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A GEOCHEMICAL SURVEY OF FERROUS AND SELECTED BASE METALS IN THE EASTERN HALF OF THE CAPITAN MOUNTAINS, LINCOLN COUNTY, NEW MEXICO

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Abstract—Anomalous amounts of ferrous and base metals, including Cu, Fe, Mg, Mn, Mo, Pb and Zn, have been detected in bulk and panned-concentrate stream sediment samples collected from major drainages extending from the Capitan Mountains. The highest concentrations were detected near magnetite-rich skarn mineralization near the contact of the Capitan pluton and the Permian sedimentary section, or in some cases, downstream from the contact where iron-rich alluvium enters stream channels. In bulk samples, Fe concentrations range from 13,600 to 217,200 ppm, Mn ranges from 100 to 1825 ppm, and Mg ranges from 475 to 220,325 ppm. In panned-concentrate samples, Fe and Mn concentrations increase while Mg decreases. Mo, Pb, and Zn concentrations range from 25 to 2550 ppm in panned concentrate. Erosion has removed most of the skarn deposits that formed at the margin of the pluton. Metals formerly contained in these deposits are now incorporated in the alluvial blanket surrounding the range. National Uranium Resource Evaluation anomalies of Ce, La, Nb and Y coincide with Fe and Mn anomalies of this study. Rare-earth-element mineralization may be present within the pluton and as alluvial concentrations of REE-bearing minerals such as sphene or bastnaesite.

INTRODUCTION

Location

The area of study encompasses about 180 sq km of the eastern Capitan Mountains in Lincoln County, New Mexico. It lies within the Lincoln National Forest and extends westward through the Capitan Mountains Wilderness to the summit of the Capitan Range, elevation 3108 m. Most of the area is covered by the Arabela and Capitan Mountains USGS 15-minute quadrangles.

Accessibility

The all-weather hard-surface roads closest to the Capitan Mountains are New Mexico State Highways 48 on the north, 380 on the south, and 368 on the east. Fair-weather surface roads extending into the study area are Forest Service road 57 on the south, Forest Service roads 256 and 163 on the north, and county road 130 on the north. The northeastern portion of the range is accessible from a primitive, dry-weather road connecting Arabela and Pine Lodge. Hiking trails, including the north and south base trails, the summit trail, and trails along stream canyons provide access into the Capitan Mountains Wilderness (Fig. 1).

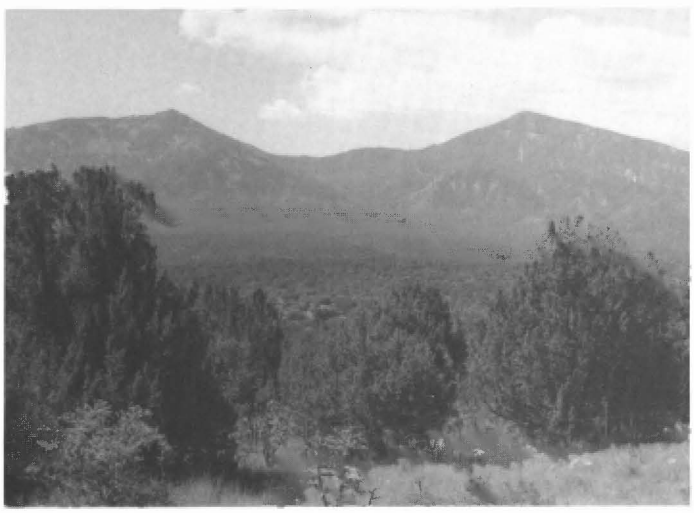


FIGURE 1. View south to the eastern end of the Capitan Mountains. Sunset Peak, elevation 2845 m, is on left; and Capitan Peak, elevation 3073 m, is on right. The Capitan Mountains Wilderness area encloses Sunset Peak and Capitan Peak.

Purpose

The purpose of this study was to evaluate the mineral resource potential of the eastern Capitan Mountains, examine the distributions of ferrous-metal and base-metal geochemical anomalies with regard to their economic potential, and to compare the sensitivity of various sampling techniques in this environment and the mode of mineralization.

The eastern Capitan Mountains were selected because a detailed multimedia geochemical survey could be employed as a suitable exploration technique, and because stream sediment, soil, and rock are available for sampling throughout almost all of the study area. In addition, isolated stream sediment samples analyzed during a National Uranium Resource Evaluation (NURE) investigation revealed copper (Cu), lead (Pb) and zinc (Zn) anomalies warranting further study (Union Carbide, 1981).

