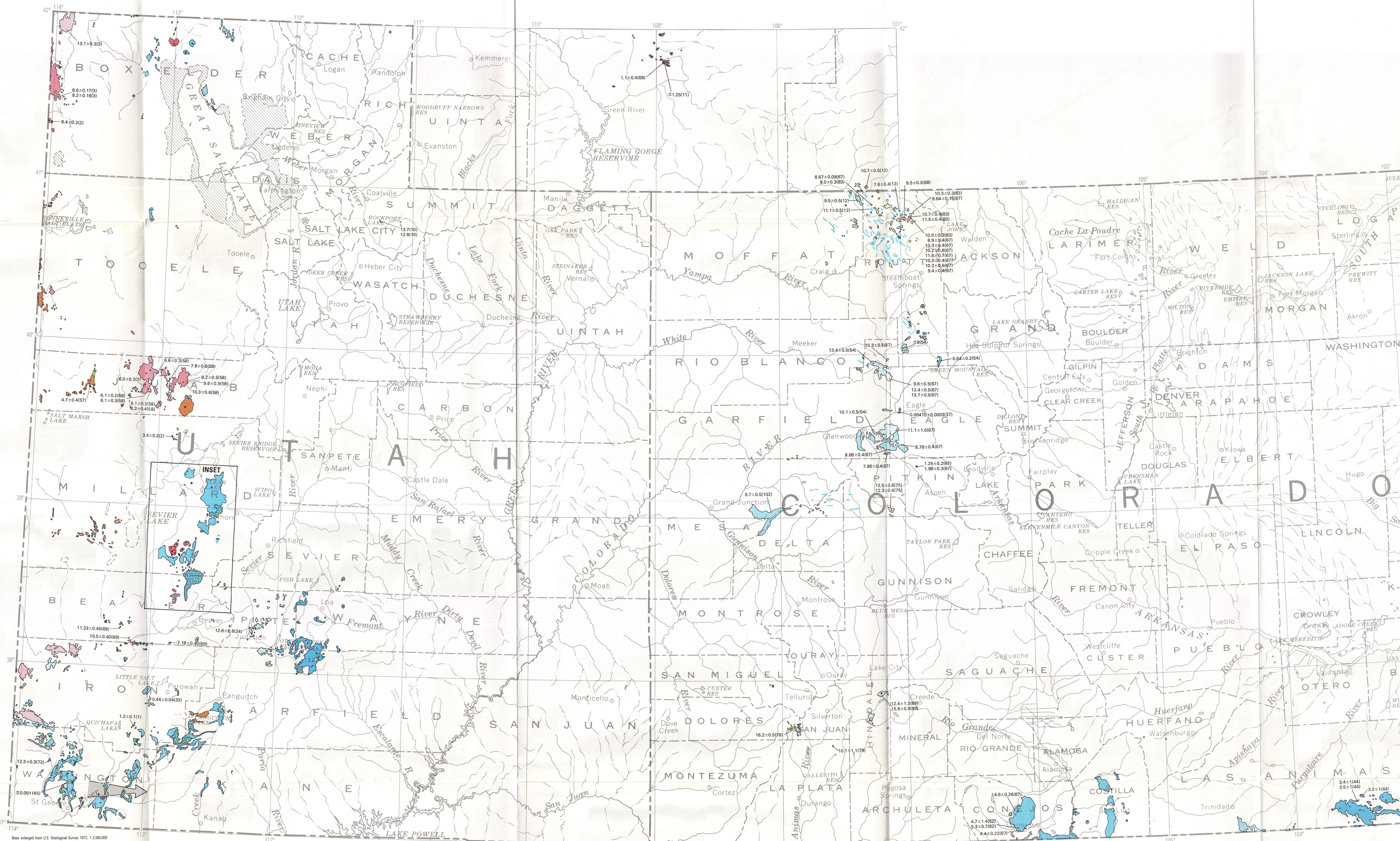
*Geologic and geochronologic data
**Geochronologic data only



Base enlarged from U.S. Geological Survey 1972, 1:2,500,000

INTERIOR—GEOLOGICAL SURVEY, RESTON, VA.—1978—G77302

Figure 1.—*Data reliability map for volcanic fields within the map area. Area rank is based on the availability of (a) detailed geologic maps, (b) detailed chemical and (or) petrographic data, and (c) adequate geochronologic data. RANK 1—Must satisfy all above criteria. RANK 2—Must satisfy 2 of above criteria. RANK 3—Must satisfy 1 of above criteria. RANK 4—Little or no adequate data. RANK 5—Not applicable. This classification is in part subjective; greatest weight is placed upon geologic maps; rock chemistry and (or) geochronologic data without detailed geologic relations and locations have minimal value. It cannot be overemphasized that a prime purpose for this reliability diagram is to point out those areas where geologic information is needed. Regardless of area rank, data gaps exist in all areas.*

