TERTIARY VOLCANIC ROCKS OF THE MINERAL MOUNTAIN AND TEAPOT MOUNTAIN QUADRANGLES, PINAL COUNTY, ARIZONA

By

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FOREWARD

The text of this report was presented orally at the October 1978, Annual Meeting of the Geological Society of America in Toronto, Canada. It is being released, with minor changes, in this informal manner to make some of the data from our studies in the Mineral Mountain and Teapot Mountain quadrangles available to those interested in Arizona geology, and not able to attend the meetings.

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ABSTRACT

The widespread distribution of Tertiary volcanic rocks in south-central Arizona is controlled in part by prevolcanic structures along which volcanic vents were localized. Volcanic rocks in the Mineral Mountain and Teapot Mountain quadrangles mark the site of a major northwest-trending structural hingeline. This hingeline divides an older Precambrian X terrane on the west from intensely deformed sequences of rock as young as Pennsylvanian on the east, suggesting increased westerly uplift. The volcanic rocks consist of a pile of complexly interlayered rhyolite, andesite, dacite, flows and intrusive rocks, water-laid tuffs, and very minor olivine basalt. Although the rocks erupted from several different vents, time relations, space relations, and chemistry each give strong evidence of a single source for all the rocks. Available data (by the K-Ar dating method) on hornblende and biotite separates from the volcanic rocks range from 14 to 19 m.y. and establish the pre-middle Miocene age of major dislocations along the structural hingeline. Most of the volcanic rocks contain glass, either at the base of the flows or as an envelope around the intrusive phases. One of the intrusive rhyolites, however, seems to represent one of the final eruptions. Intense vesiculation of the intrusive rhyolite suggests a large content of volatiles at the time of its eruption. Mineralization is associated with the more silicic of these middle Miocene volcanic rocks; specifically, extensive fissure quartz veins contain locally significant amounts of silver, lead, and zinc and minor amounts of gold. Many of the most productive deposits are hosted by the volcanic rocks, although others occur in the Precambrian rocks. Magnetic data correspond roughly to the geology in outlining the overall extent of the volcanic rocks as a magnetic low.

INTRODUCTION

The Mineral Mountain and Teapot Mountain 7 1/2 ′ quadrangles are located in south central Arizona between Phoenix and Tucson (fig. 1), south of the Superior volcanic field of Royse, Sheridan, and Peirce (1971). The quadrangles are about 3 km south of the town of Superior, which is also the location of the Magma copper deposit, and are about 1 km west of the Ray porphyry copper deposit.

GENERAL GEOLOGY

Figure 2 shows the general geology of this region. There is a Precambrian metamorphic terrain cropping out extensively on the west, Tertiary volcanic rocks in the center along the boundary between the Mineral Mountain and Teapot Moutain quadrangles, and intensely deformed Paleozoic rocks in the east. These volcanic rocks lie along a north-northwest-trending zone which previously has been referred to by Hammer and Peterson (1968) as a major