Geology and geography of the Capitan pluton

The Capitan Mountains trend east-west and are 32 km long and 8 km wide. The Tertiary Capitan pluton (Allen, 1988) is texturally and chemically zoned from granophyric aplite to equigranular to porphyritic, biotite, subsolvus, alkali-feldspar granite. Vegetation ranges from the piñon-juniper association between 1800 m and 2200 m, through a transition zone between 2200 m and 2700 m dominated by ponderosa pine, to the spruce-fir association above 2700 m (Martin, 1964).

Average annual precipitation in Lincoln County ranges from 63.5 cm to 76.2 cm, and the mean annual temperature ranges from 58°F at the lower elevations to less than 48°F on the mountains (Sprankle, 1983).

MINERAL DEPOSITS

The principal identified mineral deposits in the Capitan Mountains are iron and manganese skarn (Kelley, 1952), and thorium and uranium quartz-fluorite veins (Phillips et al., 1990). Several iron deposits are scattered around the perimeter of the intrusion and occur as magnetite-rich skarn deposits within the Permian San Andres Formation (Fig. 2).

The largest iron deposit associated with the Capitan Mountains is the Capitan iron deposit (see Smith, this volume). This deposit occurs in gently westward-dipping San Andres Limestone underlain by the western end of the intrusion (Kelley, 1952). Two smaller iron deposits and one manganese deposit occur within the study area, near the contact of the San Andres Formation and the Yeso Formation with the Capitan pluton. The manganese ore itself, however, is reported to occur within a shear zone in granite (Tuftin, 1984). Gold (0.02 oz/ton) and silver (<1 oz/ton) were assayed from material collected near the Arabela manganese mine (Tuftin, 1984).

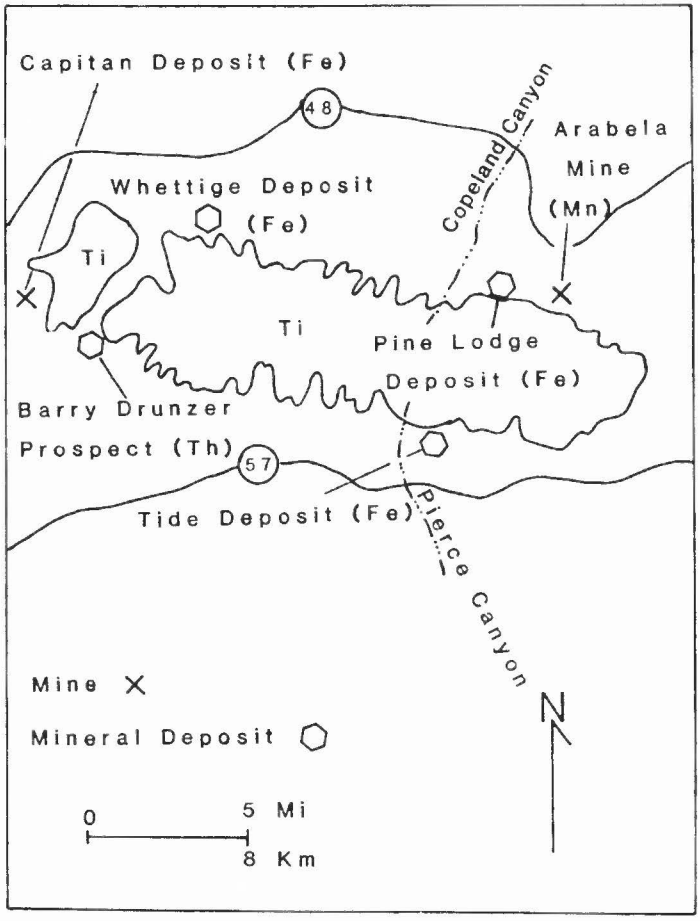


FIGURE 2. Mines and mineral deposits near the igneous-sedimentary rock contact of the Capitan pluton. Ore has been produced from the Capitan iron deposit and the Arabela manganese mine.

Thorium deposits near Capitan Pass occur as joint or fracture fillings in granite and are associated with breccia zones (Tuftin, 1984). Uranium deposits may occur on the north slopes of the mountains, near Capitan Peak (Union Carbide, 1981).

SAMPLE COLLECTION AND PREPARATION

The initial stream sediment sampling effort involved collecting samples from the principal streams at 1.6-km intervals beginning at the study area boundary and extending to the stream head. Follow-up sampling techniques consisted of collecting samples at 183-m intervals upstream from sample locations showing anomalous metal values, and collecting samples traversing the streams from bank to bank. Panned-concentrate samples were prepared by panning a few kilograms of stream sediment until a concentrate of black sand was attained.

