

EXPLANATION • STIO5 LOCALITY AND IDENTIFICATION NUMBER OF STREAM-SEDIMENT SAMPLE X YV228 LOCALITY AND IDENTIFICATION NUMBER OF ROCK

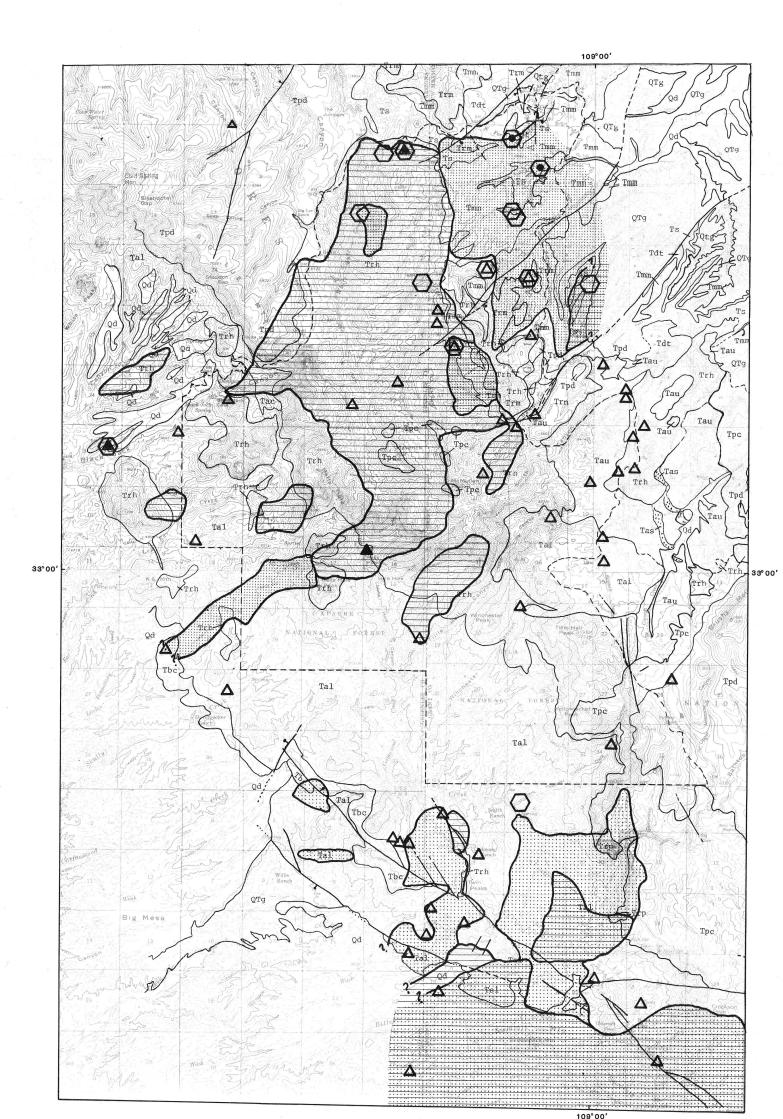
Generalized geology by J. C. Ratte, 1981

Base from U.S. Geological Survey 1:62,500

Steeple Rock, 1959; 1:24,000, Mule Creek,

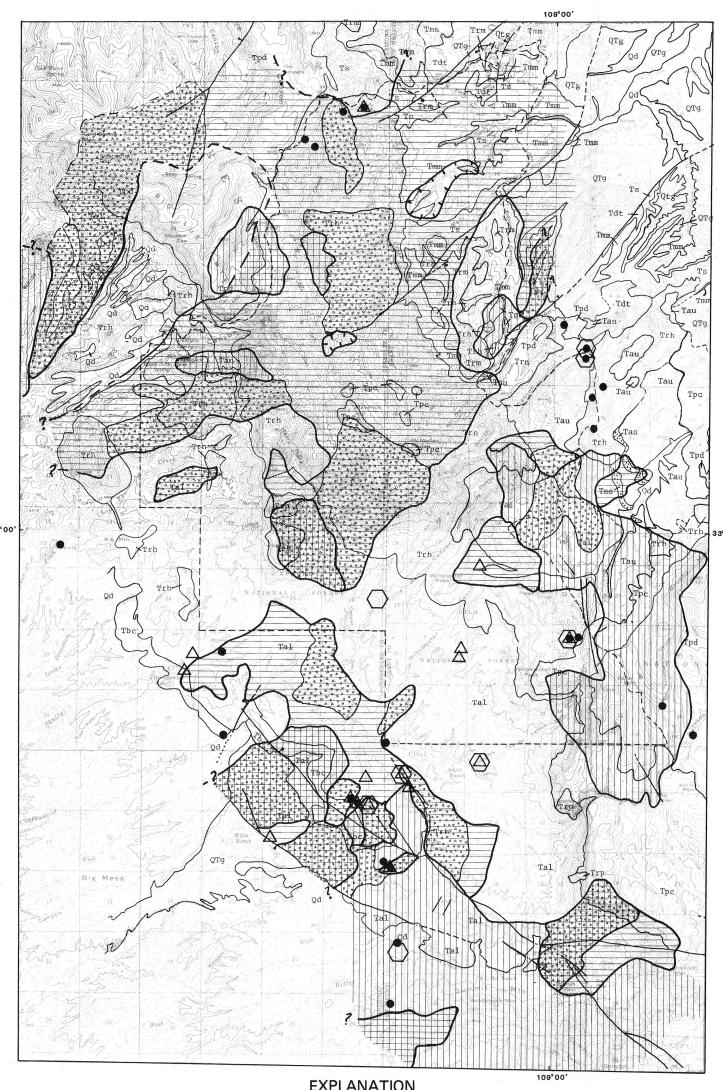
Big Lue Mountains, 1962; York Valley, 1959;