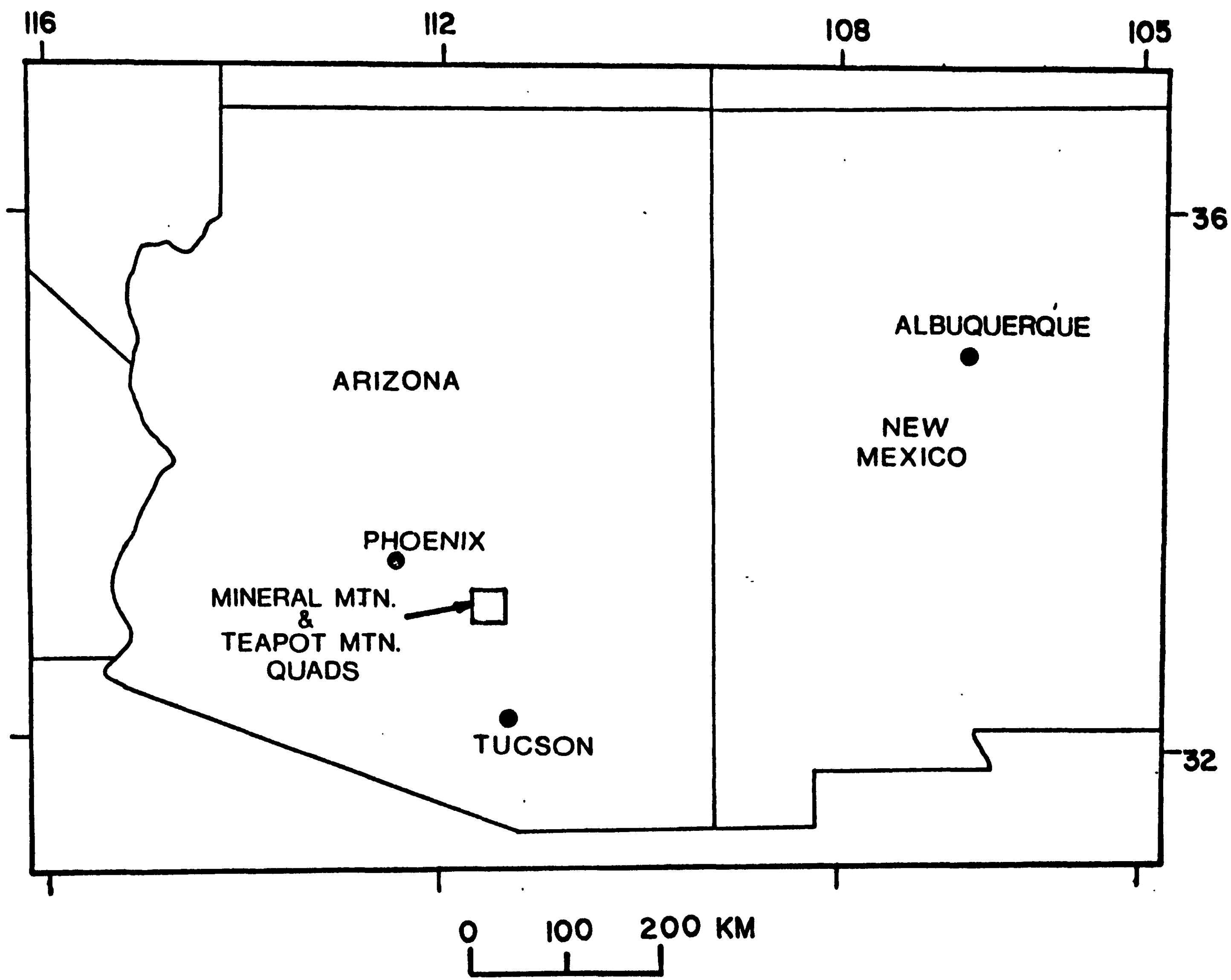

Figure 1.--Index map showing the location of the Mineral Mountain and Teapot Mountain 7-1/2-minute quadrangle.

structural hingeline. Along this hingeline the Tertiary magmatism, including both volcanic and intrusive rocks, appear to be at least partially structurally controlled. The Precambrian Pinal schist consists of two distinctly different terrains: a brown low-grade schist and an apparently tectonically juxtaposed higher metamorphic grade, white to gray schist which is internally intensely deformed. Precambrian YX Madera diorite crops out near the northern boundary of the Mineral Mountain quadrangle west of the Precambrian Y Apache Group and Troy Quartzite (fig. 2). The Madera here has been dated at 1588±8 m.y. (E. H. McKee, 1978, written commun.) by using the K-Ar method on a hornblende. In addition, several mineral separates from the quartz monzonite of Mineral Mountain, which crops out near the southwest corner of the Mineral Mountain quadrangle, yielded 65-66 m.y. ages from unpublished data S. C. Creasey and E. H. McKee (1978). On the west, the Precambrian basement is cut off by a major and apparently deep seated range front fault that places unconsolidated Quaternary sediments against the Pinal Schist, quartz monzonite of Mineral Mountain, and Precambrian Ruin Granite. Near the northeast corner of the Mineral Mountain quadrangle (fig. 2) there is a north-trending mass of Precambrian Y sedimentary rocks of the Apache Group and Troy Quartzite.

Figure 3 is a view toward the northeast of the Apache Group, Pinal Schist, and the generally flat lying Tertiary volcanic rocks that rest unconformably on the Precambrian. The Tertiary rocks are in depositional contact with the underlying Pinal Schist which is, in turn, here thrust over the Apache Group rocks at the bottom of figure 3. The absence locally of Paleozoic rock to the west of the hingeline, together with the generally east to west decreasing age in the Tertiary sequences (which will be described fully below), seem to indicate that there was pre-Tertiary uplift to the west.

The Tertiary rocks in the Mineral Mountain and Teapot Mountain quadrangles include significant exposures of volcanic rocks (fig. 4), all roughly equivalent in age. The Oligocene Whitetail Conglomerate, which has been dated at 33 m.y. (Krieger, 1978, unpub. data) crops out widely in the south central and eastern parts of the Teapot Mountain quadrangle. The Miocene Apache Leap Tuff, dated at 20.8 m.y. (recalculated from Creasey and Kistler, 1962, using new decay constants and isotopic abundances recommended in 1976 by the International Commission on Stratigraphy, Subcommission on Geochronology (Steiger and Jager, 1977)) crops out only in the Teapot Mountain quadrangle and has not been recognized farther to the west than a few isolated patches almost at the boundary between the two quadrangles. The volcanic rocks consist of four major groups: tuff, which is almost entirely water laid, dacite, rhyolite, and thin basalt flows. The tuff is roughly dacitic in composition and is generally lithic rich, although, small amounts of crystal tuff occur. The tuff has been faulted as have all of the other rocks in the Tertiary section, and although tuff high in the sequence is generally flat lying (fig. 3), there are fault-bounded tilted blocks elsewhere lower in the Tertiary sequence. The water-laid tuff unit hosts small amounts of all of the other types of Tertiary volcanic rock. Dacite occurs both as flows and as dikes. The proportion of hornblende and quartz phenocrysts in this unit varies significantly. Both flows and dikes of dacite vary modally from 0- to 38-volume-percent quartz and 0- to 23-volume-percent hornblende. In addition, plagioclase (An_{40-50}) and biotite phenocrysts are ubiquitous in the unit. In general the dacite is quite glassy. Locally, the groundmass is almost

