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Petrochemical Studies of the Pinnacles Wilderness Contiguous Wilderness Study Area, Monterey and San Benito Counties, California

by

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INTRODUCTION

In 1984 and 1985, the U. S. Geological Survey and the U. S. Bureau of Mines conducted a mineral and energy resource appraisal and assessment of the Pinnacles Wilderness Contiguous Wilderness study Area (BLM No. CA-040-303)., which covers 5,838 acres in the southern Gabilan Range near Hollister, California (Fig. 1). This report presents the results of studies of the trace-element composition of the igneous rocks of the area.

The Pinnacles Wilderness Contiguous Wilderness Study Area is located in west-central San Benito County and east-central Monterey County, about 30 mi. south of Hollister, California (Fig. 1). It is composed of five parcels of public land administered by the Bureau of Land Management that cover an area of 5,838 acres and are adjacent to the Pinnacles National Monument.

The study area is in the southern Gabilan Range, which is part of the Coast Ranges physiographic province. Access on the north is via the county-maintained gravel road (Gloria Road) in Bickford Canyon that connects Gonzales with California State Highway 25, and by private dirt roads and fire trails from the Gloria Road and Highway 25.

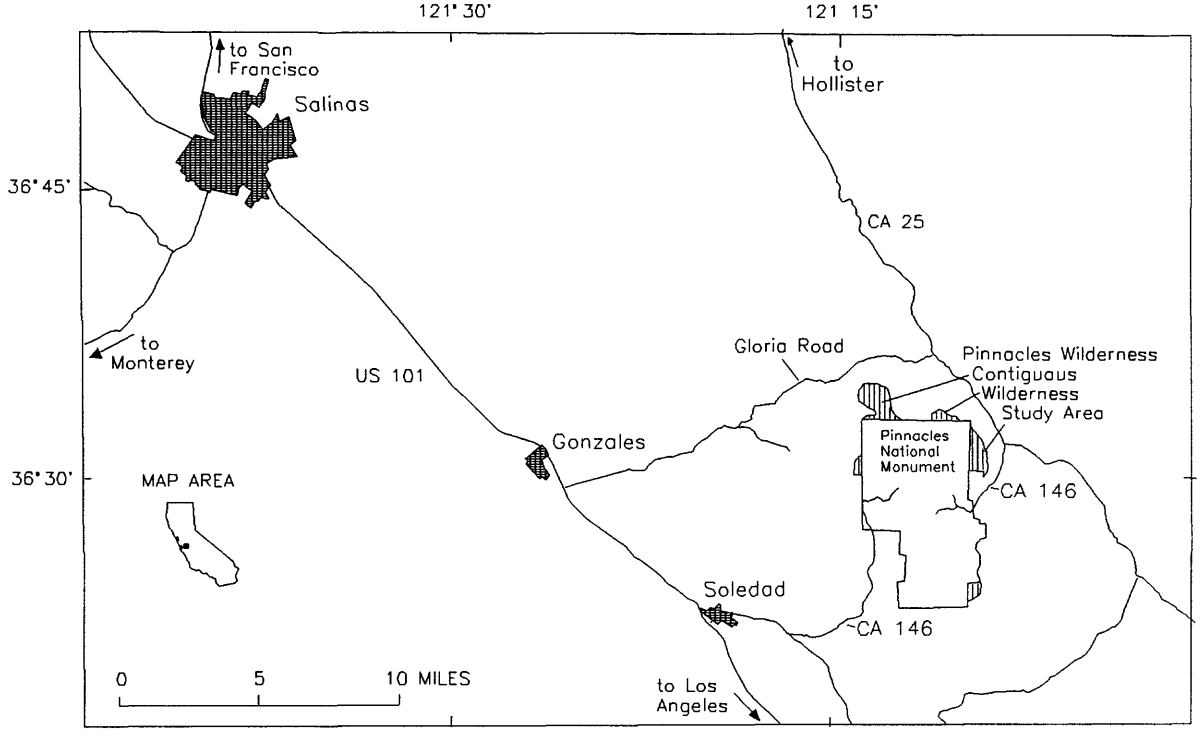


Figure 1. Index map showing location of Pinnacles Wilderness Contiguous Wilderness Study Area.