MAP A.-SAMPLE LOCALITY MAP



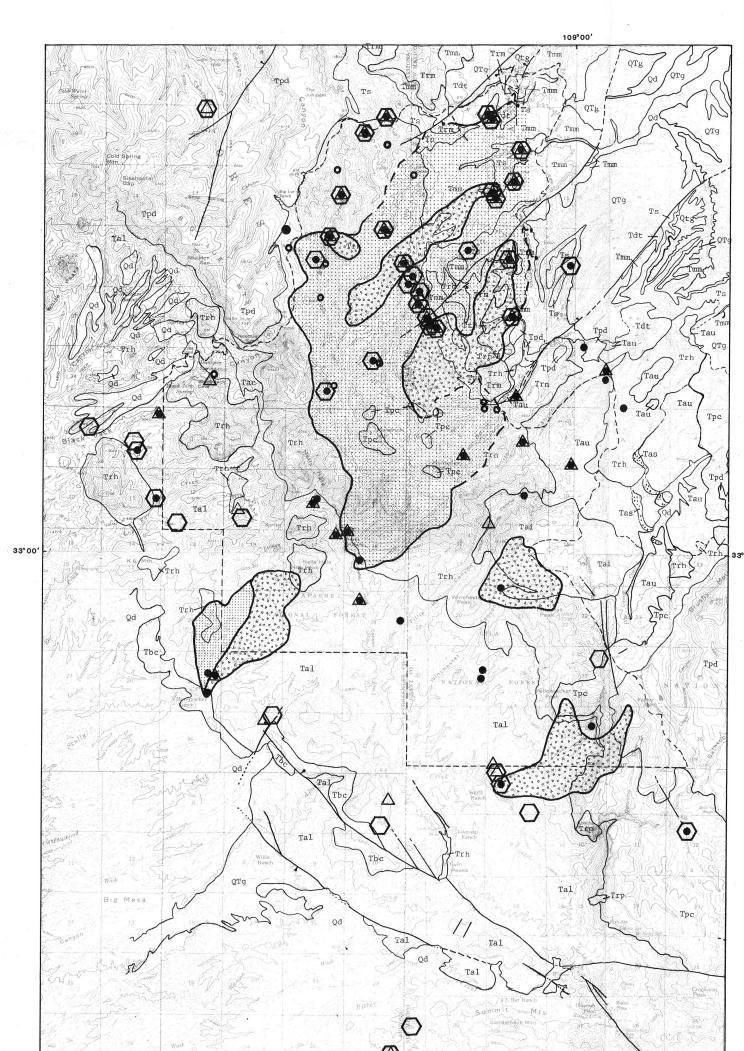
**EXPLANATION**  SAMPLE SITE CONTAINING Bi (> 20 PPM) IN THE \_\_\_\_\_\_ ISOPLETH ENCLOSING MAXIMUM DRAINAGE (SOURCE) NONMAGNETIC (NM-1) FRACTION AREAS FOR ANOMALOUS MO VALUES IN EITHER △ SAMPLE SITE CONTAINING Pb (> 150 PPM) IN EITHER THE NONMAGNETIC (NM-1)OR THE # AREAS WHERE MO OCCURS AT OR ABOVE DETECTABLE MAGNETIC (M-1) FRACTION LEVELS (> 10 PPM) IN THE NM-1 FRACTION SAMPLE SITE CONTAINING Sb AT OR ABOVE AREAS WHERE MO OCCURS AT OR ABOVE DETECTABLE DETECTABLE LEVELS ( $\geq$  200 PPM) IN THE NM-1 LEVELS (> 10 PPM) IN THE M-1 FRACTION

MAP D.-MAP SHOWING THE DISTRIBUTION AND RELATIONSHIP OF ANOMALOUS MOLYBDENUM TO ANOMALOUS BISMUTH, LEAD, AND ANTIMONY IN HEAVY-MINERAL CONCENTRATE FRACTIONS



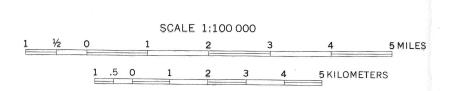
**EXPLANATION**  SAMPLE SITE CONTAINING W AT OR ABOVE
 ISOPLETH ENCLOSING MAXIMUM DRAINAGE (SOURCE) DETECTABLE LEVELS (> 100 PPM) IN EITHER AREAS FOR ANOMALOUS Cu VALUES IN EITHER THE NONMAGNETIC (NM-1) OR MAGNETIC (M-1) FRACTIONS AREAS WHERE CU VALUES ARE > 150 PPM IN THE SAMPLE SITE CONTAINING AS AT OR ABOVE NM-1 FRACTION DETECTABLE LEVELS (> 500 PPM) IN THE NM-1 AREAS WHERE Cu VALUES ARE > 150 PPM IN THE M-1 FRACTION SAMPLE SITE CONTAINING AG (> 1 PPM) IN THE NM-1 FRACTION OR AU DETECTED VISUALLY OR AREAS WHERE Cu VALUES ARE > 500 PPM IN CHEMICALLY IN EITHER FRACTION EITHER FRACTION

MAP B.-MAP SHOWING THE DISTRIBUTION AND RELATIONSHIP OF ANOMALOUS COPPER TO ANOMALOUS SILVER, GOLD, ARSENIC AND TUNGSTEN IN HEAVY-MINERAL CONCENTRATE FRACTIONS



**EXPLANATION** NONMAGNETIC (NM-1) FRACTIONS AREAS FOR HIGH LEVELS OF ANOMALOUS BE IN THE NM-1 FRACTION. DASHED WHERE INFERRED SAMPLE SITE WHOSE SOURCE AREA PROBABLY CONTAINS HIGH AMOUNTS OF Be, BUT WHERE THE AREAS WHERE BE VALUES ARE > 50 PPM IN THE NM-1 FRACTION IS MISSING (INSUFFICIENT FOR NM-1 FRACTION AREAS WHERE BE VALUES ARE > 100 PPM IN THE △ SAMPLE SITE CONTAINING B (>30 PPM) IN THE SAMPLE SITE CONTAINING Sn (> 1000 PPM) IN THE NM-1 FRACTION

MAP E.-MAP SHOWING THE DISTRIBUTION AND RELATIONSHIP OF ANOMALOUS BERYLLIUM TO ANOMALOUS BORON AND TIN IN HEAVY-MINERAL CONCENTRATE FRACTIONS



O SAMPLE SITE CONTAINING NO AT OR ABOVE \_\_\_\_\_\_ ISOPLETH ENCLOSING MAXIMUM DRAINAGE (SOURCE) DETECTABLE LEVELS (> 70 PPM) IN THE AREAS FOR HIGH LEVELS OF ANOMALOUS NO IN MAGNETIC (M-1) FRACTIONS THE M-1 FRACTION SAMPLE SITE CONTAINING Nb (> 70 PPM) AND Zn 