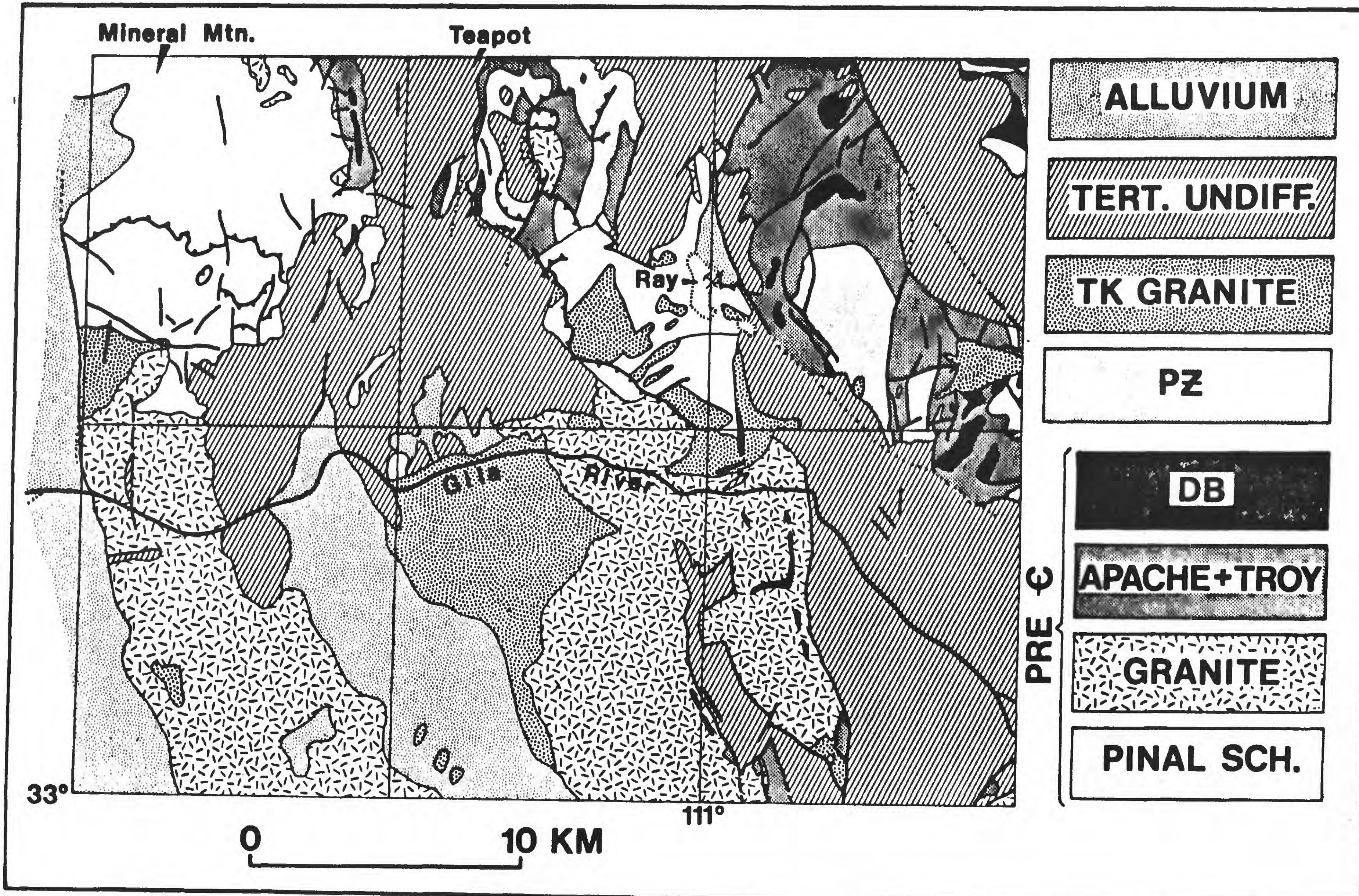

Figure 2.--Geologic sketch map showing regional geologic relations mostly to the east and southeast of the Mineral Mountain and Teapot Mountain quadrangles. Modified from Krieger (1977, pl. 1), Theodore and others (1978), Creasey and others (1975), Cornwall and others (1971), Cornwall and Krieger (1975a), Cornwall and Krieger (1975b), and Wilson and Moore (1959).

Figure 3.--View toward the north-northeast near the northeast corner of Mineral Mountain quadrangle showing the Precambrian X Pinal Schist thrust over the Precambrian Y Apache Group, both of which are overlain unconformably by flat-lying Tertiary volcanic rocks. The volcanic rocks here are mostly water-laid tuff.

