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MEGABRECCIA OF THE BIG TEN PEAK CALDERA, NYE COUNTY, NEVADA

by

William J. Keith [1]

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[1]U.S. Geological Survey
4200 University Drive
Anchorage, AK, 99508-4667

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ABSTRACT

The Big Ten Peak caldera in northern Nye County, Nevada, is a resurgent-type Tertiary caldera whose entire fill of ash-flow tuff has resurged as a complex that includes a few relatively undeformed prisms. A resurgent plug has carried with it megabreccia blocks as much as 1 km in maximum dimension that ring the plug and define the rim of the caldera. Some of the megabreccia blocks are mineralized with argentiferous galena, sphalerite, and pyrite, but the mineralization apparently is older (77.9 Ma) than the formation of the caldera (27 Ma).

INTRODUCTION

The Big Ten Peak caldera is one of many calderas that formed in central and southern Nevada from 34 to 17 Ma (Best and others, 1989; Stewart, 1980). The calderas formed in response to eruption of a large number of silicic ash-flow and air-fall tuffs in a northwest-trending zone stretching from Lander and Churchill Counties on the northwest to Lincoln County on the southeast (Stewart, 1980). The Big Ten Peak caldera forms part of the south-central Monitor Range, Nye County, Nevada (fig. 1). It is approximately 16 kilometers in diameter and displays a resurgent plug of ash-flow tuff rising to over 2,700 m elevation--about 460 m above the adjacent terrain. It is part of a rugged mountain range consisting of sharp ridges and deeply incised canyons. Elevations in the area range from under 1,800 m in Ralston Valley and West Stone Cabin Valley to over 2,700 m in the area between Cottonwood Canyon and Little Cottonwood Canyon. The surrounding area is typical basin-and-range topography characterized by north- to northeast-trending fault-bounded mountain ranges separated by sediment-filled valleys that together define classic horst and graben structural terrane. Mineralization in the form of lead-silver veins and pipes, gold-silver veins, and disseminated molybdenum in skarn occurs in the Longstreet mining district, which includes most of the caldera.

Purpose of Study

The purpose of this study was to map and determine the evolution of the Big Ten Peak caldera and to report on the distribution and origin of the megabreccia blocks exposed along the caldera rim and their included epithermal mineralization. The