On the east and west, access is via California State Highways 25 and 146, and private dirt roads that lead from them. Access from the south is poor; the nearest road is a county-maintained gravel road in the Topo Valley, 3 mi. south of the study area.

The geology of the Pinnacles National Monument and vicinity was first discussed by Fairbanks (1894). Andrews (1936) published the first detailed geologic map and description of the area. Subsequent geologic studies include Wilson (1943), Hinds (1952), Jennings and Strand (1959), Dibblee (1971,1975), Ross (1962a,b), and Matthews (1976a,b). Descriptions of mines and prospects in or near the area were reported by Crawford (1894), Bradley and Logan (1919), Boalich (1922), Andrews (1936), Wilson (1943), Eric (1948), Butler and others (1962), Hart (1966), and Smith and others (1971).

USGS personnel examined the study area in May of 1985. Existing geologic maps were field checked and about 40 rock samples were collected. 28 of them were analyzed using energy-dispersive X-ray fluorescence methods for Mn, Fe, Cu, Zn, Ga, As, Rb, Sr, Y, Zr, Nb, Mo, Sn, Ba, La, and Ce. Rock samples were slabbed in order to study their textures.

We wish to thank personnel of the Hollister office of the BLM and the Pinnacles National Monument staff of the NPS for their cooperation, as well as several private landowners for access to parts of the study area.

GEOLOGIC SETTING

The oldest rocks in the study area are felsic intrusive rocks, primarily of Cretaceous age, with some small pendants and inclusions of metamorphic rock. They have been described by Ross (1962a,b). Overlying the Cretaceous igneous rocks is a series of volcanic rocks, assigned by Matthews (1976a) to the Pinnacles Volcanic Formation. These rocks occur as a homoclinal, west-dipping section in a graben, bounded on the west by the Pinnacles fault and, on the east, by the Chalone Creek fault (Fig. 2). Rocks from the Pinnacles Volcanic Formation have been dated, using K-Ar methods, by Turner (1968) to be about 23.5 ma, or Early Miocene, in age. Though Matthews (1976a) presents a more complex subdivision, these rocks may be divided into two major units, a rhyolite unit and a breccia unit.

The rhyolite unit, which is oldest, consists of a series of primarily rhyolitic flows and intrusions. These flows and intrusions issued from a series of northwest-trending fissures that are represented by a swarm of rhyolitic dikes outside of the graben. In a few areas, notably on South Chalone Peak, in the southern part of the study area, complex vent breccias occur, indicating the source of the youngest eruptions of this unit. In the central part of the study area, a small volume of more mafic rocks, dacite and andesite, is present. A few of the dikes are dacitic in composition.

Overlying these flows and intrusions is the breccia unit, a thick section that consists primarily of rhyolitic breccias. These breccias form the spectacular pinnacles, which are the chief scenic attraction of the National Monument. The clasts in the breccia consist primarily of lithic fragments of the underlying rhyolitic flows and intrusions. The matrix is fine-grained volcanic material. Matthews (1976a) was led by evidence that includes marine fossils, graded bedding, and stratification into