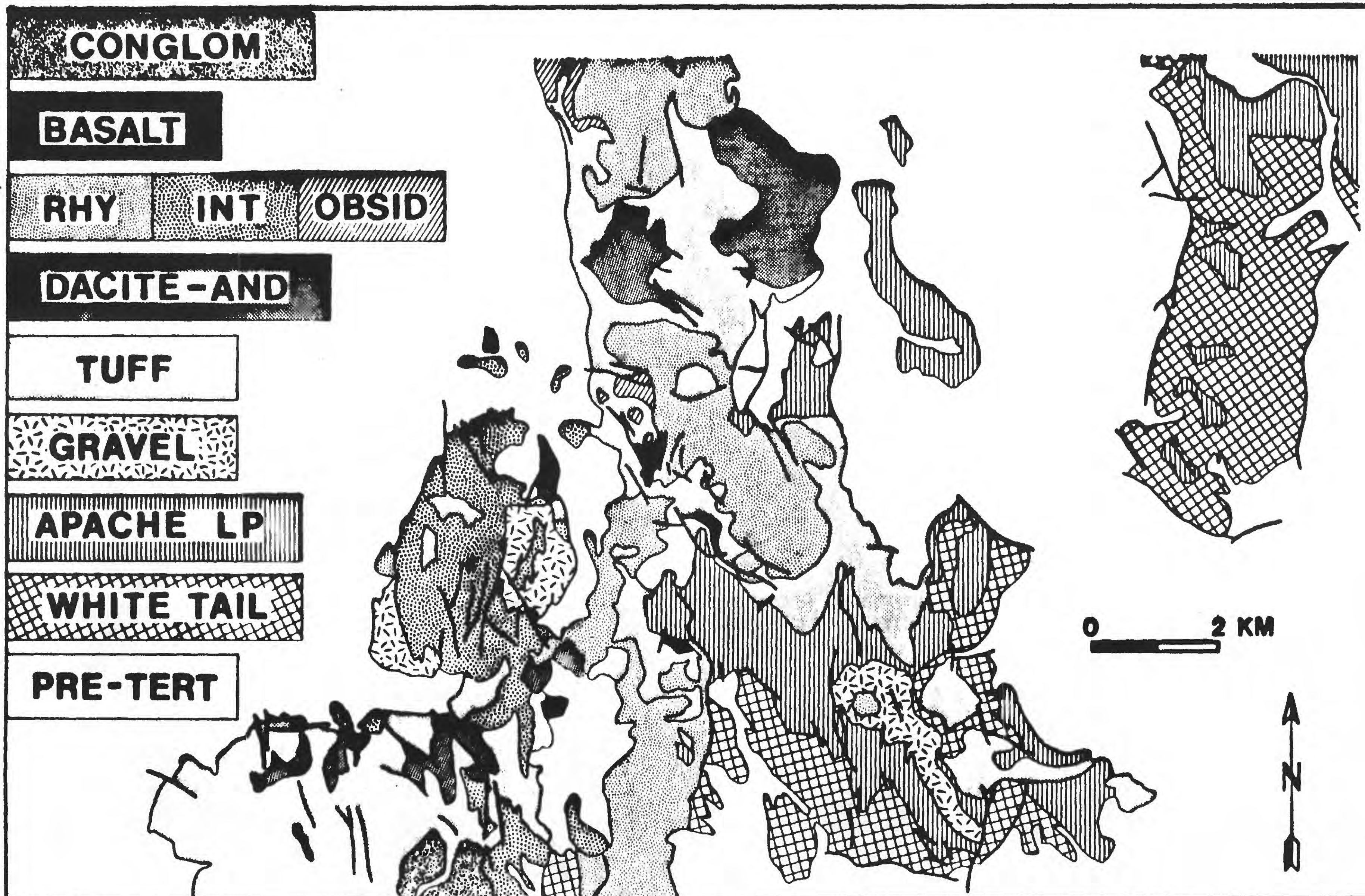

Figure 4.--Geologic sketch map of the Mineral Mountain and Teapot Mountain quadrangles showing only the major Tertiary map units. Modified from Creasey and others (1975) and Theodore and others (1978).

entirely composed of partially devitrified glass. Basalt occurs sporadically throughout the tuffs and is made up of thin flows 90 to 120 cm thick. These flows are aphanitic olivine basalts which show chilled basal portions and vesiculated tops. The flows could be and probably are outliers of a thicker mass in the central part of the area since they tend to thicken toward the central part of the volcanic pile. The rhyolitic rocks occur both as massive cliff-forming intrusive rocks and as gently rounded flow rocks. The intrusive phases of rhyolite almost invariably show a glass rind along the margins which varies in thickness from 1 to 5 m. Phenocrysts in the rhyolitic rocks are generally limited to sanidine, quartz, and sporadic biotite. Rhyolite flows also contain a glass phase of variable thickness which is limited to the basal parts of the flows. The rhyolitic and dacitic rocks appear to be roughly contemporaneous because they both flow on, and also intrude each other.

One of the larger rhyolitic bodies in the general area of the Martinez mine is especially interesting in that it apparently shows evidence for being one of the last of this Tertiary volcanic complex to be erupted. It evidently contained a large quantity of volatiles and as it fractured the overburden and released the confining pressure, the mass vesiculated. Evidence for this is included in the following two figures. Figure 5 shows a close-up of the intrusive contact of a highly vesiculated dikelike mass of rhyolite that is chilled and solidified against typical rhyolite. The vesiculated rhyolite contains vesicles (fig. 6) that are elongate in the direction of movement and that reach 8 cm in small dimension. Thin sections of this highly vesiculated unit show phenocrysts of quartz and sanidine in overall proportions typical of the nonvesiculated rhyolitic rocks throughout the area.

K-AR AGES AND CHEMISTRY

Figure 7 shows the localities of the Tertiary volcanic rocks which have been dated by S. C. Creasey and E. H. McKee using the K-Ar method. The rocks, all roughly Miocene in age, range from 14-19 m.y.;biotite, hornblende, and whole-rock samples were dated.

Figure 8 shows the minerals dated and the bars represent the $\pm$ uncertainties in the age determinations. Such plots emphasize graphically the overall 14-19 K-Ar age range of the Miocene volcanic rocks. The age labeled "blow out" on Figure 8 represents the 14.4 ± 0.3-m.y. age determination on a biotite separate from the vesiculated intrusive just described above. Note that this age is the youngest K-Ar age obtained, and geologically we judge the vesiculation to be one of the youngest volcanic events. Most likely this reflects the large amount of volatiles associated with this particular mass of intrusive rhyolite.

Figure 9 shows the relations between aeromagnetic data and the volcanic rocks. The data are contoured in intervals of 100 gammas, and they show a regional gradient generally increasing in a northwesterly direction.

Chemically, all the Miocene volcanic rocks define a calc-alkaline trend (fig. 10), which lies on the one formed by the rocks related to the Superior volcanic field (Keith, 1978, Table 3). The solid dots are analyses from this study. The open circles are unpublished data from S. C. Creasy and the 2 squares near the alkali corner are from Bohmer (1965).

Figure 5.--Close-up view of the intrusive contact of a highly vesiculated mass of rhyolite (left center) that is chilled and solidified against typical nonvesiculated intrusive rhyolite. Note location: Mineral Mountain quadrangle, 30 m west of the main shaft of the Silver Bell mine in the N-1/2 sec. 18, T. 3 S., R. 12 E.