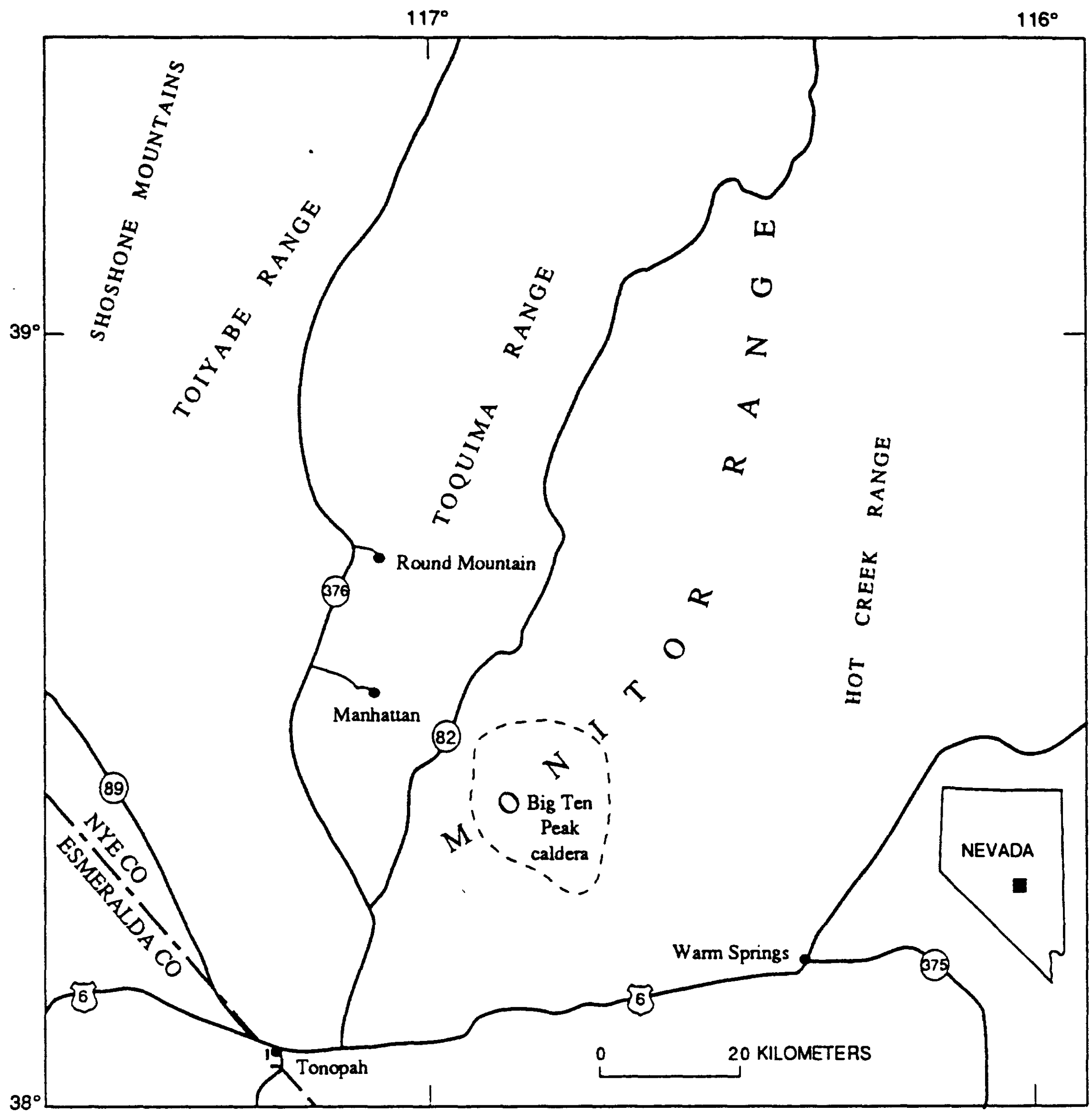


Figure 1. Index map showing location of the Big Ten Peak caldera in Nye County, Nevada.

specifics of the geology have been reported elsewhere (Keith, 1987a, b).

Previous studies

No detailed studies of the Big Ten Peak caldera have been published other than two preliminary geologic maps by the author (Keith, 1987a, b). Kleinhampl and Ziony (1984, 1985) published reports on the mineral resources and the geology of northern Nye County, and Bonham and Noble (1982) published an abstract on the mode of resurgence in the development of the Big Ten Peak caldera. Bonham and Garside (1979) in their study of the geology of the Tonopah, Lone Mountain, Klondike, and northern Mud Lake 15-minute quadrangles discuss briefly the outflow sheet and some of the megabreccia blocks related to the caldera. Shawe and Snyder (1988) published a thorough study on megabreccia blocks in the Manhattan and Mount Jefferson areas west and northwest of the Big Ten Peak caldera which helps explain the presence of smaller breccia blocks in the intracaldera ash-flow tuffs.

CALDERA

The Big Ten Peak caldera is a resurgent-type caldera approximately 16 km in diameter, outlined by a ring of megabreccia, rhyolite dome/flow complexes, and a major northwest-trending fault zone on the south side (fig. 2). It is one of many calderas in this part of Nevada formed during a period of silicic volcanism occurring between 34 to 17 Ma (Best and others, 1989; Stewart, 1980).

Resurgence in the caldera has not followed the classical central resurgence as described by Smith and Bailey (1968), a process characterized by doming and a large amount of fracturing. The entire intracaldera sequence of tuffs and lava flows appears to have been uplifted as a few huge, generally undeformed prisms (Bonham and Noble, 1982) that now stand at approximately 2,800 m in elevation. These prisms consist of latitic to rhyolitic ash-flow tuffs and associated lava flows. Compaction foliation within the intracaldera units is very shallowly dipping and the units are only slightly disrupted by faulting, folding, or fracturing (Keith, 1987a, b). The eastern and western margins of the caldera are marked by the presence of large megabreccia blocks, and the northern margin is marked by the presence of rhyolite dome and (or) flow complexes and minor amounts of the large megabreccia blocks. The southern margin of the caldera is part of a zone of northwest-trending high-angle normal faults that transects the Monitor Range (Keith, 1987a).