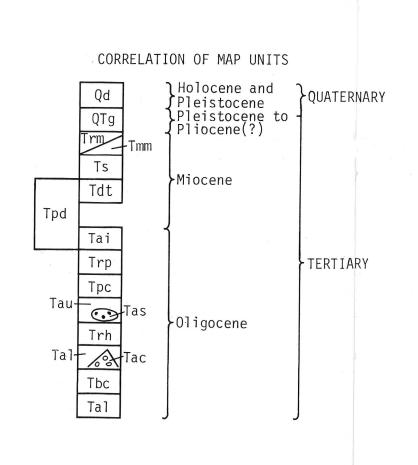
 □ AREAS WHERE ND VALUES ARE > 300 PPM IN THE

  $(\geq 1000 \text{ PPM})$  IN THE M-1 FRACTION M-1 FRACTION SAMPLE SITE CONTAINING .Zn (> 1000 PPM) IN AREAS WHERE NO VALUES ARE > 1000 PPM IN THE

MAP C.-MAP SHOWING THE DISTRIBUTION AND RELATIONSHIP OF ANOMALOUS NIOBIUM TO ANOMALOUS ZINC AND BARIUM IN HEAVY-MINERAL CONCENTRATE FRACTIONS

△ SAMPLE SITE CONTAINING Ba (> 5000 PPM) IN

THE NONMAGNETIC (NM-1) FRACTION



DESCRIPTION OF MAP UNITS ALLUVIUM, PEDIMENT GRAVELS, AND OTHER SURFICIAL DEPOSITS (HOLOCENE AND GILA CONGLOMERATE (PLEISTOCENE TO PLIOCENE?) RHYOLITE OF MULE CREEK (MIOCENE) RHYOLITE ASH-FLOW AND AIR-FALL TUFF MEMBER OF THE RHYOLITE OF MULE CREEK (MIOCENE) VOLCANICALSTIC MUDFLOW DEPOSITS (MIOCENE) PORPHYRITIC ANDESITE AND BASALTIC ANDESITE (MIOCENE) DACITIC LAVA FLOWS AND DOMES (MIOCENE) COARSELY PORPHYRITIC ANDESITE INTRUSIVE (OLIGOCENE)

RHYOLITE PORPHYRY PLUGS (OLIGOCENE) PORPHYRITIC LAVAS OF CROOKSON PEAK (OLIGOCENE) -- Includes isolated outcrops of similar lavas on Maverick Hill and McMullen Peak UPPER ANDESITE FLOWS (OLIGOCENE) VOLCANICLASTIC SEDIMENTARY ROCKS

(OLIGOCENE)--Thin (0-30 m) sequence of sandstone and breccia interlayered with andesite flows RHYOLITE OF HELLS HOLE (OLIGOCENE) LOWER ANDESITE FLOWS (OLIGOCENE) ANDESITE CONE (OLIGOCENE)--Volcaniclastic

the flank of a partly exhumed andesitic BLOODGOOD CANYON TUFF (OLIGOCENE) -- Rhyolite ash-flow tuff interlayered with lower andesite flows

sediments, tuff, and flows dip 20-30° on

---- CONTACT concealed, bar and ball on downthrown side ---- APPROXIMATE BOUNDARIES OF HELLS HOLE FURTHER PLANNING AREA

STUDIES RELATED TO WILDERNESS The Wilderness Act (Public Law 88-577, Sept. 3 1964) and related acts require the U.S. Geological Survey and the U.S. Bureau of Mines to survey certain areas on Federal lands to determine their mineral resource potential. Results must be made available to the public and be submitted to the President and the Congress. This report presents the results of a geochemical survey of the Hells Hole Further Planning rea (RARE II)in the Apache National Forest, Greenlee County, Ariz. and the Gila National Forest, Grant County, N. Mex. The Hells Hole Further Planning Area 03138) was classified as a proposed wilderness and further planning area during the Second Roadless Area

Review and Evaluation (RARE II) by the U.S. Forest

Service, January 1979.

The Hells Hole Further Planning Area (RARE II) is 34,000-acre (14,000 hectare) area lying on the Arizona-New Mexico border. The area is bounded on the north by Agizona-New Mexico State Highway 78, on the east by unimproved roads and privately owned land, and on the south and west by the Gila and Apache National Forest boundaries. Clifton, Ariz., is about 20 mi (32 km) from the western boundary via Arizona State Highway 78 and U.S. Highway 666. A geochemical reconnaissance investigation was undertaken in the study area and vicinity in 1979-1980. The chief purpose of this investigation was to provide a geochemical basis or "framework" for a mineral resource appraisal of the area. This report presents selected results and interpretations. The complete analytical data obtained in this investigation may be found in Hassemer and others

The Hells Hole Further Planning Area and adjacent areas are underlain entirely by middle to upper Tertiary volcanic rocks or by volcaniclastic sedimentary rocks derived from them (map A). For the purpose of this geochemical investigation, the area is divided into two parts: a southern part, which is largely outside the study area and consists of gently northeastward-dipping andesitic lava flows and a single outflow sheet of rhyolitic ash-flow tuff; the second part, which includes most of the study area, is the site of a major intrusive-extrusive volcanic enter. The intrusive rocks and extrusive lava flows of this center range in composition from andesite and low-silica rhyolite through rhyodacite and high-silica hyolite (Ratte and Hedlund, 1981). The rocks of the area are broken by high-angle faults of two major systems of regional extent. A northwest-trending fault system is prevalent in the southwestern part of the area, is mineralized, and epresents the extension of vein systems from the adjacent Steeple Rock mining district. A northeasttrending fault system is most common in the northeastern part of the area and is not mineralized (Ratte and Hedlund, 1981). In the southwestern part of the area, the most pronounced alteration is silicic and is associated with northwest-trending faults, sometimes forming a ridge or reef along the trace of the faults. Propylitic alteration is associated with a number of

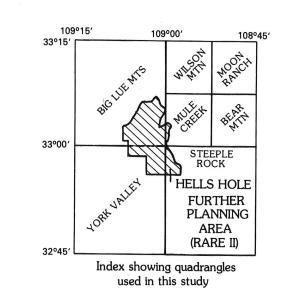
smaller northwest- and northeast-trending fractures. Strong argillic alteration was noted in a strike valley, located northwest of Twin Peaks In the volcanic center, the coarsely porphyritic andesite intrusive (Tai, map  $\underline{A}$ ) is somewhat propylitized throughout and is more intensely propylitized along its western and southern margins where it is intruded by the younger rhyolite of Hells Hole (Trh). Along upper Sawmill Creek the andesite intrusive is cut by quartz veins, some of which are mineralized. Within the rhyolite of Hells Hole and the younger rhyolitic units, altered rocks are confined to local fumarolic areas. This alteration consists mainly of hematite and manganese stains, silicification, and minor argillic alteration. occurring north, east, and south of McMullen Peak (Ratte and Hedlund, 1981).