Twenty major streams were sampled for a total of 125 bulk stream sediment samples, 12 samples of bank material, and 12 soil samples. The sizes for each type of sample material ranged from 2.5 to 3.0 kg. Sampling methodology and digestive procedures are described in Ellinger and Cepeda (1989).

LABORATORY ANALYSIS

A Perkin-Elmer Model 4000 spectrophotometer and air-acetylene flame were used to analyze solutions for copper (Cu), iron (Fe), magnesium (Mg), manganese (Mn), molybdenum (Mo), lead (Pb) and zinc (Zn). Calibration standards were prepared from cupric sulfate (for Cu), ferrous ammonium sulfate (Fe), magnesium sulfate (Mg), manganous sulfate (Mn), molybdenum trioxide (Mo), lead chloride (Pb), and zinc chloride (Zn). USGS Geochemical Exploration Standards were used as internal standards. Iron concentrations in the six standards range from 34,200 parts per million (ppm) to 247,000 ppm (Gladney and Burns, 1984). Below 50,000 ppm, the analytical error ranges from 36% to 58%, but error decreased with increasing Fe concentration and is less than 3.3% above 100,000 ppm. Error at the lower concentrations is probably a function of the calibration curve for the spectrophotometer. Manganese concentrations in the standards range from 140 to 960 ppm, and error ranged from 23% to 34%.

STATISTICAL METHODS AND ANOMALY IDENTIFICATION

Statistical methods of data analysis were used to distinguish between background, threshold, and anomalous element concentrations. Levinson (1974) and Rose et al. (1979) reported that threshold can be considered to be the mean plus two or three times the standard deviation of a data set. For this study, threshold was calculated as the mean plus two times the standard deviation to produce the largest number of anomalies, and to reduce the chances of eliminating significant anomalies only slightly less in value than the mean plus three times the standard deviation. Table 1 gives for each data set the high and low values, the standard deviation, the mean, the background range and the threshold.

A graphical distribution of background and anomalous concentrations are illustrated by Fig. 3 for Fe in panned concentrate. By plotting

TABLE 1. Tabulated statistical data for elements in bulk (B) and panned concentrate (PC) samples. Concentrations are in ppm.

Element	Standard Deviation	Mean (x)	Background Range		
			Low		x+2s
Fe (B)	29,419	36,239	13,600	—	95,077
Fe (PC)	181,522	247,494	26,375	—	610,538
Mg (B)	28,834	9566	475	—	67,234
Mg (PC)	2308	3199	1075	—	7815
Mn (B)	335	543	100	—	1213
Mn (PC)	1835	2926	250	—	6596
Cu (B)	11	5	0	—	27
Cu (PC)	14	5	0	—	33
Mo (B)	48	147	50	—	243
Mo (PC)	445	800	200	—	1690
Pb (B)	50	157	75	—	257
Pb (PC)	27	57	0	—	111
Zn (B)	104	171	75	—	379
Zn (PC)	313	440	75	—	1066

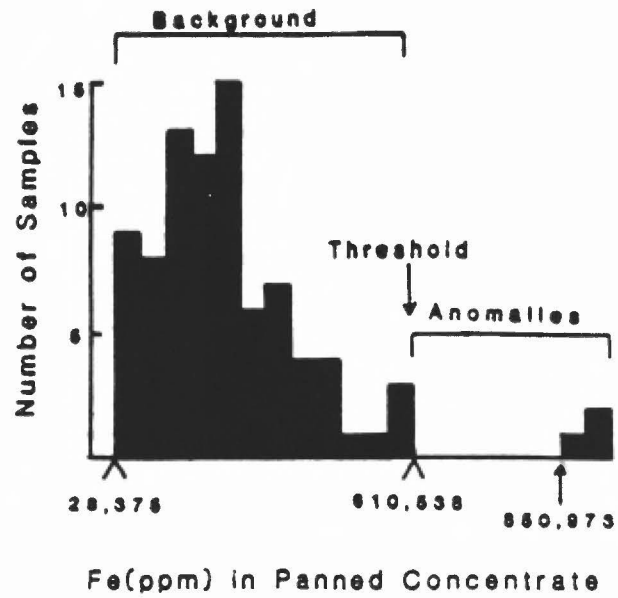


FIGURE 3. Histogram showing the corresponding ranges for background and anomalous concentrations, and the threshold concentration, for Fe in panned concentrate. Concentrations are in ppm.

frequency vs. concentration, it is apparent that background concentrations form adjacent class intervals containing a large number of values at the lower end of the concentration scale. Conversely, anomalous concentrations occur in a small number of class intervals at the higher end of the scale, calculated to be above the 95th percentile. Statistical distributions for the other elements included in this study are similar to Fe in panned concentrate. Element concentrations identified as anomalous by statistics were not evidence of economic mineralization, but did suggest the range of element concentrations indicative of mineralization and which concentrations warranted further study.