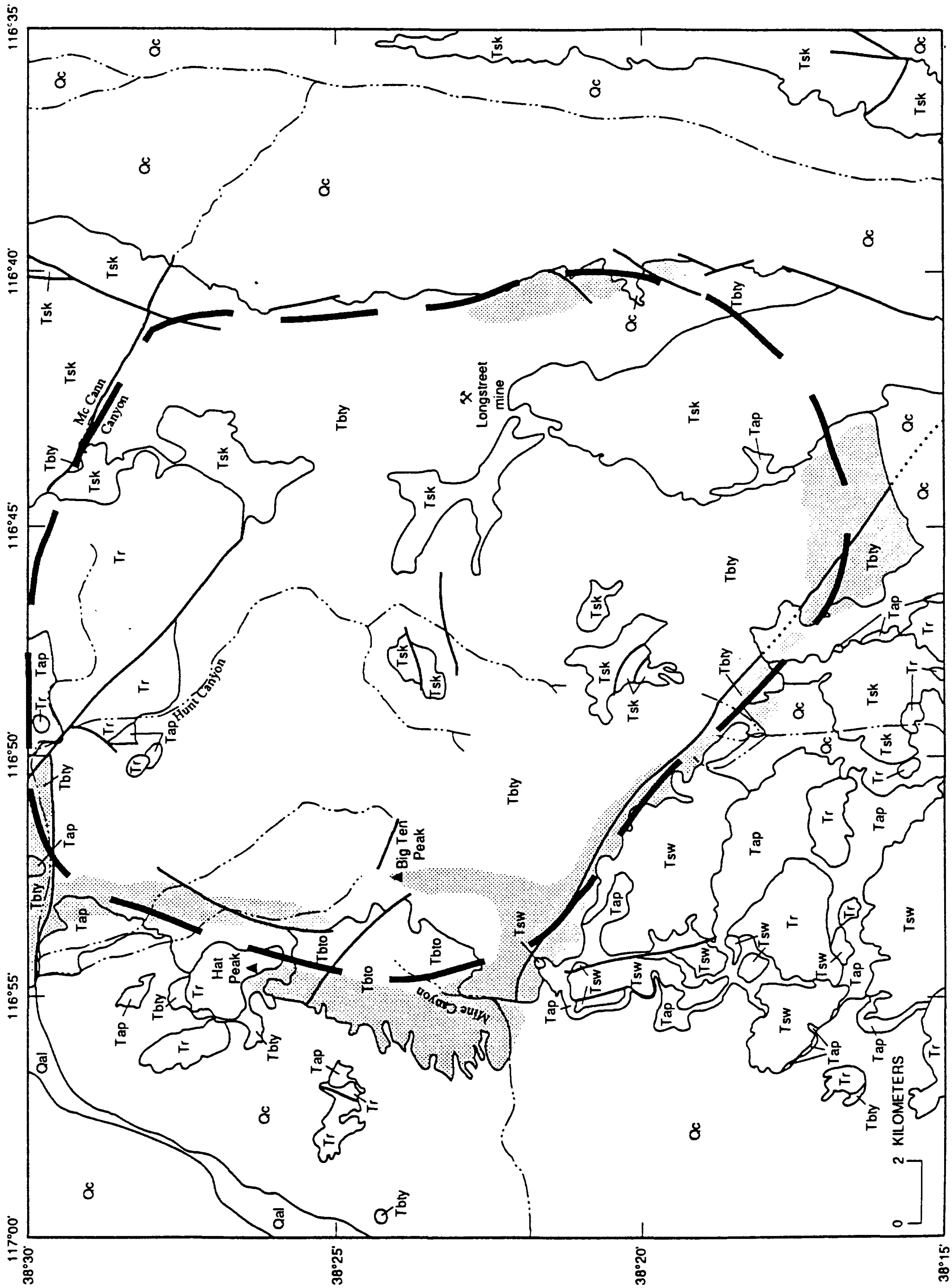
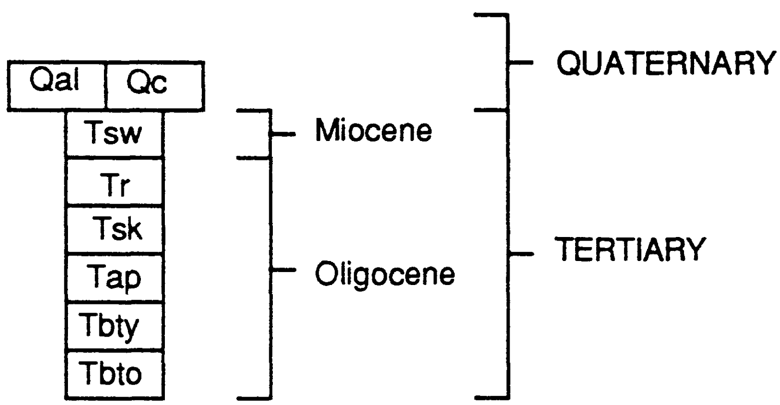


Figure 2. Generalized geologic map of the Big Ten Peak caldera and vicinity.

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

Qal	Alluvium (Quaternary)
Qc	Colluvium (Quaternary)
Tsw	Tuff of Saulsbury Wash (Miocene)
Tr	Rhyolite (Oligocene)
Tsk	Shingle Pass Tuff and Tuff of Kiln Canyon, undivided (Oligocene)
Tap	Ash and pumice (Oligocene)
	Tuff of Big Ten Peak (Oligocene)—Divided into:
Tbty	Younger tuff unit
Tbto	Older tuff unit

Contact—Approximately located

Fault—Approximately located

Zone containing megabreccia blocks

Approximate caldera boundary

The lithic nature of the tuffs filling the caldera complicate radiometric dating by standard K-Ar and $^{40}Ar/^{39}Ar$ methods. However, some ages are available from adjacent formations rocks that depositionally overlie the tuffs filling the caldera and place the minimum age of the caldera at about 27 Ma (Shawe and others, 1987).