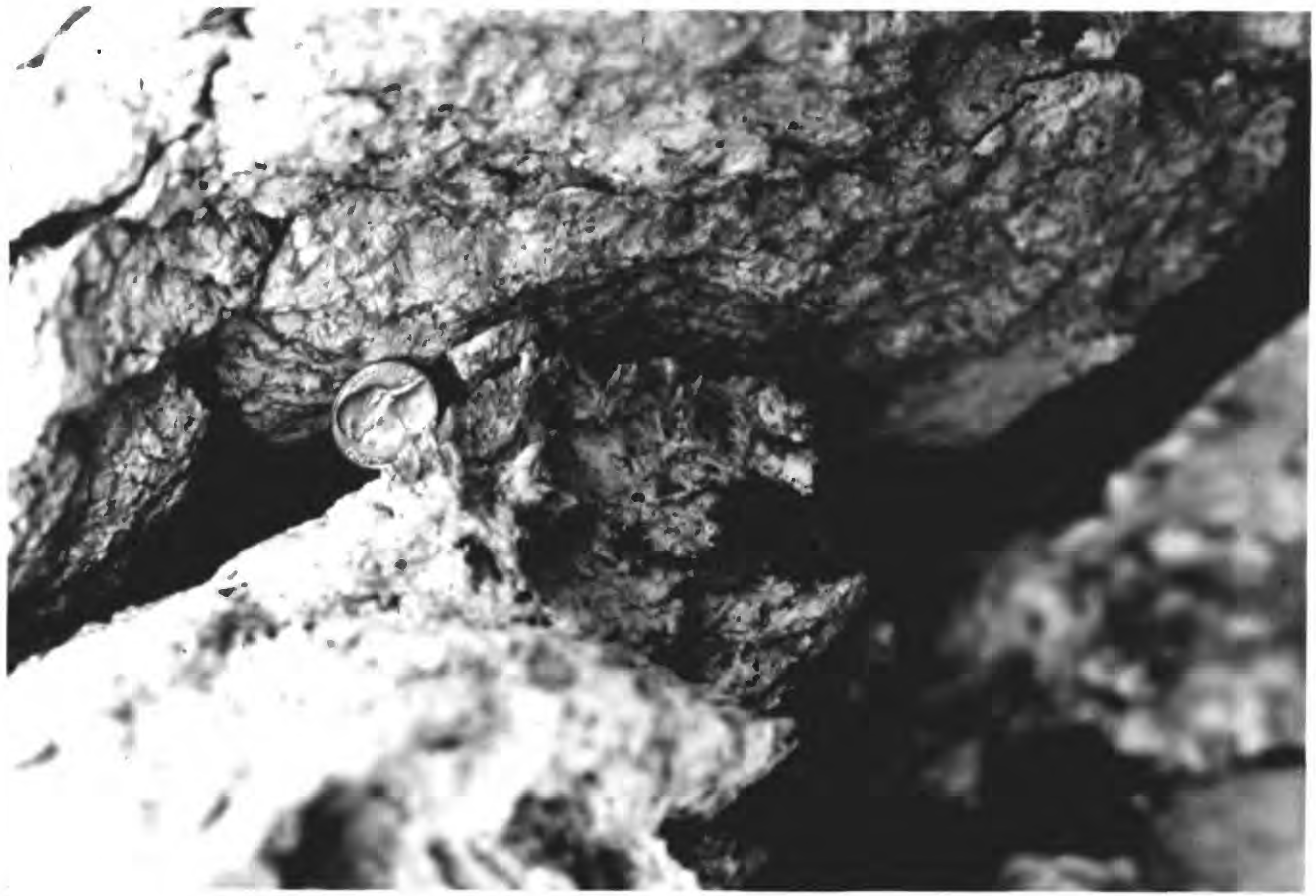

Figure 6.--Close-up view of vesicle. Location: same as figure 5.

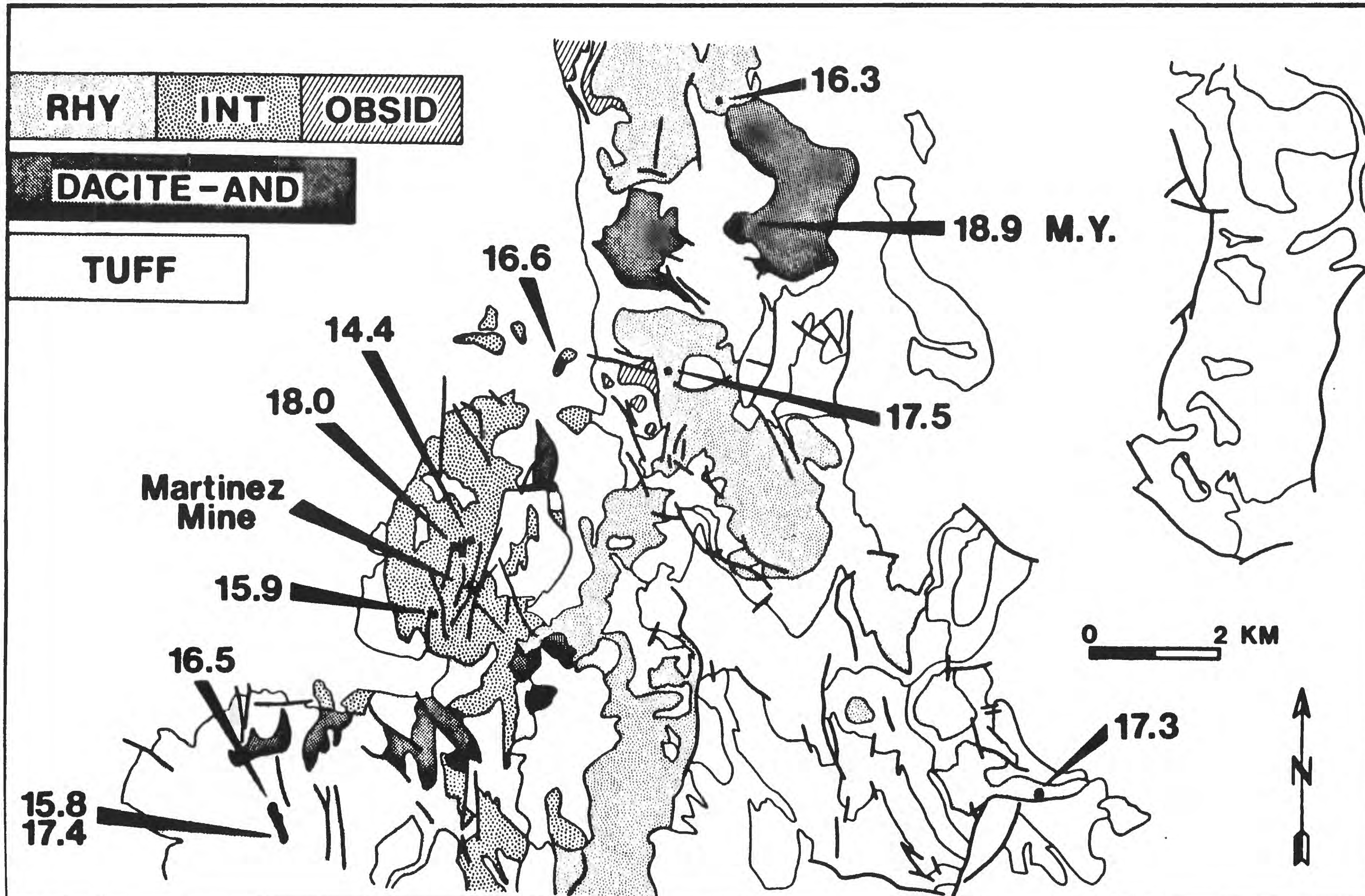

Figure 7.--Sketch map showing the localities sampled and the K-Ar ages in millions of years (m.y.) obtained from the water-laid tuff, dacite, and rhyolite map units in the Mineral Mountain and Teapot Mountain quadrangles.