RESULTS

Iron

Iron concentrations in bulk stream sediment samples, less than 60-mesh fraction, range from 13,600 to 217,200 ppm (Fig. 4). Greater concentrations occur in panned concentration samples which range from 26,375 to 946,600 ppm (Fig. 5). In general, the locations of anomalies indicated by bulk and panned concentrate samples coincide. The highest concentrations occur in Hale Canyon adjacent to the granite-sedimentary rock contact, and over an alluvial fan. Concentrations decrease upstream from the contact into the granite while concentrations several kilometers downstream remain uniform or even increase.

In Hale Canyon, abundant magnetite float occurs on the surface of the alluvial fan and no magnetite mineralization was found in place. Alluvial magnetite probably originated from a skarn deposit replacing the San Andres Formation. Erosion of the skarn deposit and San Andres Formation has left magnetite-rich alluvium above Yeso Formation beds.

In Pierce Canyon, in a setting analogous to Hale Canyon, an anomaly was detected near the granite-sedimentary rock contact and over an alluvial fan. Magnetite float on the alluvial fan is abundant in the vicinity of the in-place Tide iron deposit. No iron anomalies were detected on the north side of the Capitan Mountains.

Manganese

Manganese concentrations range from 100 to 1825 ppm in bulk sample (Fig. 6), and from 250 to 11,350 ppm in panned concentrate.

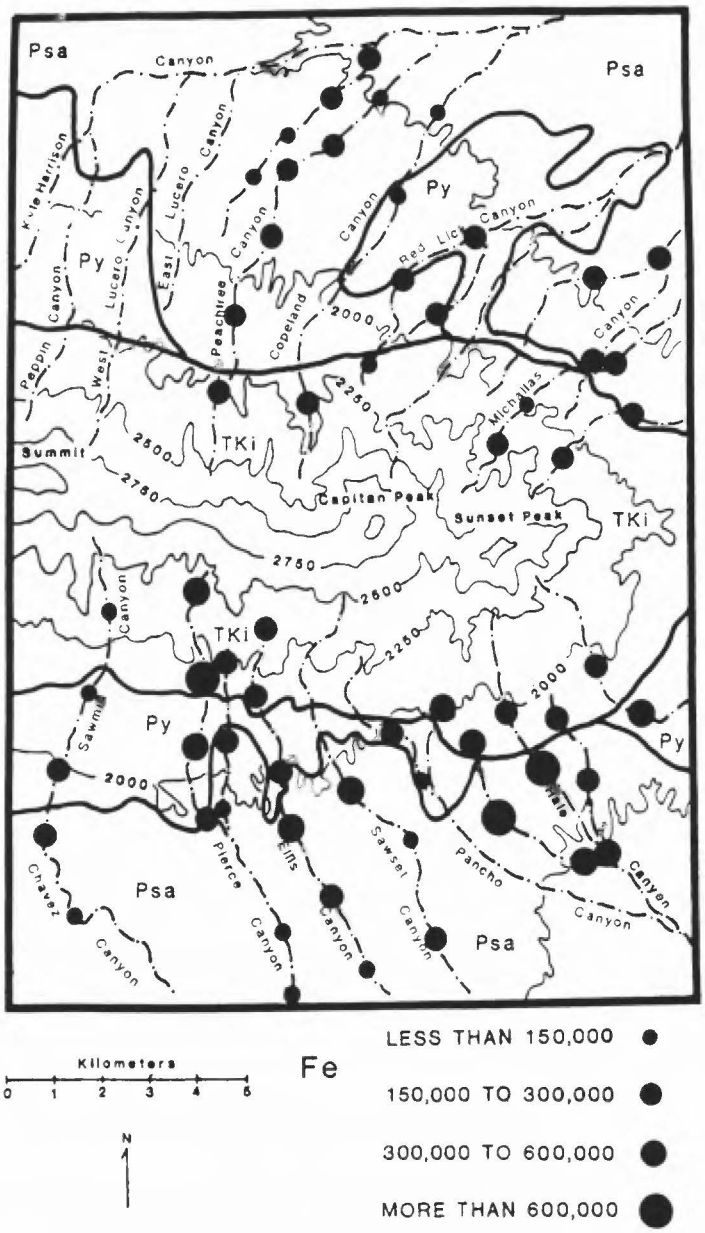


FIGURE 4. Iron concentrations in bulk stream sediment samples for the less than 60 mesh fraction. Concentrations range from 13,600 to 217,200 ppm.