Flanking Units

The material flanking the caldera consists largely of three units: from oldest to youngest, the ash and pumice unit (unit Tap, fig. 2), rhyolite dome and (or) flow complexes unit (Tr), and the tuff of Saulsbury Wash (Tsw) (Kleinhampl and Ziony, 1985). These units are related genetically and are probably also related to the caldera forming units (Tbty and Tbto).

The ash and pumice unit (Tap) is white, gray, and buff airfall and water-laid material that is typically poorly indurated; locally the unit reaches thicknesses of approximately 107 m. Both the rhyolite dome-flow complexes and the tuff of Saulsbury Wash overlie this unit in much of the area. The ash and pumice unit consists of ash, glass shards, pumice, minor amounts of quartz, plagioclase, alkali feldspar, biotite, lithic fragments of igneous rocks and black shale, and thin lenses of latitic cobbles. The airfall material typically shows sorting and distinct bedding. Numerous potassium-argon and fission track dates (Shawe and others, 1987) place the minimum age of this unit (Tap) at approximately 27 Ma (table 1). This age also restricts the minimum age of the caldera to about 27 Ma because the unit is the oldest unit overlying the caldera-forming tuffs.

The rhyolite of the dome-flow complexes (Tr) shows variations in color from white to red to gray, and is typically crystal poor. It contain sparse phenocrysts of plagioclase, alkali feldspar, quartz, clinopyroxene, orthopyroxene, and opaque minerals. These complexes occur on or near the trace of the inferred ring fracture system of the caldera and are depositional on the ash and pumice unit and the caldera-forming units. Rhyolite also intrudes and alters part of the uplifted tuff of Big Ten Peak. Potassium-argon age determinations on the rhyolite show ages of 24.8 ± 1.5 Ma (Marvin and others, 1973) and 24.6 ± 0.7 Ma (McKee and John, 1987).

The youngest of the flanking units is the tuff of Saulsbury Wash (Tsw). This unit was named by Kleinhampl and Ziony (1985) for prominent exposures along the southern part of Saulsbury Wash (south of the mapped area) where it overlies older ash-flow tuffs. It consists of a red-brown to purple rhyolitic ash-flow tuff. It contains a moderate amount of crystal fragments of plagioclase, quartz, alkali feldspar, biotite, and hornblende and sparse lithic fragments of the megabreccia blocks. The tuff typically shows a basal vitrophyre which locally appears to follow joints up into the welded part of the tuff. Potassium-argon ages derived from this unit are 21.6±0.6 (Kleinhampl and Ziony, 1985) and 20.6±0.6 Ma (McKee and John, 1987). The tuff of Saulsbury Wash is locally in depositional contact with the ash and pumice unit.

Table 1. Unit ages that constrain the age of the ash and pumice unit and, therefore, the minimum age of the Big Ten Peak caldera (Shawe and others, 1987).

UNIT	METHOD	MINERAL	AGE
ash tuff	K-Ar	biotite	27.0 ± 1.0 Ma
	Fission Track	zircon	24.8 ± 2.6 Ma
latite flow?	K-Ar	biotite	26.8 ± 1.0 Ma
	Fission Track	zircon	24.8 ± 2.6 Ma
black sand	Fission Track	zircon	22.7 ± 2.2 Ma
	Fission Track	apatite	25.4 ± 6.9 Ma
latite plug	K-Ar	biotite	26.6 ± 1.0 Ma
	Fission Track	zircon	25.5 ± 2.6 Ma
	Fission Track	apatite	37.9 ± 11.3 Ma
latite plug	K-Ar	biotite	26.3 ± 0.9 Ma
	K-Ar	hornblende	27.8 ± 3.4 Ma
	Fission Track	zircon	27.9 ± 3.4 Ma
	Fission Track	apatite	28.1 ± 8.5 Ma
rhyolite plug	Fission Track	zircon	25.1 ± 2.3 Ma

That three flanking units are genetically related is indicated by their similar rare earth element (REE) relations (fig. 3). The REE data (table 2) are interpreted to indicate that these units, as well as the tuff of Big Ten Peak, originated from the same magma chamber but not necessarily from the same vent.

Caldera Units

The material that fills the caldera and forms small outflow sheets consists of two lithic-rich ash-flow tuff units--an older and a younger unit which, together, compose the tuff of Big Ten Peak. Both of these units show a wide variation in degree of welding, and both have megabreccia blocks resting on them.