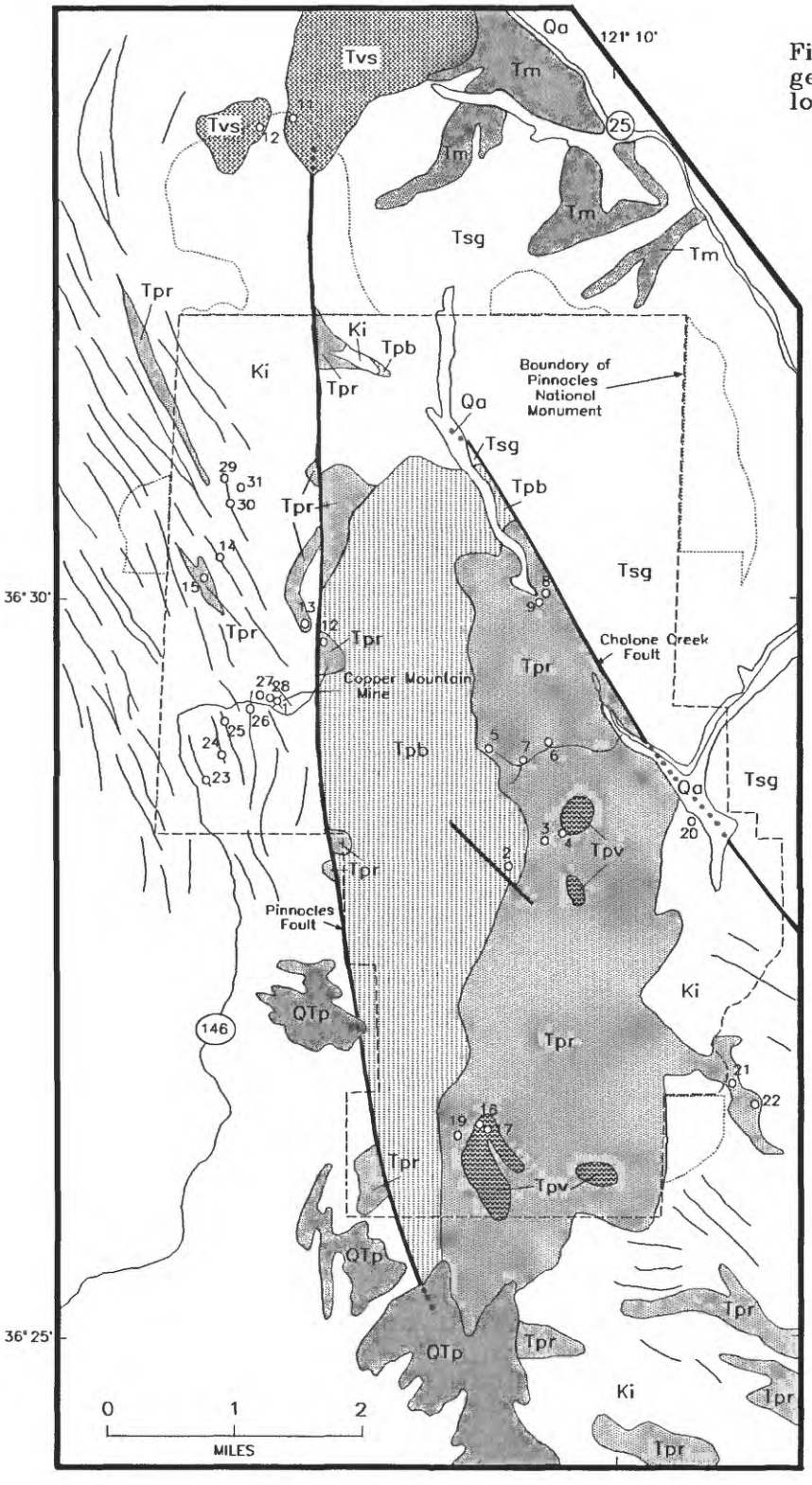
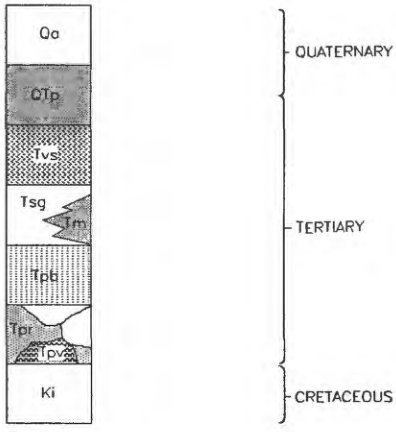


Figure 2. Generalized geology and sample locations.

EXPLANATION

CORRELATION OF MAP UNITS



Boundary of Wilderness Study Area

Qa	ALLUVIUM (QUATERNARY) Modern alluvium, consisting of locally derived silt, sand, and gravel; product of erosion of modern ephemeral streams.
QTp	PASO ROBLES FORMATION (QUATERNARY and TERTIARY) Terrestrial silts, sand, and gravel; preserved as terraces.
Tvs	VOLCANICLASTIC SEDIMENTS (MIOCENE) Light gray breccia and conglomerate of rhyolitic debris.
Tm	MONTEREY FORMATION (MIOCENE) Marine diatomaceous and siliceous shale; locally sandy.
Tsg	SANDSTONE AND CONGLOMERATE (MIOCENE) Light gray conglomerate of unsorted clasts of granitic and rhyolitic rock in arkosic sandstone matrix
Tpb	BRECCIA OF PINNACLES FORMATION (MIOCENE) Buff breccia and conglomerate of rhyolitic fragments in a volcanic matrix.
Tpr	RHYOLITE OF PINNACLES FORMATION (MIOCENE) Buff rhyolite flows and intrusions; flow-banded and massive; includes some dacite and andesite.
TPv	VENT BRECCIA (MIOCENE) Coarse breccia of rhyolitic fragments in volcanic matrix; fills throats of volcanic vents.
Ki	INTRUSIVE ROCKS (CRETACEOUS) Granite, quartz monzonite, and granodiorite.