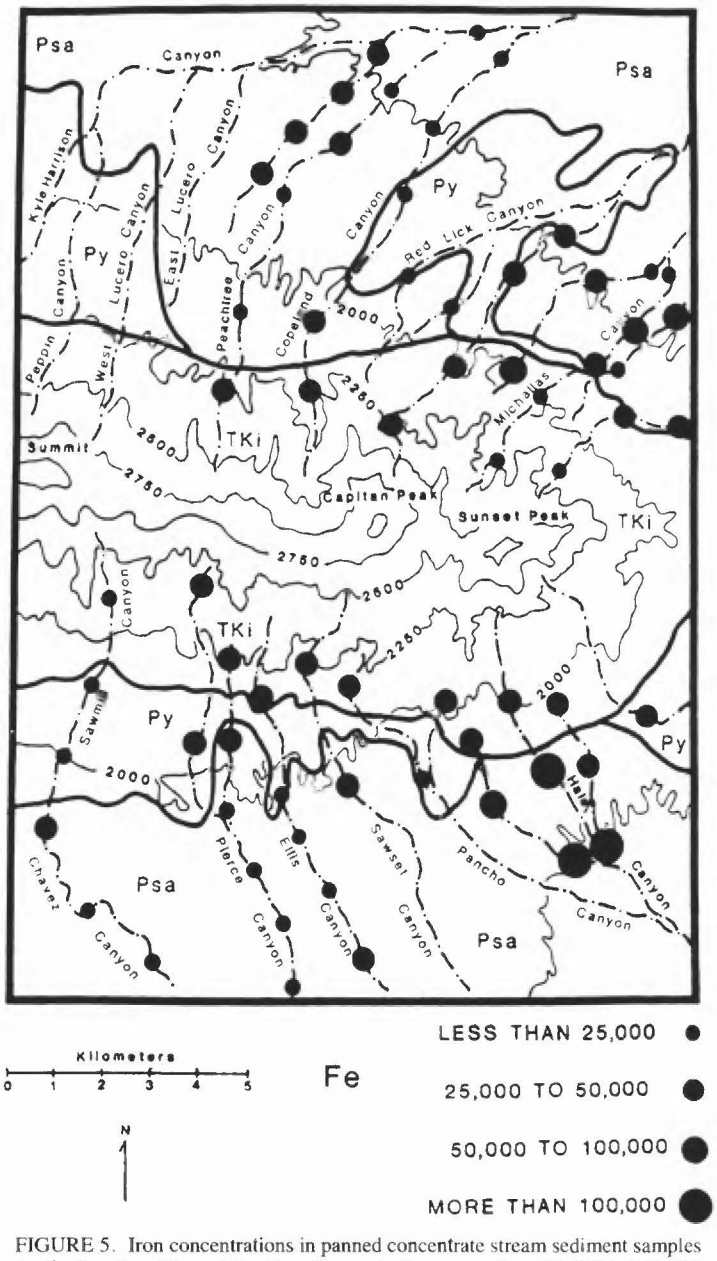


FIGURE 5. Iron concentrations in panned concentrate stream sediment samples for the less than 60 mesh fraction. Concentrations range from 26,375 to 946,600 ppm.