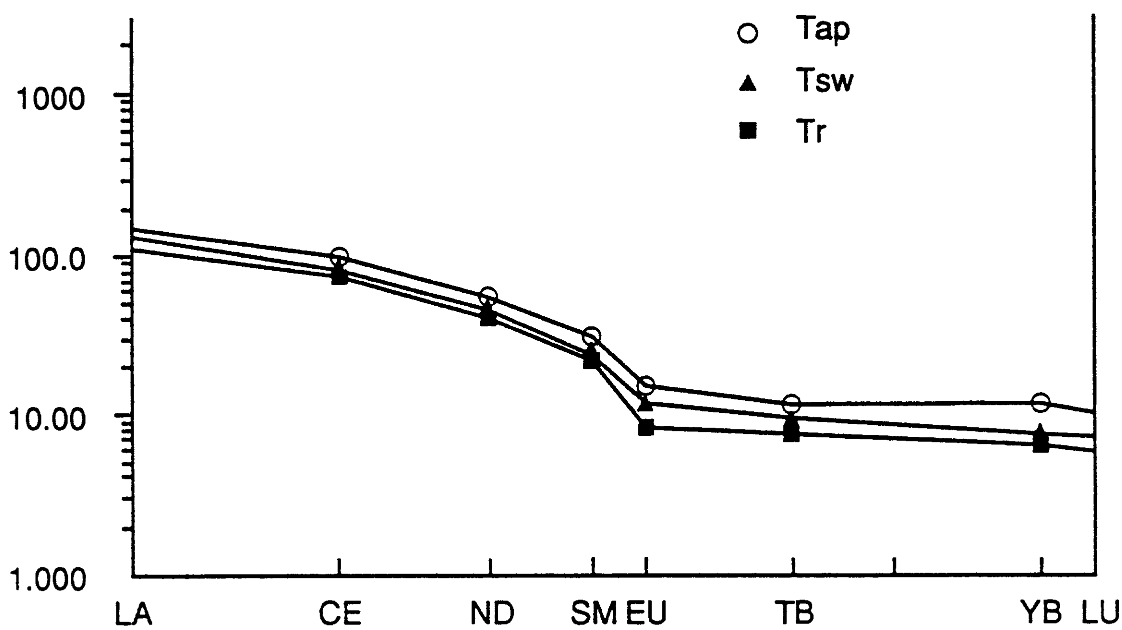


Figure 3. REE plot showing the relation between chondrite normalized rare earth elements from the units that flank Big Ten Peak caldera.

Table 2. Major oxides, in weight percent, and rare earth elements (REE), in parts per million, for flanking units of the Big Ten Peak caldera

[Analysts L.F. Espos, J.R. Gillison, L.J. Schwarz, and H. Smith]

MAJOR OXIDES								NORMALIZED VOLATILE FREE						
	TC8247	TC82282	TC8291	TC8202	TC8294	TC8295	TC8297	TC8247	TC828	TC8291	TC8202	TC8294	TC8295	TC8297
SiO_2	79.00	69.70	75.10	76.70	72.90	67.10	74.50	81.10	74.80	76.40	78.00	76.20	73.10	75.50
Al_2O_3	9.90	13.00	12.80	12.00	12.80	13.80	13.10	10.20	13.90	13.00	12.20	13.40	15.00	13.30
Fe_2O_3	1.00	1.00	0.78	0.69	0.45	1.04	1.08	1.03	1.07	0.79	0.70	0.47	1.13	1.10
FeO	0.09	0.14	0.14	0.15	0.32	0.36	0.27	0.09	0.15	0.14	0.15	0.33	0.39	0.27
MgO	0.16	0.39	0.10	0.24	0.11	0.44	0.31	0.16	0.42	0.10	0.24	0.11	0.48	0.31
CaO	0.92	0.80	0.80	0.78	0.81	1.17	1.26	0.94	0.86	0.81	0.79	0.85	1.27	1.28
Na_2O	2.40	2.50	3.60	3.40	3.27	2.89	3.33	2.46	2.68	3.66	3.46	3.42	3.15	3.38
K_2O	3.70	5.40	4.70	4.10	4.90	4.67	4.49	3.80	5.79	4.78	4.17	5.12	5.09	4.55
H_2O+	1.20	4.40	0.35	0.58	3.34	5.66	0.42	–	–	–	–	–	–	–
H_2O-	1.10	1.40	0.10	0.25	0.23	0.33	0.16	–	–	–	–	–	–	–
TiO_2	0.16	0.17	0.18	0.20	0.10	0.23	0.18	0.16	0.18	0.18	0.20	0.10	0.25	0.18
P_2O_5	0.04	0.04	0.04	0.05	0.00	0.06	0.06	0.04	0.04	0.04	0.05	0.00	0.07	0.06
MnO	0.04	0.09	0.06	0.07	0.05	0.07	0.04	0.04	0.10	0.06	0.07	0.05	0.08	0.04
CO_2	0.06	0.03	0.07	0.08	0.02	0.16	0.10	--	–	–	–	–	–	–
TOTAL	99.77	99.06	98.82	99.29	99.30	98.98	99.30	100	100	100	100	100	100	100