SAMPLING AND ANALYTICAL METHODS The geochemical sampling program utilizes primarily the magnetically separated, heavy-mineral fractions derived from panned concentrate, streamsediment samples. This method of geochemical exploration (Hassemer and others, 1979: Watts and others, 1978) is particularly suited to the Southwest where migration of metals is dominated by mechanical The majority of alluvial samples were collected from small tributaries (map A). Parts of the stream bed most likely characterized by minimal gravity sorting were preferentially sampled to obtain the maximum variety (widest range of specific gravities) of heavy minerals conveniently obtainable. A heavy-mineral concentrate was obtained by panning the 10-12 lbs (5 kg) of bulk material that was collected from each alluvial sample site. Panning reduces the proportions of barren material relative to the ore-related minerals, which generally have a high specific gravity. By physically isolating those minerals related to the mineralizing process, the

element values obtained can be greatly enhanced. Further processing of concentrate samples sieving to  $\langle 14 \text{ mesh } (\langle 1.2 \text{ mm}),$ discarding coarse material: (2) bromoform separation, discarding light fraction (specific gravity <2.85); (3) electromagnetic separation using a Frantz Isodynamic Separator at 0.1 amp and 1.0 amp (forward setting 25°, side setting 15°), discarding the magnetic at 0.1-amp fraction (mainly residual magnetite). The final setting at 1.0 amp yields the two fractions to be a) Nonmagnetic at 1.0-amp (NM-1 fraction--The fraction from which most of the major rock-forming minerals have been removed, leaving such minerals as sphene, apatite, and zircon in unmineralized areas; calc-silicate minerals in skarn zones; and, in mineralized zones, most of the common primary and secondary ore minerals-sulfides, sulfates, sulfosalts, carbonates, and halides. Such minerals as galena, chalcopyrite, smithsonite, cerargyrite, native gold, barite, fluorite, and cassiterite, if they are present, will be found in this (b) Magnetic at 1.0-amp (M-1) fraction--The fraction that contains the heavy. mafic, rock-forming minerals such as biotite, amphibole, and pyroxene. More importantly, this fraction contains manganese and iron oxides. including limonite derived from sulfides. Such minerals as pyrolusite, columbite, and the gossan minerals, if

present, will be found in this concentrate fraction; (4) microscopic examination for mineralogy (in general, a brief scan); and (5) pulverization to  $\langle 150 \text{ mesh } (\langle 0.10 \text{ mm}) \rangle$ and analysis by semiquantitative emission spectrography. <sup>1</sup>Use of a specific brand name is for descriptive purposes only and does not constitute endorsement by the U.S. Geological Survey.

HELLS HOLE



High concentrations of elements in the nonmagnetic (NM-1) fraction indicate that primary and(or) secondary ore minerals are exposed at the surface (Watts and others, 1978). High concentrations of elements in the magnetic (M-1) fraction, especially in the iron and manganese oxides, may indicate oxidation products derived from sulfides and associated minerals, or may indicate precipitation products derived either from a deeply circulating solution source (for example, hot springs) or from a static solution interface (for example, ground water at the zone of oxidation). The occurrence of an element in a specific fraction and the association of an element with other elements to form an element suite or "fingerprint" of mineralization, may provide a clue to the depth of mineralization as well as the type of mineralization. Rock samples were taken where appearance or structure indicated the possibility of detecting mineralization or of determining the suites of elements involved in obviously mineralized rocks. Prospects, faults, veins, dikes, and rocks that looked altered were sampled when encountered, but no attempt to systematically sample rocks was made in this reconnaissance study. Rock samples consisted of grab, chip, and composite mine-dump samples. These samples were mechanically crushed and pulverized to <150 mesh (<0.10 mm) before being analyzed. Sixty-one rock and 186 stream-sediment sample sites were established (map  $\underline{A}$ ). Unfortunately, the nonmagnetic fractions of 17 samples were lost prior to analysis. All samples were analyzed by semiquantitative emission spectrography for the determination of 31 elements using the field method of Grimes and Marranzino (1968). A more extensive discussion of sample types, sample procedure and theory, analytical methods, statistical methods,

Maps B-E present a combination of shading and symbols to illustrate the distribution and relationship of various elements, and to delineate areas of geochemical interest. In order to show a maximum number of elements on a minimum number of maps, the elements are not necessarily grouped in geochemically related assemblages (for example, barium and niobium, map C). Furthermore, only those areas or sample sites containing anomalous amounts of the specified element are shown. The term anomalous, as used in this report, and the terms mineralization and metallization do not have an economic or mineraldeposit context, but rather indicate an increased element-mineral content that is above the normal, regional-background level. The threshold levels used define an anomaly were not derived from frequency distributions of element data obtained in the study area because potential areas of interest can be masked by high, local-background levels. The threshold levels used were derived from thousands of concentrate samples collected in southeastern Arizona and southwestern New Mexico.

analytical data for all sample media may be found in

Hassemer and others (1981).

Fluorite, which can be readily identified in the mineralogical scan, is not shown on the maps of this report. Except for sample site BL 619 (map A), all luorite occurrences listed in table 1 were found in samples taken south of 33°N. lat.; the distribution and abundance of fluorite in this area is covered in Watts and Hassemer (1980). Table 1.--Estimated percentage of fluorite in the

[Samples <10%, YV 103; YV 106; YV 108; YV 109; YV 115; YV 223; YV 224; YV 231. Data in percent] Fluorite No. Fluorite No. Fluorite

YV 326

YV 219 20 YV 323 A number of fluorite occurrences were reported by Griggs and Wagner (1966) in and adjacent to the outhern part of the area, including a small deposit of siliceous fluorite near the Moore Place in the southeastern corner of the area. The occurrence of fluorite in the area is related to the northwesttrending fracture system. The relationship of the fluorite mineralization to the base- and preciousmetal mineralization is uncertain, but if the two are part of the same mineralizing episode, then fluorite might be a surface indicator or "pathfinder" mineral for metallization at depth. No fluorite was seen in samples collected from drainages whose sediments were derived solely from the silicic rocks of the volcanic complex.