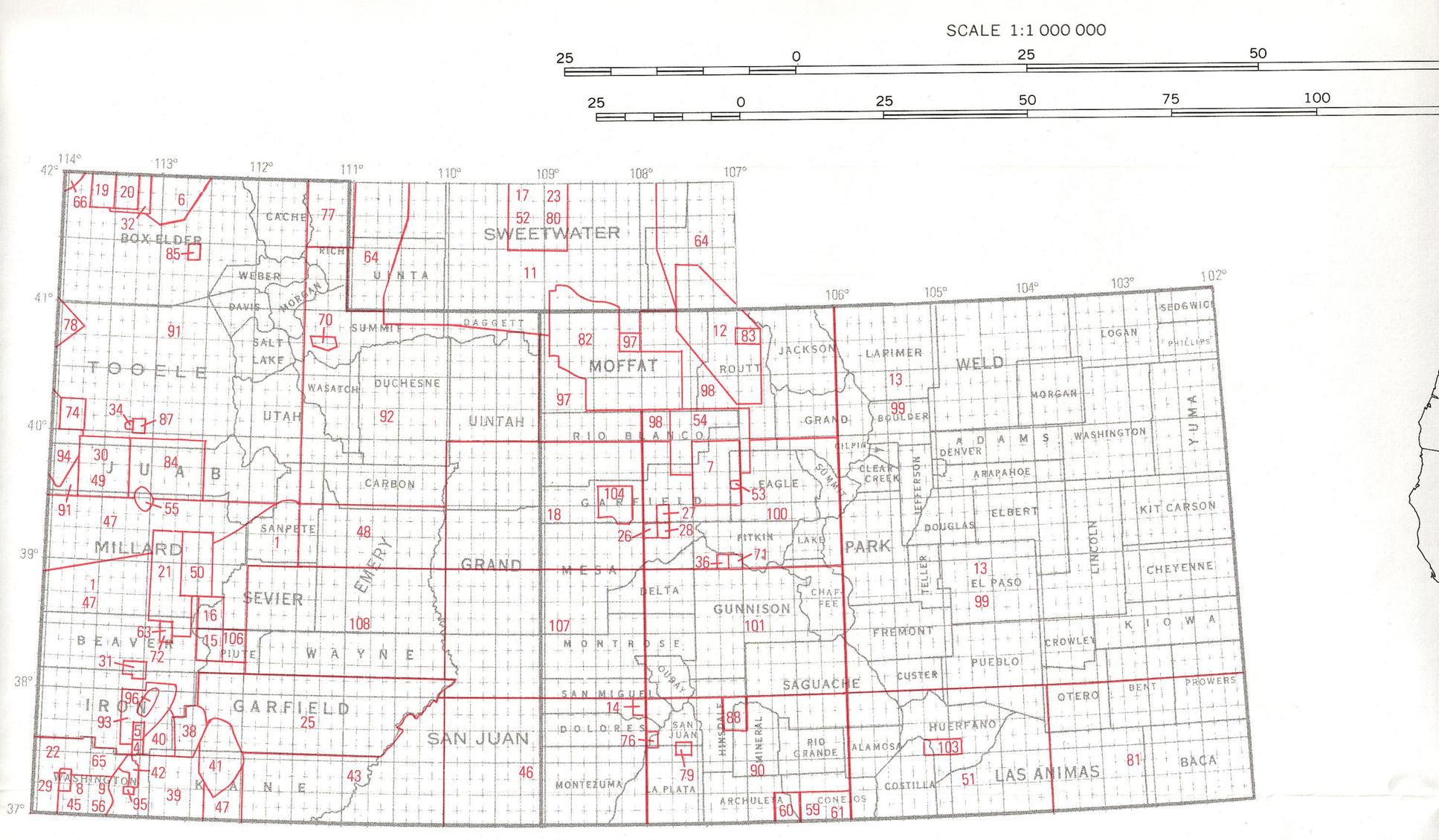
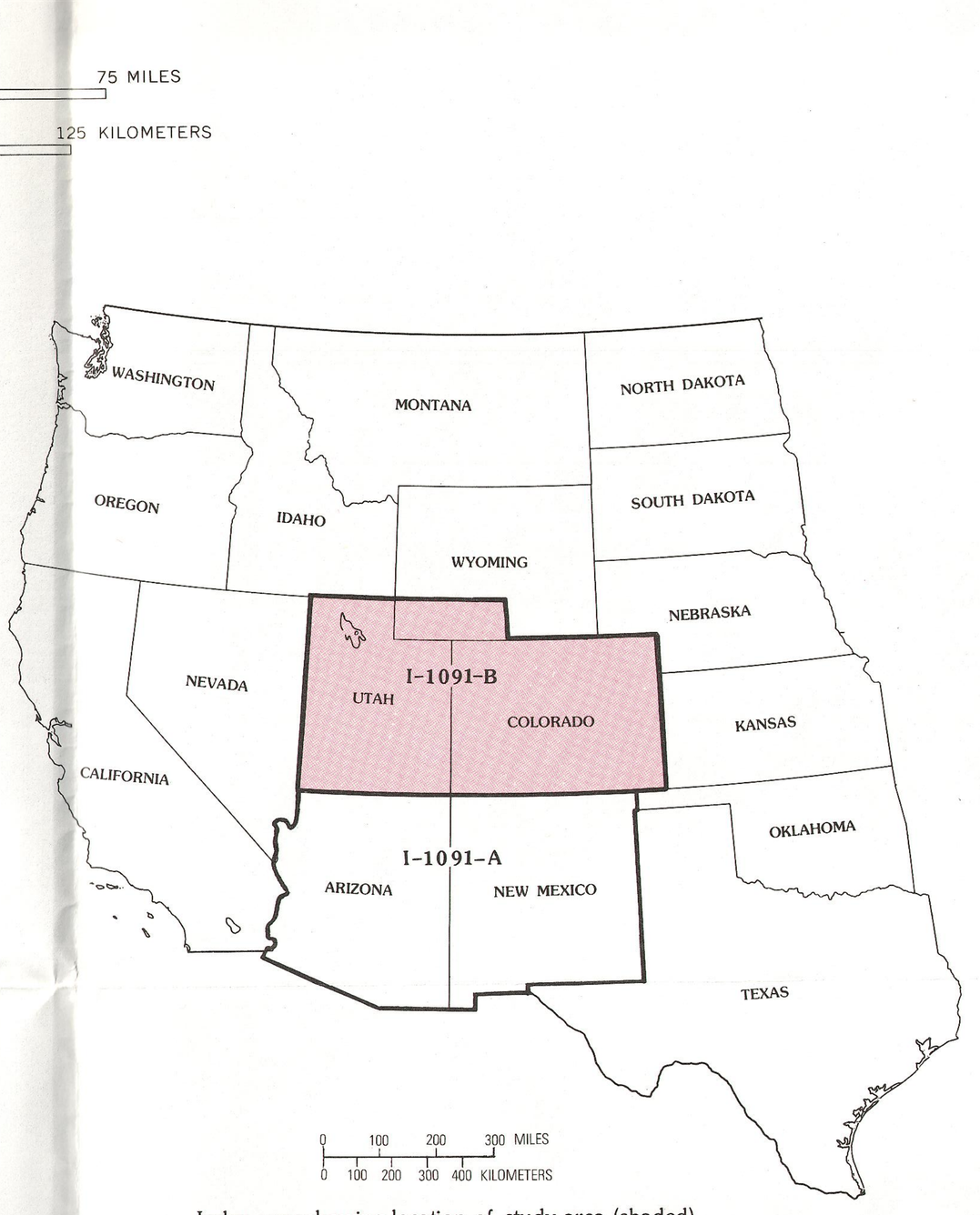