RARE EARTH ELEMENTS								CHONDRITE NORMALIZED						
	TC8247	TC82282	TC8291	TC8202	TC8294	TC8295	TC8297	TC8247	TC828	TC8291	TC8202	TC8294	TC8295	TC8297
La	–	–	–	–	38.6	48.5	43.5	–	–	–	–	117.	147.	132.
Ce	–	–	–	–	65.2	83.5	71.4	–	–	–	–	74.1	94.9	81.1
Nd	–	–	–	–	23.8	32.0	27.0	–	–	–	–	39.7	53.8	45.2
Sm	–	–	–	–	3.89	5.30	4.16	–	–	–	–	21.5	29.3	23.0
Eu	–	–	–	–	0.537	0.987	0.746	–	–	–	–	7.78	14.3	10.8
Tb	–	–	–	–	0.331	0.500	0.400	–	–	–	–	7.04	10.6	8.49
Yb	–	–	–	–	1.19	2.14	1.36	–	–	–	–	5.95	10.7	6.80
Lu	–	–	–	–	0.188	0.318	0.214	–	–	–	–	5.53	9.35	6.29

TC8247, 8291, and 8294 are samples of rhyolite from unit Tr.
TC 8282 and 8295 are samples of the rhyolitic ash and pumice unit Tap.
TC8202 and 8297 are samples of rhyolite ash flow tuff from unit Tsw.

The older of the two units (Tbto) is a gray-green lithic tuff with varying amounts of broken crystals of plagioclase, alkali-feldspar, quartz, biotite, and hornblende. Lithic fragments consist largely of shale and granitic rocks with lesser amounts of limestone, quartzite, and volcanic rocks. Locally the older tuff unit contains small latitic lava flows of similar mineralogy. The base of the older tuff unit is not exposed in the immediate vicinity of the caldera.

The younger of the two lithic-rich ash-flow units (Tbty) is various shades of white, orange, and brown. Mineralogy of welded parts of this unit includes plagioclase, alkali-feldspar, quartz, biotite, and sparse hornblende. Lithic fragments include: (1) limestone, quartzite, schist, and shale or slate that are all probably derived from the Cambrian Gold Hill Formation or Zabriskie Quartzite (Kleinhampl and Ziony, 1985); (2) plutonic rocks of unknown age; (3) rhyolite, andesite, latite, and exotic tuff fragments of probable Tertiary age. Volcanic lithic fragments also are present as blocks as much as 10 m wide in the northern part of the caldera. Both caldera-fill units have megabreccia blocks resting on them.

MEGABRECCIA

The term "megabreccia" as used herein, generally follows Lipman's (1976, p. 1398) definition, in which many clasts exceed 1 m in diameter. Genetic criteria of Lipman's definition require that these breccias be early-formed collapse breccias, but the term "megabreccia" has rapidly become more generalized. Such megabreccias are being reported in the literature with increasing frequency (Elston, 1984; Fiske and Tobisch, 1978; Lipman and Sawyer, 1985; Shawe and Snyder, 1988; Thompson, 1985). The megabreccia of Big Ten Peak caldera contains irregularly shaped blocks as much as 1 km in maximum dimension (Keith, 1987a, b), and they are probably more properly related to resurgent dome emplacement following caldera collapse. The megabreccia, the rhyolite dome-flow units, and a major northwest-trending fault, form a ring outlining the Big Ten Peak caldera (fig. 2). Overall, the larger blocks range in size from about 500 to 1,000 m and consist of various granitic rocks, quartzite, limestone, shale, schist, tuffs, and lava. Some clusters of smaller blocks (10-100 m, fig. 4) of quartzite appear to represent a larger block that has broken up.

Granitic blocks are confined to the northwest quarter of the caldera wall. They do not correlate with any of the granitic rocks in the immediate area, although Kleinhampl and Ziony (1984, p. 139)

Figure 4. Photograph showing some of the smaller, broken-up breccia blocks of quartzite.