YV 317

Geochemically, the area of investigation lies within a copper province. A copper-lead-zinc ore body occurred at the Carlisle Mine in the Steeple Rock district (Griggs and Wagner, 1966) less than 2 mi (3 km) from the southeast corner of the area; and, one of the major copper-producing areas of the Southwest, the Clifton-Morenci district, lies only 12 mi (20 km) to the west. Copper is widespread in anomalous amounts throughout the area (map B), with a number of localities showing an intensification of copper mineralization. Chalcopyrite, chalcocite, azurite, malachite, chalcanthite, cuprite, and chrysocolla were observed both in the heavy-mineral concentrates and in outcrop. Small nodules and stringers of native copper occur within northeast-trending veinlets of cuprite about 2 mi (3 km) southwest of the Willis Ranch (YV In the southern portion of the area, the Twin Peaks-Willis Ranch area contains high levels of anomalous copper in both concentrate fractions. The area is an extension of the Steeple Rock mining district and is anomalous in a number of elements in both concentrate (maps B-E) and rock samples (tables 2-4, 6-8). Argillic, propylitic, and silicic alteration occur in this area, as do numerous primary and secondary copper minerals. The geochemical patterns are broken off at a fault contact between the andesites and the pediment gravels, but it is likely the copper mineralization persists westward beneath this overburden with the possibility of additional centers of mineralization. Copper occurs in anomalous amounts in the M-1 fraction on the southwest side of the fault wherever bedrock is exposed; furthermore, this copper mineralization continues both to the south and to the southwest of the southernmost sample site, YV 230 (Watts and Hassemer, unpublished data, 1982). In the volcanic center, a number of areas of interest occur within or overlap the boundaries of the study area. These areas include: (1) Hells Hole Canyon which has a large number of tributaries that are anomalous in both the NM-1 and M-1 concentrate fractions. Chalcopyrite and pyrite were identified during the mineralogical scan of samples from this area; (2) the area between Black Jack Canyon and Lop Ear Creek, where the strong northeasterly elongation of the pattern of anomalous copper suggests fracture control of the mineralization. Pyrite was the only sulfide mineral identified in the mineral scan of samples from this area; (3) Coal Creek, which is

anomalous in a number of elements (maps B-E), although pyrite was the only sulfide identified in the concentrate samples; (4) the area containing the upper tributaries of North Sawmill Canyon, the locus of a vent area (Ratte and Hedlund, 1981). One sample of altered rhyolite (BL 203) contained 1,000 ppm copper (table 2). The area is not shown as an area containing higher levels of anomalous copper on map B, pecause data for the NM-1 fractions of the samples taken there (BL 339, 340, 341) were not available. Pyrite was the only sulfide identified in those samples; and (5) the head of Sawmill Creek, where increased levels of copper in the M-1 fraction occur roughly centered over an andesitic intrusive. Anomalous copper values in the NM-1 fraction occur on the north and south contacts of this intrusive, and the area is cut by a number of silver-bearing quartz veins. These veins contain carbonate and sulfides, principally pyrite, and minor, secondary copper minerals (Ratte, oral commun., 1980). An area of anomalous copper in the M-1 fraction extends southward from the intrusive andesite. This area coincides with the outcrop area of a coarsely porphyritic andesite. not shown on the generalized geologic base. A sample of this unit (ST 103, map A) contained 70 ppm copper (Hassemer and others, 1981), an amount of copper that the mafic accessory minerals can readily accommodate within their crystal lattices. The concentration of these minerals in the M-1 fraction could account for part or all of this copper anomaly, In the northwestern corner of the area is another occurrence of high copper values. This intensification is defined by three, rather large drainages on either side of Sixshooter Gap. The two, northeastflowing drainages have fault segments subparallel to their valleys. The northeast trend of the drainages and fault segments suggests that mineralization in this anomaly may also be fracture controlled. The

Table 2.--Copper in selected rocks
[Data in ppm]

area is not clear.

Cu No. Cu No. Cu No. Cu YV 2C >20,000 YV 118 15,000 BL 64 200 BL 213 300 YV 104 7,000 YV 122 100 BL 72 300 MC 8 100 YV 111 7,000 BL 6A 300 BL 203 1,000 ST 100 100 YV 116 700

relationship, if any, of this mineralization to the

mineralization of the volcanic center in the study

SILVER AND GOLD Silver occurs in anomalous amounts in panned concentrates (table 3) and in rock samples (table 4) mainly from three general areas (map B): mineralized, northwest-trending structural zone in the southern portion of the area, where the silver is associated with massive silicification and gold- and base-metal mineralization; (2) the upper reaches of Sawmill Creek, an area cut by north-northwesttrending, in silver-bearing quartz veins containing carbonate and sulfides, principally pyrite, and minor secondary copper minerals; and (3) areas north, east, and south of McMullen Peak where the silver mineralization appears to be related to solfataric activity, as indicated by red cliffs of intensely oxidized rhyolite. The spotty distribution of silver values in panned concentrates is probably related to the presence of very fine-grained silver minerals. Guigues and Devismes (1969, p. 76) warn that there may be poor recovery of those minerals that are smaller than 0.004 in. (0.1 mm). Fine-grained argentite is believed to be the principal silver mineral in the Steeple Rock district (Griggs and Wagner, 1966, p. 20) and this is probably the case in the study area and adjacent areas. The same problem of fine-grained source minerals also applies to gold. In their study of the Steeple Rock district, Griggs and Wagner (1966, p. 19) found the gold to be too finely divided to be resolved with a microscope. The gold flake seen in sample YV 216

(table 3) was estimated to have been less than 0.0004 in. (0.01 mm) in diameter. Further discussion of this problem and other problems related to concentrates may be found in Hassemer and others (1981). The presence of gold in the lower (YV 317) and selected statistics, and a complete listing of the raw upper (ST 302) reaches of Dark Thunder Canyon extends. by several miles northward, the area of known gold mineralization. The occurrence of gold in the M-1 fraction at site ST 302 may result from gold being a trace element in an oxidized sulfide (limonite after sulfide) or may result from the gold being incorporated in an aggregate of minerals, one or more of which is magnetic enough to cause the aggregate to be found in the M-1 fraction.