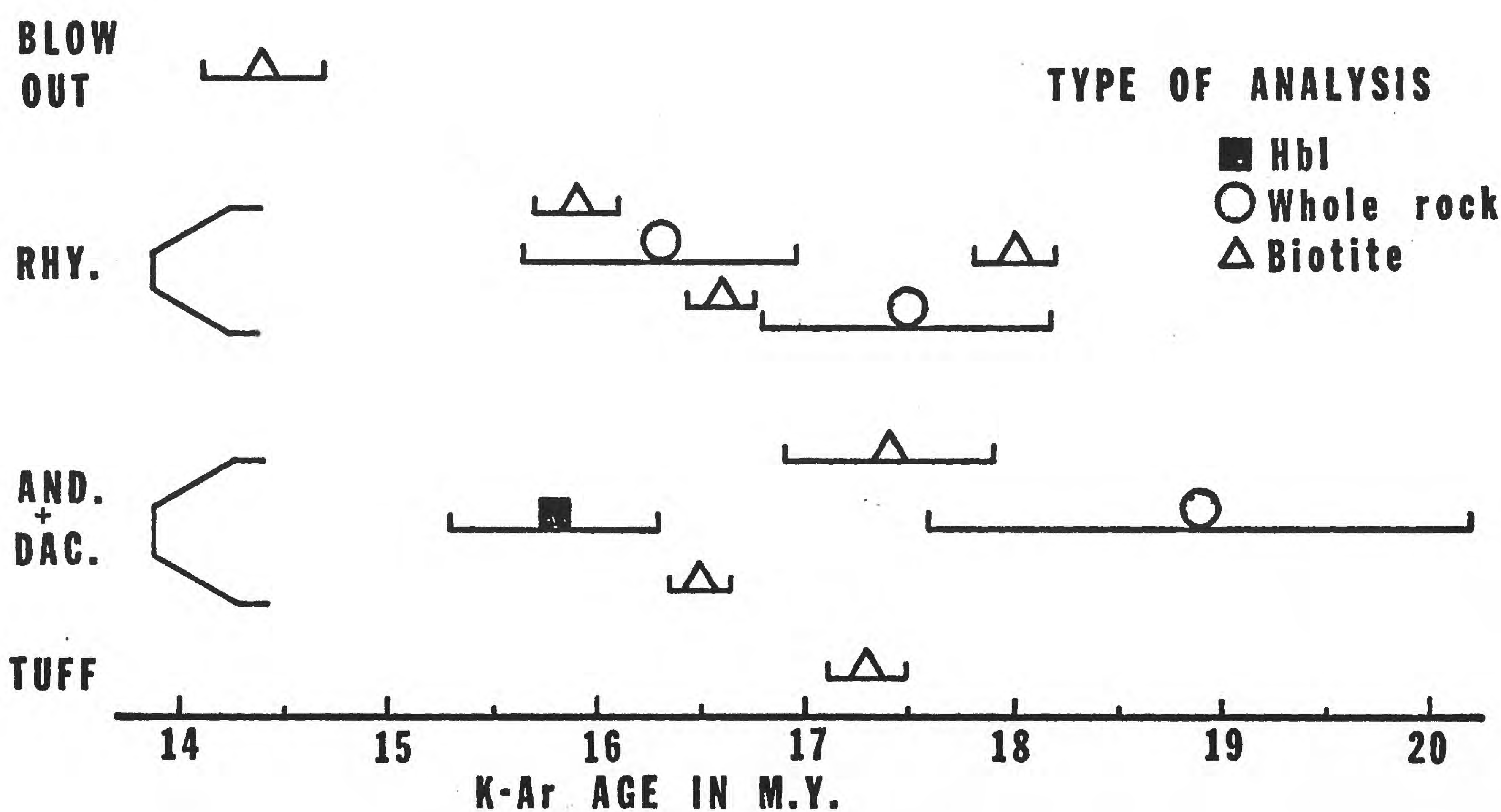

Figure 8.--Bar graphs of K-Ar ages of volcanic rocks, Mineral Mountain and Teapot Mountain quadrangles.