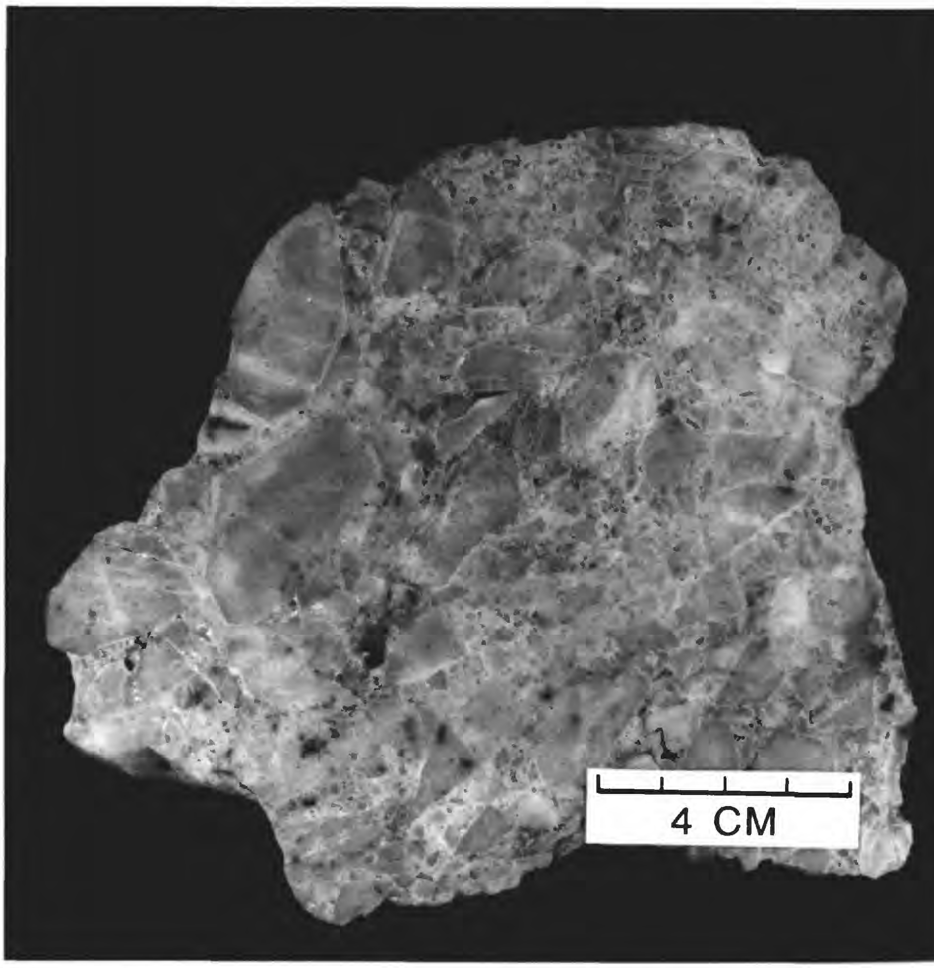


Figure 5. Photograph showing some of the matrix supported quartzite that has been crushed and re-cemented.

Peak caldera appear to be resting on, rather than enclosed by, the tuff of Big Ten Peak. One of the largest of the megabreccia blocks rests on top of Big Ten Peak approximately 460 m above the adjacent terrain. If the megabreccia of Big Ten Peak caldera is indeed composed of landslide blocks, then the material surrounding the caldera would have to have been eroded away leaving the blocks and the intra-caldera material intact. This mechanism is unlikely since the tuff of Big Ten Peak is poorly welded in its upper portions and should have eroded at nearly the same rate or faster than the flanking material. Another argument against the landslide mechanism is the fact that the nearest exposure of quartzite is over 16 km northwest in the Manhattan area (Shawe and Snyder, 1988) and that there is no geologic evidence in the intervening area to support thrusting or gravity sliding.

The smaller blocks in the tuff of Big Ten Peak could either have been eruptive blocks (that is, blocks plucked from the walls during venting) or from collapsing caldera walls. In either case, the blocks would have to be lifted to the level of the caldera rim by the eruptive column. Because the large blocks appear to be resting <u>on</u> rather than <u>in</u> the tuff, it would be fortuitous for the vents around the caldera rim to have been the unique sites where especially large blocks were plucked out and selectively moved up to the paleo-surface level during a final eruptive pulse. It would be even more so for the blocks to fall into the vents at the end of the eruption and then all be lifted up by the last column of rock emplaced.

The preferred explanation for emplacement of these blocks is simple and unique (fig. 6):

A. The Big Ten Peak eruptive process probably started with an eruption of silicic tuff through bedrock consisting of limestone, shale, quartzite, plutonic rocks, and a few relatively young (probably Tertiary) ash-flow tuffs and lavas.

B. As the eruptions continued to deplete the magma chamber, the caldera started to form. As the eruption and accompanying subsidence continued, small vents probably formed at or near the edge of the caldera along developing ring fractures. Because the ring-fracture vents were substantially below the top of the caldera rim, much of the material erupting from the small vents was dumped into the caldera.

C. The third stage of the process involved small-scale lava flows and dikes, spalling of wall material into the caldera, and finally, pressure building up in the magma chamber under the caldera.

D. As pressure built up, the entire caldera began to rise as a few coherent prisms (Bonham and Noble, 1982). This process plucked