Table 3.--Distribution of gold and silver in

, detected but less than value shown; --, none found; data in ppm] [Au detected during mineralogical scan]

Table 4.--Silver in rocks [Only one rock sample (YV 123) contained sufficient gold 5 ppm) to be detected by spectrography; L, detected but less than value shown; data in ppm]

YV 104 7 YV 2C 300 BL 6A 1 BL 71 1.5 Table 6.--Molybdenum in rocks
YV 111 15 ST 100 1 BL 17 L(0.5) BL 72 2 [L, detected but less than value shown; data in ppm] 15 MC 3 100 BL 31 L(0.5) BL 203 15 MC 5 2 BL 32 L(0.5) BL 213

Arsenic values occur at only a few sample sites, partly because of a very high spectrographic detection limit (500 ppm in the concentrate fractions). Arsenic is found in both the fringes and central zones of a porphyry metal system similar to silver and lead (Jerome, 1966, p. 81). The majority of arsenicbearing samples occur in the northwest-trending structural zone in the southern part of the area (map Several of the anomalous samples occur in an area f observed argillic alteration. The location of the arsenic within the minerals of the concentrate fractions is not known. None of the rock samples had detectable arsenic (200 ppm).

Tungsten is found in both concentrate fractions generally at or just below the spectrographic limit o detection (100 ppm). The tungsten-bearing minerals have not been identified. Three areas contain anomalous amounts of tungsten (map B): (1) the large northwest-trending structural zone in the southern portion of the area, where tungsten in both fractions s associated with the base- and precious-metal mineralization (maps  $\underline{B}$  and  $\underline{D}$ ). Two rock samples from this area had detectable tungsten, YV 118 and YV 2C (<50 ppm and 50 ppm, respectively); (2) the lower reaches of Sawmill Creek on the eastern boundary of the study area, where samples had detectable tungsten ( $<100~\rm{ppm}$ ) in the M-1 fraction only. The tungsten is associated with anomalous lead (map D) in both concentrate fractions and anomalous manganese (Hassemer and others, 1981) in the M-1 fraction, which suggests that tungsten may occur in iron-manganese oxides, possibly as a precipitate from hot(?) ground waters; and (3) the northern boundary of the study area in White Mule Creek and Coal Creek, where both fractions contained detectable tungsten (as much as 500 ppm) in the M-1 fraction. The possibility of the tungsten-bearing minerals forming in a hot groundwater or hot-springs type environment is increased by its association with arsenic (map  $\underline{B}$ ), boron, beryllium and tin (map  $\underline{E}$ ), and antimony (map  $\underline{D}$ ). However, no vent areas or hot spring edifices were seen.

Niobium enrichment in the M-1 fraction is directly related to outcrop areas of rhyolitic rocks and is most prominent in the north-central part of the study area (map C). The highest values for niobium occurrence,  $5{,}00\overline{0}$  ppm Nb (1.4 percent Nb<sub>2</sub>0<sub>5</sub>), were found south of Arizona-New Mexico State Highway 78 at a widening of the alluvial valley of White Mule Creek and at a tributary to Coal Creek. As shown by spectrographic analysis of handpicked crystals (table 5), the niobium occurs mainly n ilmenite and a tabular form of pseudobrookite (Fe<sub>2</sub>TiO<sub>5</sub>) and, in minor amounts, in magnetite and a prismatic form of pseudobrookite. The magnetite and ilmenite are oxidized to limonitic pseudomorphs, some of which contain unoxidized cores of the original minerals. Columbite was not observed during the

mineralogic scan.

The analytical sample consisted of 4 to 6 mineral crystals; G, greater than the value shown; N, not detected at the value shown; L, less than the value

Mineral Fe(%) Ti(%) Mn(ppm) Nb(ppm) Ta(ppm) Zn(ppm) 70 3 G(15,000) 100 N(50) 7,000 magnetite 50 G(3) G(15,000) 3,000 50 2,000 Ox idized Pseudobrookite, 50 G(5) G(20,000) 70 N(50) 2,000 prismatic form Pseudobrookite, 50 G(5) 30,000 3,000 L(50) N(1,000) flat tabular ("picture

The occurrence of niobium as a substitute within the lattice of various titanium-bearing minerals means that not only will the niobium values vary with changes in the percentages of mineral species present, but also that the niobium will be present in nonstoichiometric amounts within individual grains of a mineral species. Thus, being an average of only a few grains, the analyses given above serve only to indicate the mineralogic location of the niobium. Both forms of pseudobrookite were confirmed by Xray diffraction analysis (T. Botinelly, oral commun. 1980). The genesis of the two forms of pseudobrookite is not known; however, the strong titanium:niobium diadochy (Rankama and Sahama, 1950, p. 606) suggests that the tabular pseudobrookite was cogenetic with ilmenite and that the elongate pseudobrookite occurred later(?). The occurrence of niobium in the heavy minerals from the area is in contrast to the niobiumbearing, heavy-mineral Sanostee placer deposits (Bingler, 1963) of northwestern New Mexico, where significant niobium was found in all titanium-bearing minerals. In this area, appreciable niobium was found in only one form of pseudobrookite, other titanium dioxide polymorphs such as brookite were not observed in the M-1 fraction, and anatase occurred only in

The distribution of zinc in the M-1 fraction is directly related to the north and northwest outcrop areas of the rhyolite of Hells Hole (Trh), and i associated with high values of niobium (map C) and titanium and manganese (Hassemer and others, 1981 Zinc was detected in only two NM-1 samples, YV 216 and BL 313. The zinc in sample YV 216 is thought to result from contamination. Three rock samples from the southern part of the area (YV 104, YV 111, and YV 32) and one sample in the study area (BL 7 contained detectable amounts of zinc (200 ppm).

small amounts in the NM-1 fraction.

Barium may be attributed to the mineral barite when occurring in the NM-1 fraction in amounts greater than 5,000 ppm. Barite was identified in the NM-1 sample during the mineralogical scan, frequently as the predominant mineral. The distribution of barite is restricted to the outcrop areas of the older, andesitic rocks and is most prominent along the west side of the northwest-trending mountain front (map C). Within the prominent trend of anomalously high barium values, the Twin Peaks-Willis Ranch area contains a number of sample sites that are not anomalous in barium. This may be a result of remobilization and removal of barium during the silicification of this area or may be a result of a difference in the level of exposure in a hydrothermal system. In the vicinity of Silver City, N. Mex. barite seems to form halos vertically and laterally in the outer zones of metal systems (Watts and Hassemer, unpublished data, 1981) and a similar situation may exist in this area. There also seems to be a spatial connection between depleted amounts of barium and increased