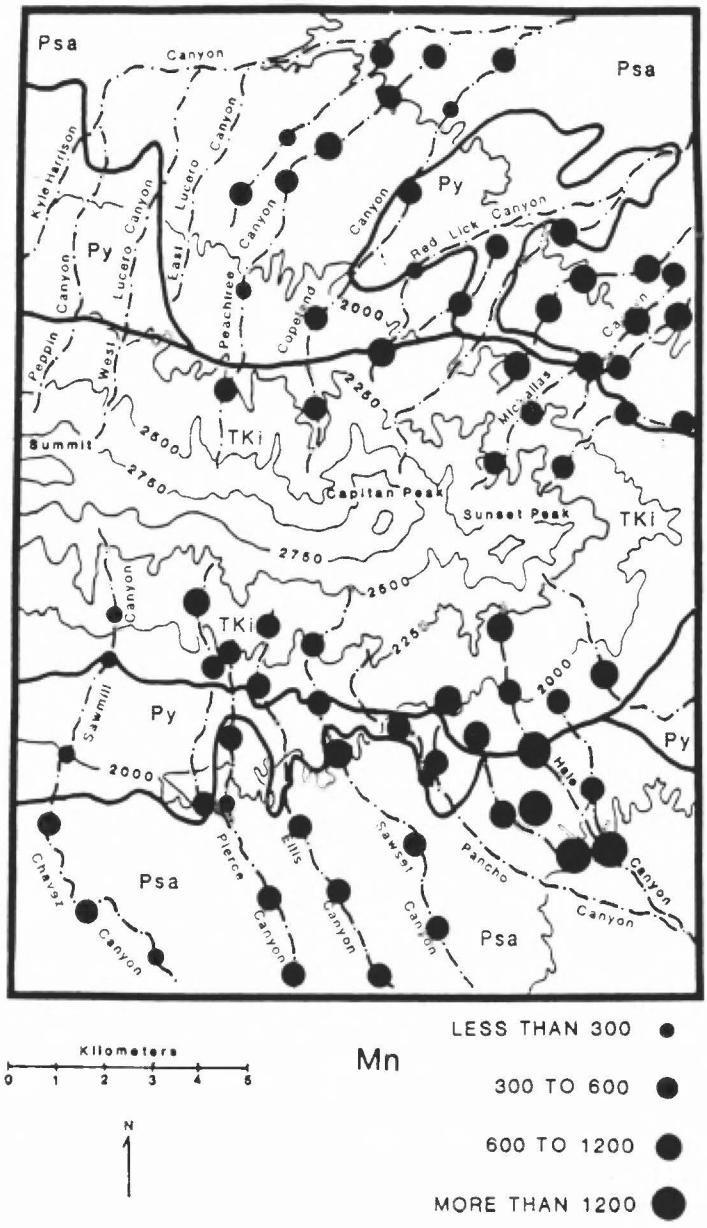


FIGURE 6. Manganese concentrations in bulk stream sediment samples for the less than 60 mesh fraction. Concentrations range from 100 to 1824 ppm.

The highest concentrations occur in Pierce, Sawset, and Hale Canyons, adjacent to the granite-sedimentary rock contact. Upstream from the contact, concentrations decrease to range from 100 to 1100 ppm in bulk sample. Typically, concentrations downstream remain uniform or even increase, although downstream in Pierce Canyon concentrations tend to decrease. We found little evidence of secondary precipitation of iron and manganese, such as crusts or concretionary accumulations, in the stream sediments. Stream cobbles and boulders, predominantly granite, are free of crusts and we found no evidence of concretionary Mn oxides in the panned concentrates.

Two possible causes of Mn anomalies are apparent. One is the abundance of sphene in stream sediment. The highest Mn concentration detected, 11,350 ppm in Pierce Canyon, was panned concentrate composed of approximately 70% sphene. The second possible cause of Mn anomalies is the transportation of Mn in solution and subsequent precipitation downstream.

Mn anomalies were not detected near the Arabela manganese mine. This may result from a lack of acid conditions required to mobilize Mn, and the small size of the deposit.

Magnesium

Magnesium concentrations range from 475 to 220,325 ppm in bulk sample, and from 1075 to 13,350 ppm in panned concentrate. Anomalies are evident just west of Seven Cabins Canyon, along Copeland and Red Lick Canyons, and just west of Pierce Canyon. Concentrations tend to increase downstream, producing anomalies several kilometers away from the intrusion. Mineralogical analysis of bulk and panned-concentrate samples revealed the presence of abundant pink dolomite rhombohedrons and an absence of Mg-bearing skarn material. Magnesium anomalies represent a decrease in granitic material and an increase in dolomitic material. Panned-concentrate values are less than bulk sample values because dolomitic material, with a specific gravity of 2.85 to 2.95, becomes diluted by panning. The euhedral nature of the dolomite crystals may suggest a hydrothermal origin.

Copper, molybdenum, lead and zinc

The highest concentrations detected for Cu, Mo, Pb, and Zn are 100 ppm, 2550 ppm, 325 ppm and 1625 ppm respectively. Although an occasional anomalous amount of Cu was detected, most measurements for Cu are below the limit of detection of the atomic absorption unit. There is no correlation between detected Cu with Fe and Mn anomalies. Pb concentrations decrease slightly in panned concentrate. Cu- or Pb-bearing minerals were not found while examining panned-concentrate mineralogy.