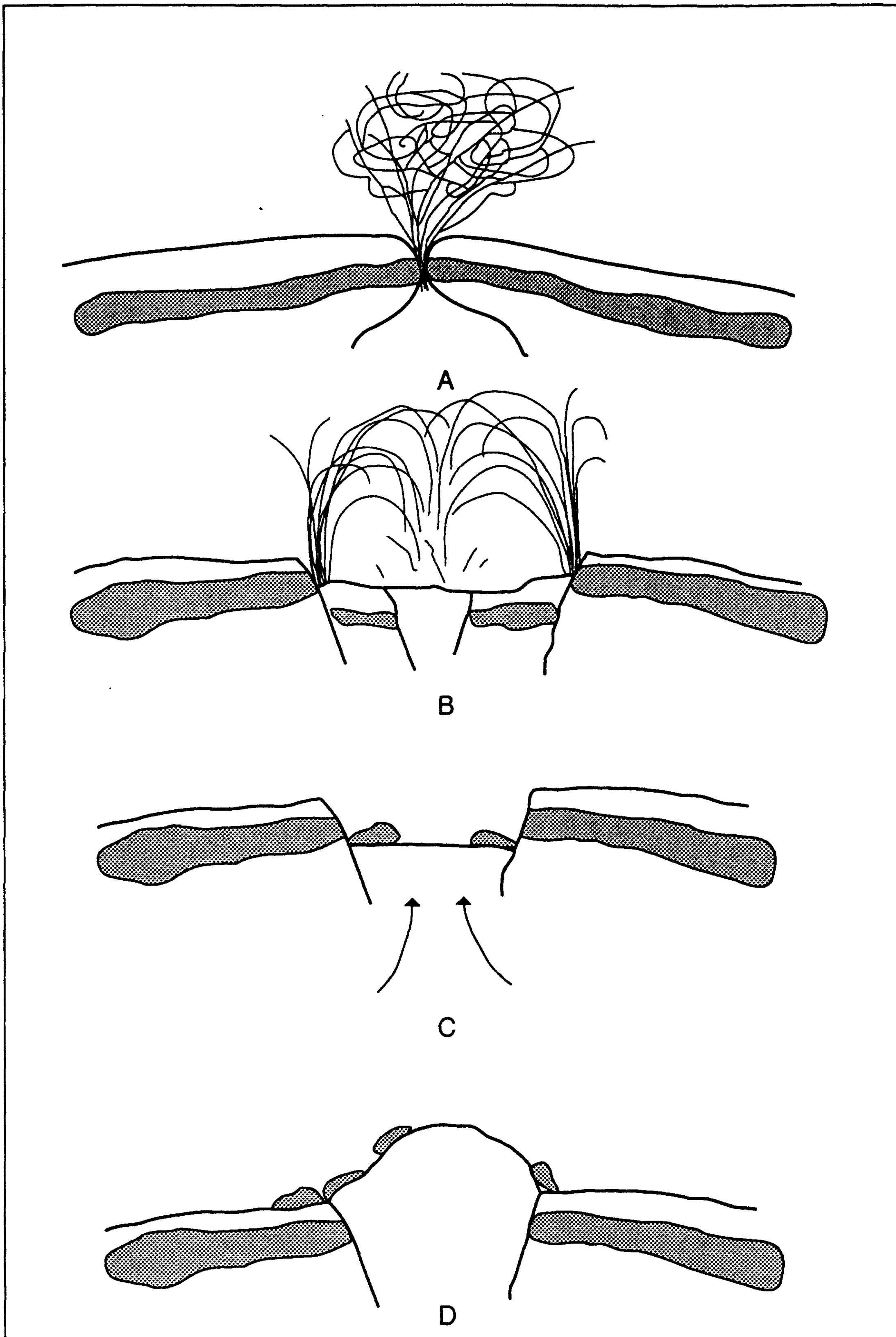


Figure 6 Theoretical origin of the megabreccia blocks from the Big Ten Peak caldera.

blocks of material out of the walls and incorporated them into the resurgent block. As these prisms reached the paleo-surface level of the surrounding terrain, fragments of them at the edges slid off onto the more stable rim areas while the prisms more centrally located and farther away from the rim remained relatively intact. Regardless of the mechanism of emplacement, it is doubtful that these megabreccia blocks traveled very far laterally from their source, and because most of their subsequent movement appears to have been vertical, the present distribution of the blocks probably represents the overall lateral distribution of these rocks at depth.

In light of these relations, the mineralization in the megabreccia blocks thus appears to be rootless. The epithermal mineralization is localized within the limestone and quartzite megabreccia blocks, and no mineralization extends into the enclosing welded tuff. The epithermal deposits typically consist of assemblages of argentiferous galena, sphalerite, and pyrite associated with varied amounts of quartz. Deposits from such systems form irregular pipes and chimneys (Kleinhampl and Ziony, 1984, Kral, 1951) and also isolated quartz veins within the megabreccia blocks. The absence of chalcedonic or opaline quartz in the mineralogy of these assemblages suggests that the deposits formed relatively deep in the epithermal mineralizing system. The 77.9-Ma age on white mica from Mine Canyon supports the contention that the mineralization is pre-caldera in age. The restricted nature of the mineralization in the blocks and the size of the blocks would appear to make mining of the individual blocks uneconomical. Also, there are not enough of the mineralized blocks to make bulk mining a viable alternative.

Other styles of mineralization in the megabreccia blocks are equally restrictive. Disseminated molybdenum in the skarn near Hat Peak has been drilled and is indeed hosted by another megabreccia block. Here also the block is too small to be of economic importance. Nonetheless, all mineralization in the megabreccia blocks, although they are not minable as such, presents a nagging question: how much more is there and at what depth?

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