amounts of copper; throughout the area 80 percent of the low-barium (<700 ppm) sample sites are anomalous n copper. However, the geochemical significance of this observation is not clear because there are numerous sample sites in areas of silicification that are enriched in both barium and copper. Also, other sites containing high copper values also have intermediate barium values. Two factors may account for these observations: first, barium can occur as a gangue mineral and is known to occur locally in mineralized veins in the neighboring Steeple Rock district (Griggs and Wagner, 1966 p. 18); second, stream sediments are a composite sample representing an entire drainage basin and tend to telescope metal zonation patterns occurring within the basin. Spearman rank correlation coefficients (Hassemer and others, 1981) indicate no relationship between barium and copper either in rocks or in the NM-1 fraction. In general, samples that are high in barium are not high in strontium (Hassemer and others, 1981); the only exception is in the vicinity of Rustlers Canyon and Black Jack Canyon. Barium tends to be redistributed in a hydrothermal porphyry system, whereas strontium tends to be removed almost entirely from the system (Neuerburg and others, 1978). Because the Black Jack Canyon-Rustler Canyon area is anomalous

n other elements (for example, copper, map B), the increased strontium may indicate proximity to a strontium source (for example, Paleozoic carbonate MOL YBDE NUM Molybdenum, as shown by values obtained from

concentrate and rock samples, occurs in three general areas (map D): (1) in the southern part of the area, in both concentrate fractions, associated with baseand precious-metal mineralization; (2) in the main body of the rhyolite of Hells Hole (Trh), in the M-1 fraction of samples taken there, and north, east, and south of McMullen Peak, as indicated by rock samples (table 6). Molybdenum was detected in the spectrographic analysis of oxidized ilmenite (30 ppm) however, this amount of molybdenum and the percentage of ilmenite in the M-1 fraction is insufficient to account for all of the anomalous molybdenum. Most of the molybdenum anomaly is presumed to occur in oxidized sulfides. Ferrimolybdite was not noted in either the concentrate or rock samples; and (3) in the outcrop areas of the rhyolite of Mule Creek (Trm). occurring in low but anomalous amounts in the NM-1 fraction. The mineralogic location of the molybdenum is not known. The association of molybdenum with other lithophile elements (map  $\underline{E}$ ) suggests a common

Anomalous lead, although somewhat scattered.

Mo No. Mo No. Mo No. Mo YV 107 5 YV 123 7 BL 31 5 BL 72 YV 111 1,000 YV 127 100 BL 46 L(5) BL 73 7 YV 2C 15 BL 49 10 BL 202 

occurs in three main areas (map D): (1) in the southern part of the area, occuring principally in the NM-1 fraction. The lead is believed to occur in secondary minerals because galena was not seen in any the concentrates. The composite rock sample, YV 111, contains 7,000 ppm lead (table 7) and 7,000 ppm copper (table 2). Although secondary copper carbonates (azurite and malachite), a secondary copper sulfide (chalcocite), and a secondary copper sulfate chalcanthite) were noted, no lead minerals could be seen in the hand specimen. Fine-grained galena was the lead-ore mineral in the Steeple Rock district (Griggs and Wagner, 1966, p. 19). If a similar situation occurs in this area, the fine-grain characteristic of the galena may permit rapid oxidation to equally fine-grained, surface-stable minerals. Such secondary lead minerals would be difficult to recognize in a hand specimen or in a rapid mineralogical scan; (2) along upper Sawmill Creek, occuring in both NM-1 and M-1 concentrate fractions. Lead in the NM-1 fraction may be related to the silver bearing quartz veins. In the uppermost reaches of Sawmill Creek the lead is scattered over an area of copper and barite mineralization; downstream, the lead is associated with tungsten (map B) and manganese (Hassemer and others, 1981) in the M-1 fraction. In most areas, the M-1 lead is thought to be in limonite that is derived from sulfides. In this area, part or all of the M-1 lead could be in ironmanganese oxides precipitated from hot(?) ground water; and (3) within the rhyolite of Hells Hole (Trh) at Coal Creek and at the head of North Sawmill Canyon, occurring mostly within the M-1 fraction. Samples of altered rhyolite (table 7) contained a slight, but definite increase in lead content over the values obtained from unaltered rocks (<20 ppm).

Table 7.--Lead in selected rocks

Pb No. Pb No. Pb No. Pb 50 BL 31 30 BL 49 70 BL 203 5 70 BL 32 50 BL 62 30 BL 239 30 30 BL 36 30 BL 71 5

In areas that are subject to intensive hunting, lead shot can create a contamination problem. In this area, three NM-1 samples (BL 301, BL 331, and BL 402) have increased amounts of lead, antimony, and bismuth resulting from shot and slug fragments. Further discussion of contamination problems and the resolution of these problems can be found in Hassemer and others (1981).

ANTIMONY AND BISMUTH

Antimony and bismuth are detected in only a few samples in the NM-1 concentrate fraction. Most of the antimony and the two valid (see lead discussion above) bismuth values occur in the outcrop area of the ounger, rhyolitic pyroclastic rocks (map D). Both elements are associated with anomalous amounts of the thophilic elements, molybdenum, (map D), beryllium, boron, and tin (map E), suggesting a common epithermal genesis in either a vapor phase or hot-springs environment. Antimony was not detected in any of the rock samples, and bismuth was detected only in the composite mine-dump sample, YV 111 (20 ppm).

Within the study area, the majority of the samples from outcrop areas of rhyolite and rhyolitic pyroclastic rocks are anomalous in beryllium (>10 ppm). Within an area of higher values (indicated by shading on map E) are two northeast-trending zones of very high beryllium values (>100 ppm). Although these patterns parallel the northeast-trending faults that ut the area, lack of data for neighboring sample sites may have contributed to the apparent northeast trend. If the trends are valid, the area of high beryllium values near the Hoverrocker Ranch may be an extension of the southernmost zone. The mineral(s) in which the beryllium occurs i not known, but the high values in the NM=1 fraction 700 ppm; YV 317) and in the rock samples (200 ppm; BL 49) suggest a distinct, beryllium mineral phase. The areal association of boron (map E) with beryllium might suggest chrysoberyl which is commonly associated with the boron-bearing mineral tourmaline, but neither mineral was seen in any of the heavy-mineral concentrates and both are unlikely in this geologic environment. The most likely minerals, euclase (BeAlSiO $_4$ (OH)), phenacite (Be $_2$ SiO $_4$ ), and trimerite (Be(Mn,Ca)SiO $_4$ ) could not be found during a brief optical search of several concentrates (W. Griffitts, oral commun., 1981). The common beryllium minerals. beryl and bertrandite ( ${\rm Be_4Si_2O_7(OH)_2}$ ), have specific gravities too low to be found in the heavy-mineral suite. The areas containing the highest beryllium values are also the areas containing anomalous amounts of tin (map E), antimony, and bismuth (map D), suggesting a common epithermal source. The Hells Hole Further Planning Area is close to an area that Griffitts (1973, fig. 12) shows as one in which beryllium is likely to be found. His northwesttrending, elongated area parallels much of the Texas-Mexico border, crosses most of southern New Mexico, and needs only a slight extension to coincide with the study area. However, only the first of the three criteria that Griffitts (1973, p. 92) used to determine potential areas of beryllium mineral

deposits are met in the study area. These criteria

are: (1) association with high-angle faults of

regional extent, usually block faults; (2) association

with fluorite-rich metallogenic provinces; and (3)

calcareous rocks as the most favorable host for

mineralization.