CONTACT

FAULT – Dotted where concealed

°23 SAMPLE LOCATION – With number

hundreds of individual beds, to conclude that this unit formed in a sub marine environment, as the result of mass slumping and turbidity currents on the flanks of an erupting vent.

Overlying the volcanic rocks is a sequence consisting primarily of continental arkose and conglomerate composed of fragments of the underlying granitic basement and debris from the Pinnacles Volcanic Formation. These rocks have been deformed into several open folds in the northeast part of the area, northeast of the Chalone Creek Fault. These beds dip generally to the northeast. They were assigned a Middle Miocene age by Wilson (1943) and Dibblee (1971,1975). Intercalated with these rocks are siliceous shales assigned to the Miocene Monterey Formation by Dibblee (1975), who also mapped a sedimentary rhyolitic breccia unit at the north end of the study area. This is composed almost entirely of rhyolitic debris from the Pinnacles Volcanic Formation and represents the same depositional environment as the arkose and conglomerate, but at a time when the Pinnacles Volcanic Formation was the primary source of the sediments.

A few terraces in the southern part of the study are covered with terrestrial gravels of Late Pliocene or Early Pleistocene age that Dibblee (1971) assigned to the Paso Robles Formation. The bottoms of many of the ephemeral stream valleys in the area are filled with river sediment of Quaternary age.

TRACE-ELEMENT GEOCHEMISTRY

Results of energy-dispersive X-ray fluorescence analysis of selected rock samples from the Pinnacles volcanic field are presented in Table 1. Sample locations are shown on Figure 2.

The results show the Pinnacles rocks to be a typical calc-alkaline volcanic series. The rhyolites are relatively low-silica (see Matthews, 1976a), and are not strongly enriched in alkalis or in incompatible trace elements such as rubidium or niobium. A few samples show perturbation of barium and strontium values, both leaching and enrichment. This is probably a result of vapor-phase alteration, and is not indicative of widespread hydrothermal alteration. The rock suite is enriched in arsenic. Several samples, both of intrusive and extrusive rhyolite, have arsenic values greater than the 15 ppm detection limit. Thus, the rocks are a potential source for epithermal precious-metal deposits, which are characterized by high arsenic.

Sample PIN-1, which is of mineralized rock from the Copper Mountain Mine, within the National Monument, shows a chemical pattern typical of epithermal precious-metal deposits related to calc-alkaline igneous rocks. It is enriched in copper, lead, and zinc, in addition to arsenic, and probably has detectable gold and silver content, though these elements were not analyzed.

RELATIONSHIP OF GEOCHEMISTRY TO MINERAL DEPOSITS

The Pinnacles volcanic field is an appropriate setting for hot spring gold-silver deposits (Berger, 1985). These are found in the shallow part of young rhyolitic volcanic centers of calc-alkaline affinity that are related to subduction zones or transform faults. They are characterized geochemically by the association of

arsenic and antimony with the precious metals. The geochemical signature of sample PIN-1 is permissive for this type of deposit, and the calc-alkaline nature of the Pinnacles rhyolites is also appropriate.

Other deposit types commonly found in rhyolitic rocks include volcanogenic uranium, volcanogenic beryllium, and rhyolite-hosted tin deposits. All these are found with high-silica alkali rhyolites, not the calc-alkaline type to which the Pinnacles rhyolites belong.