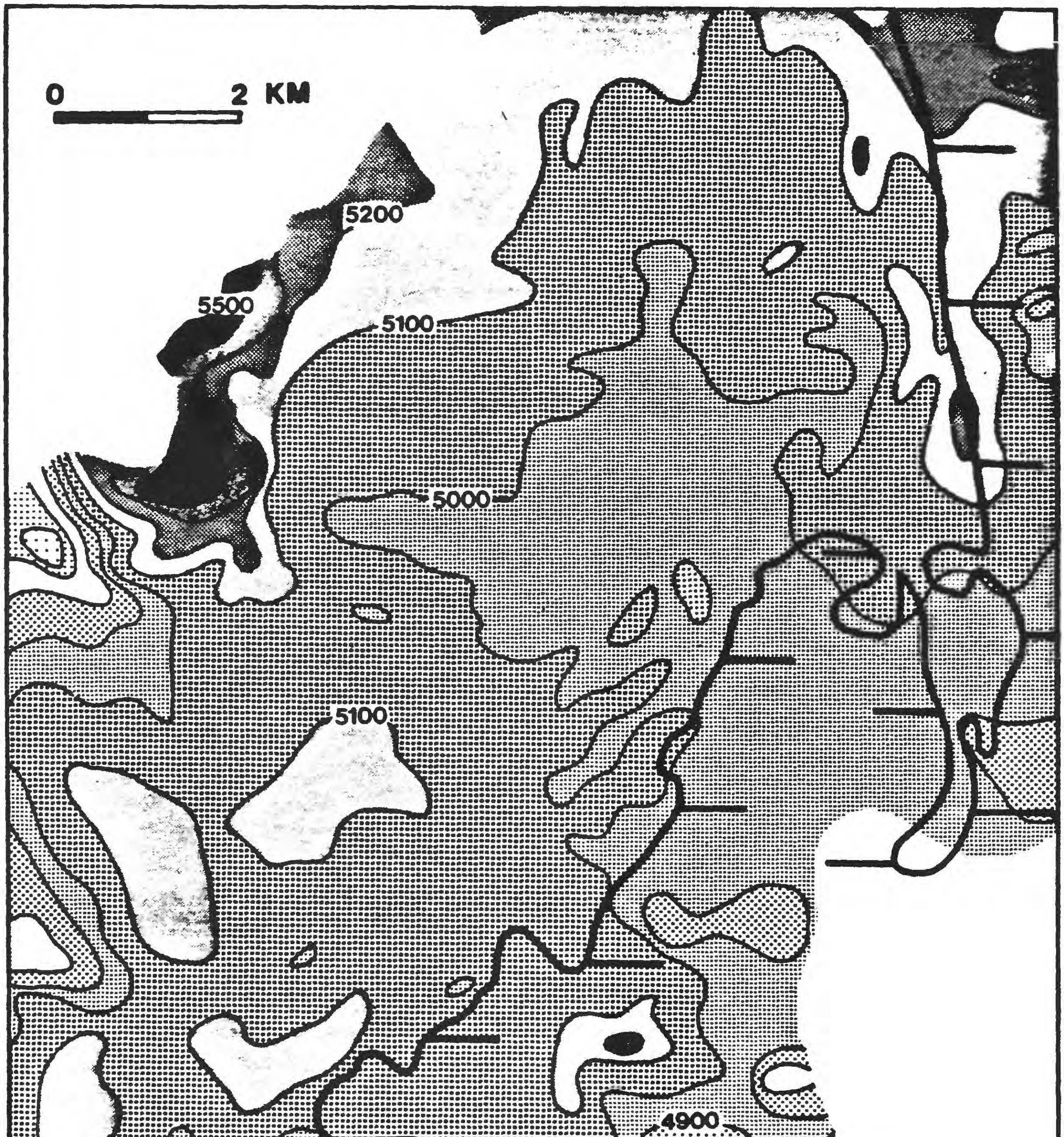

Figure 9.--Aeromagnetic map of part of the Mineral Mountain 7-1/2-minute quadrangle. Contour intervals 100 gammas. Generalized contact of major outcrops of Miocene volcanic rocks shown also. Hachures on side of volcanic rocks.