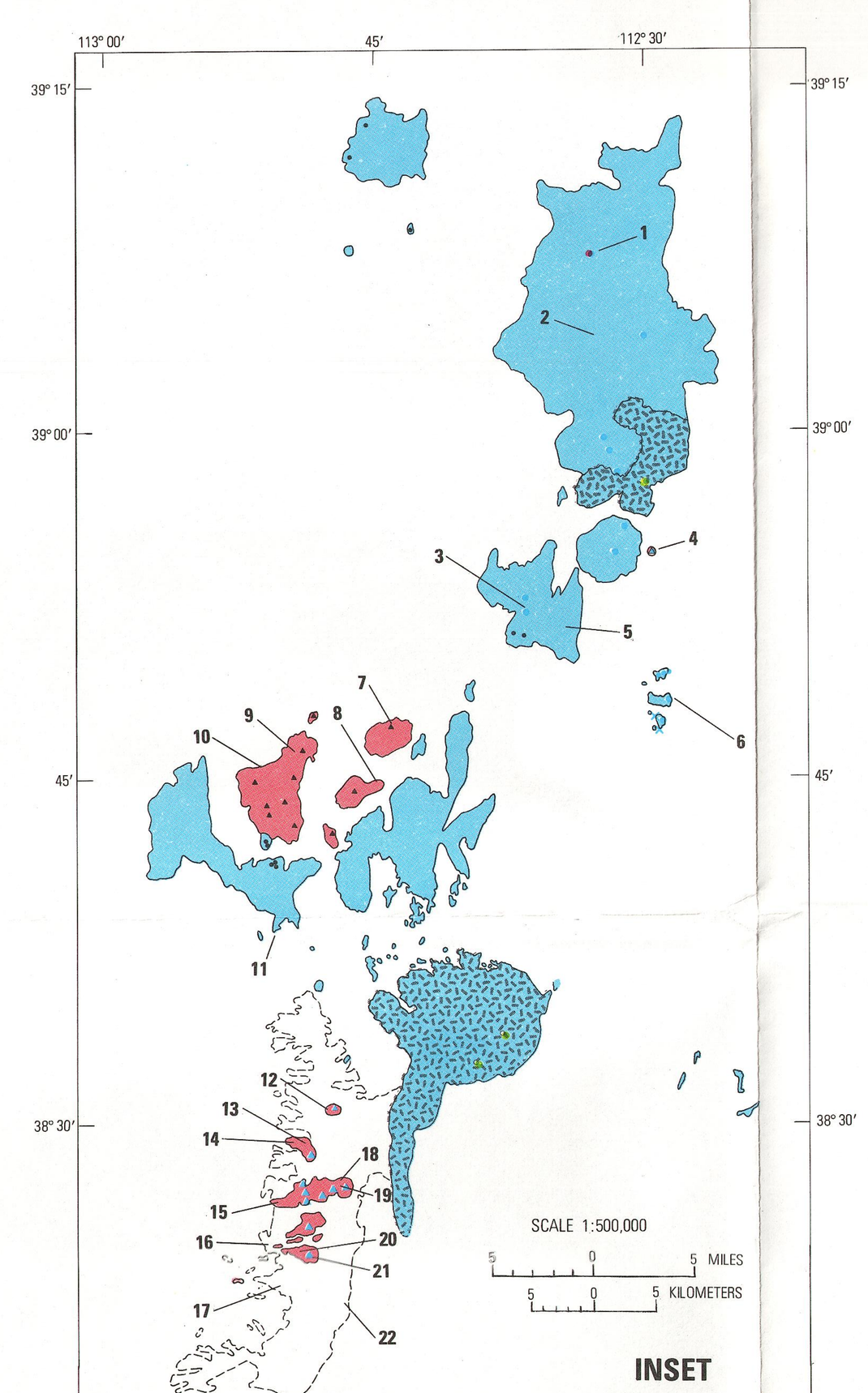