NURE ANOMALIES

Anomalies in stream sediment detected by the NURE program include barium (Ba), cerium (Ce), copper, lanthanum (La), lead, manganese, niobium (Nb), silver (Ag), thorium (Th), yttrium (Y) and zinc (Union Carbide, 1981). In the Hale Canyon area, Ag, Ba, Ce, Cu, La, Pb and Zn anomalies were detected by the NURE study, and Fe and Mn anomalies were detected by this study. Nb and Y anomalies detected by the NURE study near Sawmill Canyon are near Fe, Mn and sphene anomalies of this study. Ba, Ce, La and Mn anomalies were detected by the NURE study at the eastern base of Sunset Peak, where access for sampling was not gained. NURE anomalies in spring water include Cu and Mo near Summit Peak, Mn and Si near Copeland Canyon, and Ag, Al, B, Ba, Fe, Mn and Sr near the eastern base of Sunset Peak.

In general, NURE anomalous locations and those identified in this study coincide. The only NURE anomalous areas not detected by this study are those near the eastern base of Sunset Peak, from which stream sediment samples were not collected for analysis, and those in spring water, which again, was not sampled. Secondary sampling may delineate NURE anomalies in Pierce Canyon and the Hale Canyon area, owing to the coincident occurrence of Fe and Mn anomalies to elements detected by the NURE study.

STREAM-SEDIMENT MINERALOGY

The mineralogy of stream sediment was examined to determine the relationship between element anomalies and the mineralogical composition of stream-sediment samples. Oil-immersion techniques were used to study the 30-to-60-mesh fraction of panned-concentrate samples collected just downstream from the intrusion. Heavy minerals include abundant magnetite, lesser amounts of sphene, biotite, anatase and ilmenite, and rarely actinolite and zircon.

Sand-sized magnetite composed approximately 50 wt% of samples producing Fe anomalies, compared to only about 1 to 10 wt% magnetite in samples without anomalous concentrations. Sphene, biotite and anatase were next in abundance to magnetite.

Mg anomalies are produced by pink dolomite crystals, up to 0.50 mm in diameter, occurring as aggregates attached to quartz, calcite, and feldspar grains. Anomalous samples do not contain actinolite, and only a few biotite grains were found.

Sphene, possibly producing the Mn anomaly in Pierce Canyon, may be derived from granite near the Tide iron deposit. Alluvial sphene crystals, up to 1 mm across, are about the same size as those found in granite throughout the Capitan pluton.

Ce, La, Nb, Y, Na and Ba concentrations increase toward the eastern

end of the intrusion, and strong Ce and La anomalies near Sunset Peak may represent alluvial bastnaesite, or sphene, but not monazite (R. M. Chamberlin, personal comm., 1986). Monazite is excluded because thorium, a common constituent of monazite, was not detected by the NURE study. Bastnaesite was not identified in panned-concentrate samples.

DISCUSSION

The major metallic element in the stream sediments derived from the Capitan Mountains is iron, with subordinate manganese and magnesium. The magnesium anomalies are apparently caused by the presence of dolomite crystals in the sediments, and are not discussed further.

The source of the iron anomalies is primarily magnetite-actinolite skarns localized adjacent to the intrusive contact, as exemplified by the Tide prospect at the head of Pierce Canyon. However, most drainages do not presently expose skarn deposits at this contact, even though the stream sediments contain abundant iron. It is apparent that, in many instances, the skarn deposits from which this magnetite was derived have been eroded away, particularly in the eastern end of the range. Cannibalization of magnetite-rich sediment from the banks of active streams maintains a high iron concentration as much as 10 km downstream from the igneous-sedimentary rock contact.

The greater degree of erosion of skarn deposits on the eastern end of the Capitan Mountains, compared to the western end, indicates that the eastern end is on a deeper and older erosional level and that tilting of the pluton may have occurred. Follow-up study is warranted and may take the form of geobarometric investigations or a search for remnants of bedded units that formed the roof of the pluton.

Manganese anomalies correlate with high concentrations of sphene. The source of the deposits may be the Capitan granite or skarn deposits at the margin of the pluton. Alluvial sphene crystals, however, are approximately the same size as those observed in the granite. Butler (1964) reported that, at the Tide iron deposit, magnetite has replaced portions of sphene crystals, suggesting at least a part of the sphene may be of contact metamorphic origin. R. M. Chamberlin (personal comm., 1986) noted that Ce, La, Nb and Y concentrations increase toward the eastern end of the Capitan pluton. Some of the observed rare-earth-element increase may be carried in the form of sphene.