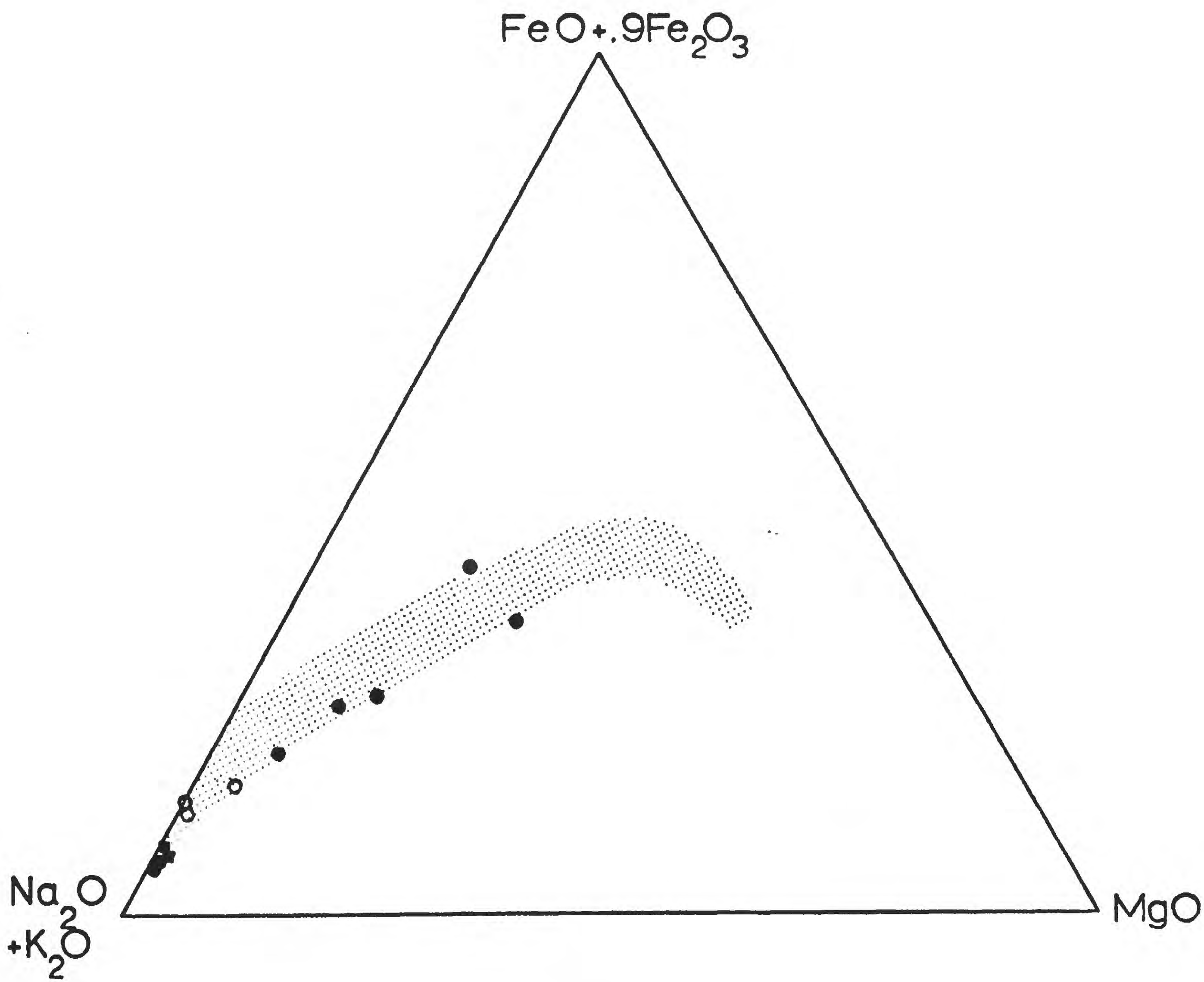

Figure 10.--Ternary $FeO+.9Fe_2O_3$: Na_2O+K_2O: MgO plot showing major oxide analyses from our study of the Miocene volcanic rocks in the Mineral Mountain (solid dots), Teapot Mountain quadrangles (open circles, from S. C. Creasey, unpub. data), Bohmer (1965) (solid squares), and the range of data available for the central part of the Superior volcanic field (modified from the data available in the references in table 3 of Keith, 1978).

MINERALIZATION

Mineralization in this general area is associated with the Tertiary volcanic rocks and is mainly silver bearing galena and minor gold. The main producers in the Tertiary volcanic rocks were the Martinez (fig. 7) and the nearby Silverbell and Columbia mines. These mines produced intermittently over the last 100 years and their cumulative production is roughly estimated at 1 million ounces of silver. Typically, the veins are composite, showing repeated opening and closing. Mineralogically, the veins, which are moderate temperature epithermal ones are composed of quartz, barite, fluorite, and galena, and minor amounts of sphalerite. Fluid inclusions from the veins were analysed using standard heating and freezing stage techniques. Fluids are moderately saline (9-13 equivalent weight percent NaCl) and filling temperatures of the inclusions are in the 190-305^{o}C range.

Our preliminary studies on these veins suggest the fluids associated with their implacement were not boiling. By assuming that our highest filling temperatures (about 300^{o}C) and a fluid composition of about 10 weight percent NaCl equivalent were probably representative of the veins depositional environment during their early stages of emplacement, we judged these veins then, to have formed at pressures greater than 80 bars or at depths greater than 900 m in a purely hydrostatic environment, or depths greater than 250 m in a purely lithostatic environment. However, such extensive post-Miocene erosion seems geologically unreasonable here, which in turn suggests a buildup of possibly greater than lithostatic pressure in the vein's environment just prior to the "blow out" indicated by the vesiculated rhyolite adjacent to some of the most highly mineralized vein systems.

REFERENCES

Bohmer, Harold, 1965, Geology of a rhyolite plug, Pinal County, Arizona: Geological Society of America Bulletin, v. 76, p. 1309-1314.

Cornwall, H. R., Banks, N. G., and Phillips, C. H., 1971, Geologic map of the Sonora quadrangle, Pinal and Gila Counties, Arizona: U.S. Geological Survey Geologic Quadrangle Map GQ-1021, scale 1:24,000.

Cornwall, H. R., and Krieger, M. H., 1975a, Geologic map of the Kearny quadrangle, Pinal County, Arizona: U.S. Geological Survey Geologic Quadrangle Map GQ-1188, scale 1:24,000.

_____1975b, Geological map of the Grayback Mountain quadrangle, Pinal County, Arizona: U.S. Geological Survey Geologic Quadrangle Map GQ-1206, scale 1:24,000.

Creasey, S. C., and Kistler, R. W., 1962, Age of some copper-bearing porphyries and other igneous rocks in southeastern Arizona, in Short papers in geology, hydrology, and topography, articles 120-179: U.S. Geological Survey Professional Paper 450-D, p. D1-D5.

Creasey, S. C., Peterson, D. W., and Gambell, N. A., 1975, Preliminary geologic map of the Teapot Mountain quadrangle, Pinal County, Arizona: U.S. Geological Survey Open-File Report 75-314.

Hammer, D. F., and Peterson, D. W., 1968, Geology of the Magma mine area, Arizona, in Ridge, John, D., ed., Ore deposits in the United States, 1933-1967 (Graton-Sales Volume), V. 2: New York, American Institute of Mining, Metallurgical and Petroleum Engineers, p. 1282-1310.

Keith, S. B., 1978, Paleosubduction geometries inferred from Cretaceous and Tertiary magmatic patterns in southwestern North America: Geology, v. 6, no. 9, p. 516-522.

Krieger, M. H., 1977, Large landslides composed of megabreccia interbedded in Miocene basin deposits, southeastern Arizona: U.S. Geological Survey Professional Paper 1008, p. 1-25.

Royse, C. F., Sheridan, M. F., and Peirce, H. W., 1971, Geologic guidebook 4—Highways of Arizona, Arizona Highways 87, 88, and 188: Arizona Bureau of Mines Bulletin 184, 66 p.

Steiger, R. H., and Jager, E., 1977, Subcommission on geochronology—Convention on the use of decay constants in geo- and cosmochronology: Earth and Planetary Science Letters, v. 36, p. 359-362.

Theodore, T. G., Keith, W. J., Till, A. B., and Peterson, J. A., 1978, Preliminary geologic map of the Mineral Mountain 7-1/2-minute quadrangle, Arizona: U.S. Geological Survey Open-File Report 78-468.

Wilson, E. D., and Moore, R. T., 1959, Geologic map of Pinal County, Arizona: Arizona University, Arizona Bureau of Mines, scale 1:375,000, 1 sheet.