Figure 2—*Map showing principal sources of geologic, petrologic, and geochronologic data. The geology and vent information in some localities have been modified or supplemented through study and interpretation of topographic maps and aerial photographs. Where applicable, an original source is used and indicated, although it might have been in part superseded or incorporated in a more recent source.*



Index map showing location of study area (shaded)



INSET

EXPLANATION

17 Number and leader indicate point source

1, 0.031±0.038(50); 0.032±0.051(50); 0.070±0.056(50); 0.098±0.078(50); 0.133±0.097(50)
2, 0.22±0.26(21)
3, 0.987±0.085(50); 0.881±0.079(50); 0.956±0.101(50); 0.935±0.072(50); 0.893±0.062(50); 0.855±0.061(50)
4, 0.42±0.07(63)
5, 0.496±0.092(50); 0.546±0.101(50); 0.582±0.127(50); 0.554±0.121(50); 0.501±0.106(50)
6, 0.717±0.083(50); 0.618±0.064(50)
7, 2.27±0.12(63)
8, 2.35±0.14(86)
9, 2.22±0.08(86)
10, 2.32±0.15(63)
11, 0.97±0.25(21)
12, 0.53±0.06(63)
13, 0.77±0.08(63)
14, 0.80±0.20(35)
15, 0.85±0.21(35)
16, 10 ±10(105)
17, 9.2±0.3(2)
18, 0.48±0.12(35)
19, 0.73±0.10(63); 0.58±0.12(63)
20, 0.68±0.04(63); 0.49±0.07(63)
21, 0.25±0.06(35)
22, 15.5±1.5(105)

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)
<0.01		■			
<5	■	■	■	■	■
5–10		■	■	■	■
10–16+		■		■	■

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

Dike, sill —Rock type indicated by color

Direction of migration of volcanic loci

10.3±0.5(67) Radiometric age date in m.y.—Number in parenthesis indicates data source. All data are radiometric (K-Ar) determinations unless otherwise noted

Boundary of Mineral Mountains granite pluton

VENT TYPE / AGE (m.y.)	>1.0	1.0–0.1	0.1–0.01	0.01–0.001	0.001–0.0001
Cone, cinder, etc.	•	•	•	•	•
Dome	▲	▲			
Shield	■				
Maar	+				
Volcanic neck	×	×			

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 Commission on Geochronology August 24, 1976

MAP SHOWING DISTRIBUTION, COMPOSITION, AND AGE OF LATE CENOZOIC VOLCANIC CENTERS IN COLORADO, UTAH, AND SOUTHWESTERN WYOMING

By
Robert G. Luedke and Robert L. Smith
1978