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Table 1. ENERGY-DISPERSIVE X-RAY FLUORESCENCE ANALYSES OF SELECTED ROCK SAMPLES

Sample No	Rock type	form	Mn	FeO	Cu	Zn	Ga	As	Rb	Sr	Y	Zr	Nb	Mo	Pb	Ba	La	Ce
PIN- 1	*		900	66.8	4020	225	<25	1400	109	185	<5	187	<5	101	150	462	24	38
PIN- 2	rhyolite	f	<100	0.9	<50	45	<25	15	235	49	24	101	23	<10	<20	352	25	44
PIN- 3	rhyolite	i	<100	1.0	<50	75	<25	<15	226	46	26	100	25	<10	<20	302	28	42
PIN- 4	rhyolite	f	<100	0.6	<50	35	<25	50	207	39	24	83	24	<10	<20	387	30	43
PIN- 5	dacite	f	230	4.2	<50	50	<25	<15	159	197	16	293	20	<10	<20	963	52	83
PIN- 6	rhyolite	f	<100	0.7	<50	100	<25	<15	230	46	28	96	27	<10	<20	300	25	55
PIN- 7	rhyolite	f	<100	0.9	<50	75	<25	20	114	652	26	95	28	<10	<20	269	22	41
PIN- 8	rhyolite	f	180	1.3	<50	85	<25	<15	166	76	17	90	19	<10	25	498	29	56
PIN- 9a	rhyolite	f	<100	0.8	<50	45	25	15	224	46	12	95	25	<10	20	317	25	44
PIN- 9b	rhyolite	f	110	0.9	<50	75	<25	<15	217	174	27	91	24	<10	<20	306	23	40
PIN-10	rhyolite	f	<100	1.0	<50	65	<25	15	244	42	26	98	29	<10	<20	290	25	47
PIN-11	rhyolite	f	<100	0.9	<50	55	<25	<15	223	57	31	99	25	<10	50	304	25	43
PIN-12	rhyolite	i	<100	1.0	<50	<30	<25	25	102	36	11	51	8	<10	125	133	<15	15
PIN-13	rhyolite	i	<100	0.9	<50	60	<25	15	271	73	20	90	25	<10	<20	353	24	42
PIN-13a	rhyolite	i	160	1.0	<50	85	<25	<15	215	57	25	95	26	<10	30	288	23	43
PIN-14	rhyolite	i	<100	1.0	<50	70	30	25	143	114	8	105	18	12	20	920	27	46
PIN-16	rhyolite	i	<100	1.3	<50	70	25	<15	190	163	11	163	14	<10	<20	1038	39	70
PIN-19	rhyolite	i	130	1.1	<50	70	<25	<15	248	53	17	97	26	<10	25	3717	57	82
PIN-20	rhyolite	f	<100	0.9	<50	70	30	<15	273	124	27	92	25	<10	25	316	24	42
PIN-21	rhyolite	i	<100	1.2	<50	85	<25	<15	157	210	25	103	20	<10	20	297	22	43
PIN-22a	rhyolite	i	<100	0.4	<50	45	<25	<15	182	40	13	75	19	<10	25	556	30	52
PIN-22b	rhyolite	i	130	0.6	<50	50	<25	<15	204	57	9	56	14	<10	<20	266	20	33
PIN-23	dacite	i	370	4.8	<50	90	<25	<15	100	449	26	210	20	<10	<20	278	<15	16
PIN-24	rhyolite	i	210	2.0	<50	65	<25	<15	136	244	16	122	8	<10	<20	1644	42	73
PIN-25	rhyolite	i	180	1.8	<50	65	<25	<15	113	301	12	118	9	<10	<20	919	33	60
PIN-28b	dacite	i	450	5.3	<50	90	<25	15	136	267	19	120	23	<10	<20	721	31	52
PIN-30	rhyolite	i	<100	1.0	<50	45	<25	<15	160	51	12	103	14	<10	<20	604	21	35
PIN-31	dacite	i	310	5.2	<50	95	<25	<15	89	505	24	203	18	<10	45	807	42	70

* - Mineralized sample from Copper Mountain mine

f = flow, i = intrusion (plug or dike)

All results are reported in parts per million (ppm) except FeO, which is reported in weight percent.

Detection limits not evident from the table: FeO, 0.02%; Rb, Sr, Zr, 5 ppm; Ba, 15 ppm.

Mn is reported to the nearest 10 ppm; Cu, Zn, Ga, As, Pb are reported to the nearest 5 ppm.

Most values are accurate to within 5% of the amount present.