Anomalous concentrations of Cu, Mo, Pb and Zn were noted in several locations, generally near the igneous-sedimentary rock contact or a short distance downstream from it (Fig. 7). The highest concentrations of Mo and Zn occur where Fe anomalies were detected in Pierce and Hale Canyons. No evidence of secondary oxides, such as coatings or concretions, were noted in the field. Although base-metal anomalies were not the focus of this study, they warrant further investigation.

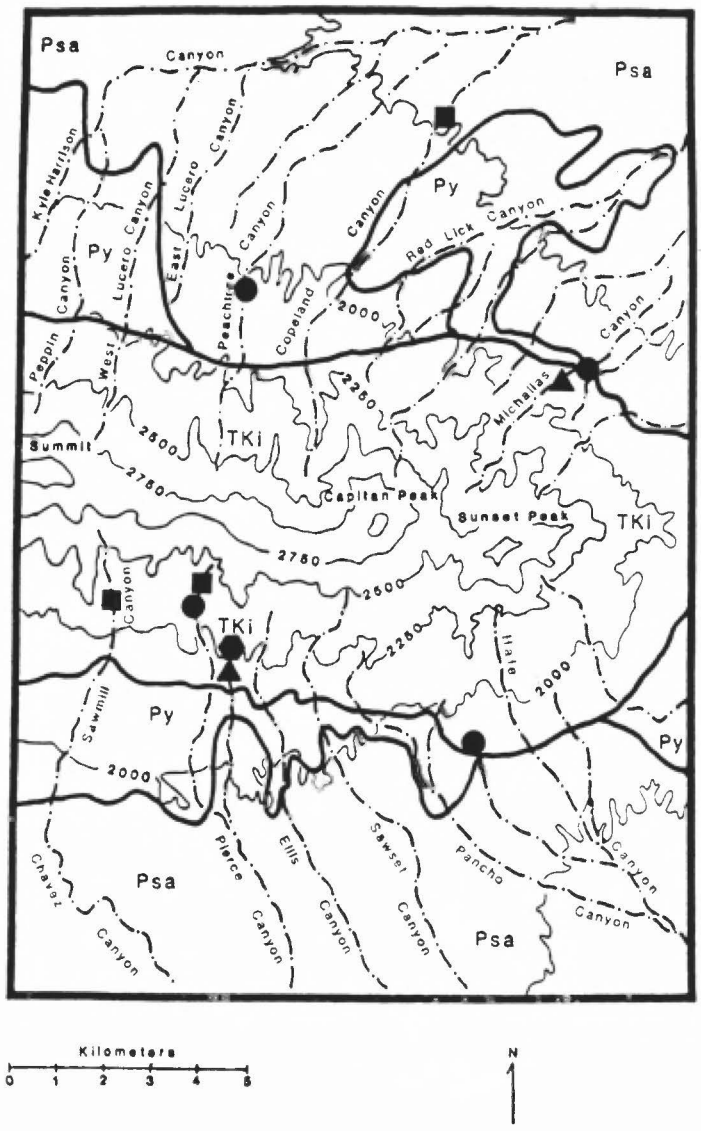


FIGURE 7. Anomalous concentrations of copper (hexagon), molybdenum (squares), lead (triangles), and zinc (circles) in bulk stream sediment samples.

CONCLUSIONS

Although anomalous concentrations of Fe and Mn occur adjacent to the Capitan Mountains, no in-place mineralization was detected, probably because none exists. Extensive erosion of the margins of the Capitan pluton removed most of the skarn deposits, particularly in the eastern end of the range, and distributed the iron throughout the alluvial blanket surrounding the range. This alluvial blanket now constitutes a probable low grade iron resource.

Additional minerals in the form of rare-earth-element mineralization may be present within the granite and as alluvial concentrations of REE-bearing minerals such as sphene or bastnaesite.

The presence of anomalous concentrations of Pb, Zn, Cu and Mo adjacent to the intrusion suggest the possibility of hydrothermal or contact-metamorphic mineralization. The concentrations of these metals, although above the threshold values by our statistical analysis, do not suggest a large base metal deposit.

ACKNOWLEDGMENTS

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The Henry Clay, shown in this circa 1890 view, along with the Little Mack on the same structure, are the northernmost mines in the White Oaks district. The Henry Clay, tied up in litigation during its early life, is said to have produced fine-looking specimens but little ore. Production after circa 1905, if any, may well have been credited to the Little Mack. New Mexico Bureau of Mines collection No. 1662, courtesy of Richard H. Jahns and John Kelt.