Although fluorite occurs in large amounts south of lat. 33°N., fluorite was not seen in samples from the large shaded area of high beryllium values nor was it seen in samples from the highberylTium area near the Hoverrocker Ranch. Fluorite was seen in samples from Dark Thunder and Winchester Canyons, but these areas are thought to be in an overlap area of northeast-trending(?) beryllium mineralization to the north and northwest-trending structurally-controlled fluorite mineralization to the The majority of samples that are anomalous in tin are directly related to outcrop areas of rhyolite and rhyolitic pyroclastic rocks (map E). The minera-

MISCELLANEOUS FIELD STUDIES

logical scans show that the tin is in cassiterite in the NM-1 fraction and most of the cassiterite occurs as a platy overgrowth in planar form around an ironoxide core. This form of cassiterite was observed only in those samples taken above lat. 33°N. and was identified using X-ray diffraction analysis f. Botinelly, oral commun., 1980). This form of cassiterite contrasts with the more usual nodular form of cassiterite (wood tin) that is seen in scattered localities in the southern part of the area, and elsewhere in Arizona and New Mexico. The platy nature of the tin occurrence indicates that the cassiterite did not occur as primarily dispersed, phase segregations in the rock matrix, but rather as a later or introduced enrichment, precipitating under the right conditions of pH and under an Eh potential between the iron-oxide core and the tin-bearing solution. These conditions could occur either at a ground-water table at the zone of oxidation, or at an interface between meteoric and hydrothermal waters. Although the cassiterite was observed to display well-developed growth lines under the polarizing microscope, the individual grains were found to be too small for fluid-inclusion studies (D. Leach, oral commun., 1981). The variation of the thickness of the platy growths, ranging from very thin plates to plates as thick as or thicker than the iron-oxide cores, may indicate a difference in the chemical activity (concentration) of the tin in solution and hence be a indicator of the distance to the source. Alternatively, the variation of thickness may indicate variability in depth to the active interface and variability in the length of time in which the tin is precipitating at that interface. The latter conditions, if they occurred here, could result in assiterite being precipitated throughout the stratigraphic thickness of the rhyolitic rock units with possible zones of increased enrichment. More detailed work is required to confirm or refute these The apparent north-northwest-trending linearity of anomalous tin seen in the center of the beryllium pattern has no structural significance. This pattern merely delineates the trace of Coal Creek as defined by sample sites on its tributaries. Two samples of altered rhyolite, BL 49 and BL 72, contained detectable tin (both 20 ppm).

The distribution of boron closely parallels the distribution of beryllium and tin in the NM-1 fraction (map E). The mineralogic location of the boron in the NM-1 fraction is not known. Boron is a common fumarolic or pneumatolytic constituent. Its association with anomalous amounts of other lithophile elements suggests a common epithermal source. Altered rhyolite samples from a vent area in the upper reaches of North Sawmill Creek contained moderately increased amounts of boron (table 8). Scattered sample sites in the northwest-trending structural zone in the southern part of the study area show increased boron values,

YV 232 70 BL 46 20 BL 63 50 BL 203 MC 5 20 BL 49 20 BL 169 20 BL 339 SUMMARY AND INTERPRETATION

The geochemical reconnaissance of the Hells Hole Further Planning Area and adjacent areas by means of samples from 186 stream-sediment sites and 61 rock samples shows the presence of anomalous elements related to two different structural settings, one outside and one largely within the study area. The distribution and associations of these elements appear to have resulted from at least three separate episodes of mineralization. Extensive mineralization is found within a northwest-trending fault zone that crosses the southern part of the area. The fault zone offsets mainly andesitic lava flows and minor, interlayered, volcaniclastic sediments and one major, rhyolitic ashflow tuff. The fault zone contains numerous siliceous veins, many of which display conspicuous, primary and secondary copper minerals. Anomalous concentrations of both base and precious metals, including copper silver, lead, arsenic, molybdenum, tungsten, and gold, are found in sediment samples from drainages that li metal content. The anomaly patterns suggest that th copper mineralization may extend west and southwestward beneath the pediment gravels and that the molybdenum mineralization may increase south and southeastward of the area. Significant amounts o fluorite, which may be a "pathfinder" mineral fo metallization at depth, also occur along the fault zone and in the upper portions of the andesitic units n the southeast corner of the area. Barium is depleted in some areas where the rocks have been intensely silicified. Within the study area, anomalous amounts of niobium, zinc, molybdenum, and manganese are found in the magnetic concentrate (M-1) fraction, occurring within and adjacent to a stock-like body rhyolite. The distribution of these elements within the minerals of the M-1 fraction indicates that there were at least two periods of niobium and molybdenum(?) mineralization, one of which may have been cogenetic with the rhyolite Within the outcrop areas of the rhyolite of Hells Hole and the rhyolite of Mule Creek, copper beryllium, boron, and tin are widespread in anomalous amounts. Local concentrations of these elements presumably result from increased permeability to mineralizing solutions, although some centers show little alteration of rocks at the surface. Anomalous amounts of silver and lead are found in areas of altered rhyolite of Hells Hole. Drainages within the younger rhyolitic units contain anomalous amounts of antimony, bismuth, and molybdenum in the nonmagnetic concentrate (NM-1) fraction. This combination of chalcophile and lithophile elements indicates a solfataric genesis. The older, intrusive andesite center of the volcanic complex contains anomalous amounts of barium, copper and lead, and silver-bearing quartz veins.

This combination of elements suggests the possibility that the mineralization here may be related to the mineralization that occurs to the south. REFERENCES CITED

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and abundance of fluorite in stream-sediment

MAPS SHOWING THE DISTRIBUTION AND RELATIONSHIPS OF SELECTED METALS IN HEAVY-MINERAL CONCENTRATES OF THE HELLS HOLE FURTHER PLANNING AREA (RARE II), GREENLEE COUNTY, ARIZONA, AND GRANT COUNTY, NEW MEXICO