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Analytical data for stream sediment, heavy-mineral  
concentrate, and outcrop samples, Sur Medio region,  
Departments of Ica, Ayacucho, and Huancavelica, Peru.  
Part A: General discussion.

by

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## INTRODUCTION

During the period September, 1981 to June, 1985, the U.S. Geological Survey (USGS) and the Empresa Minera del Centro del Peru (CENTROMIN) conducted a geochemical survey of the Sur Medio region of southwestern Peru (fig. 1). The study was an integral part of a mineral resource assessment, undertaken jointly by the two agencies. The purpose of this report is to make available to the public, the geochemical data generated by the study.

The study area is a northwest trending strip approximately 170 km long, averaging 60 km wide, and encompassing some 10,000 km<sup>2</sup> in area (fig. 1). The area is bounded roughly by the Rio Pisco basin on the north, the Rio Ingenio basin on the south, the 3,300-m contour on the east, and the Pan American highway on the west. The city of Ica, situated on the Pan American Highway, 300 km south of Lima, served as headquarters for the project geologists, chemists, and support staff.

Access to the study area from the north and south is afforded by the Pan American highway, a two-lane paved road bordering the study area on the west. From the highway to the interior of the study area, access is gained by a number of unimproved roads that follow the major river valleys crossing the area from west to east. These roads are generally negotiable only by four-wheel drive vehicles, and during the Andean rainy season are often rendered impassable by floodwaters emanating from higher elevations.

## GEOGRAPHICAL SETTING

The rugged topography of the Sur Medio area is typical of the western flank of the Peruvian Andes: steep slopes, angular morphology, and deeply incised drainages. The major drainage systems of the area, are from north to south, the Rio Pisco, the Rio Ica, the Rio Grande, and the Rio Ingenio. Elevations above sea level range from approximately 300 m along the western margin of the area to greater than 3000 m along the eastern margin.

The climate of the Sur Medio region is exceptionally dry. The western part of the area, toward the coastal plain, rarely receives measurable rainfall; sparse cactus is the principal vegetation and windblown sediment forms spectacular dunes. The eastern part of the area, where elevations are much greater, receives minor rainfall during the Andean wet season, from December to April. Here, the vegetation consists mainly of grass and desert shrubs. Only the major river channels that issue from the high Andes commonly carry water during the rainy season; their tributaries in the Sur Medio area rarely flow, irrespective of season. Mean annual temperature in the area varies with elevation, but it exceeds 20°C over much of the area.

Rock exposures cover at least 80 percent of the area. The remaining 20 percent or less is covered by loess in the western part of the area and by thin soil in the eastern part.

## GEOLOGICAL SETTING

Geologically, the study area encompasses a 170-km segment of the composite Peruvian Coastal Batholith, which consists of mid-Cretaceous to early Tertiary plutons, largely of granodiorite to quartz-diorite composition. The batholith intrudes late Jurassic to middle Cretaceous sedimentary and volcano-sedimentary rocks. Tertiary volcanic rocks extensively overlie older rocks along the eastern margin of the area.

The area is generally considered to be a copper province, but deposits of other metals also occur. According to Vidal (1980), the following types of deposits are present: 1) barite-sphalerite-galena-pyrite-chalcopyrite lodes and disseminations (massive sulfide deposits), 2) chalcopyrite-molybdenite-scheelite-galena skarns, 3) amphibole-magnetite-chalcopyrite sheets and dikes, 4) chalcopyrite-molybdenite-pyrite disseminations (porphyry copper deposits), 5) quartz-specularite-chalcopyrite veins, 6) calcite-chalcopyrite-bornite veins and breccia pipes, and 7) quartz-calcite-auriferous pyrite veins.

## GEOCHEMICAL SAMPLE PROCEDURES

### Sample Design

The regional-scale sampling design was intrinsically simple. Initially, potential sample sites were marked on 1:100,000-scale topographic maps of the region near the mouths of all first-order (unbranched) streams. In practice, some sites were sampled on second-order streams to provide coverage where first-order streams are absent or accessible only with great difficulty. The resulting sample density is approximately one (1) sample per 10 km<sup>2</sup>, which is probably sufficient to detect district-scale mineralization, but which is insufficient to detect all individual deposits. Samples were collected at 733 sites.

### Sample Collection

**Stream sediment.** Each sample consisted of 8 kg of sediment, sieved on-site to eliminate lithic fragments larger than 2-mm diameter in order to effectively increase the size of the sample. To minimize sampling error, each sample was composited from at least 6 sub-samples collected along the active stream channel within 50 m of the mapped site. Almost all samples were collected immediately upstream of confluences, but in all cases above levels at which sediment crossover had probably occurred. At field headquarters, a 1-kg sample, to be retained for subsequent preparation and chemical analysis, was taken from the bulk (8 kg) sample by coning and quartering. The remaining 7 kg was subsequently panned to obtain a heavy-mineral concentrate.

**Heavy-mineral concentrate.** Each 7 kg remaining from the bulk stream-sediment sample was panned by traditional techniques in a steel gold pan of 35-cm diameter to the point at which the loss of the ferromagnesian minerals just commenced. The resulting concentrate was retained for heavy liquid and magnetic separations and for subsequent chemical analysis.

**Rock.** An outcrop sample weighing approximately 1 kg was collected near most stream sediment collection sites. Additional outcrop samples were collected where a rock unit was clearly inhomogeneous, where two or more rock types were present, or where mineralized rock was observed.

### Sample Preparation

**Stream sediment.** To eliminate contaminating loess particles and large lithic fragments from the sediment samples, each 1-kg sample was sieved to a  $>.25$  mm,  $<1.0$  mm fraction. This fraction was then ground to  $<0.0625$  mm by ceramic plate pulverizer.

**Heavy-mineral concentrate.** The panned concentrate samples were introduced into separatory funnels containing bromoform (sp. gr. 2.83) and the heavy minerals were drawn off, cleaned in acetone, and air dried. The resulting heavy-mineral fraction was then separated magnetically into three fractions of decreasing magnetic susceptibility: 1) the c-1 fraction consisting mainly of magnetite; 2) the c-2 fraction, consisting mainly of ferromagnesian silicates and secondary iron oxides; and 3) the c-3 fraction, consisting mainly of metallic sulfides and other ore-related minerals, including native gold. The concentrate fractions were pulverized manually, utilizing a corundum mortar and pestle.

**Rock outcrop.** The rock samples were reduced by jaw crusher to  $< 1/2$ -cm fragments which in turn were pulverized to  $<0.0625$  mm in preparation for chemical analysis.

### CHEMICAL ANALYSIS

Weighed samples of stream sediment (10 mg), heavy-mineral concentrate (5 mg), and rock (10 mg) were analyzed for 31 chemical elements by a six-step, semiquantitative method of emission spectrography (Grimes and Marranzino, 1968). Because determinations were made by optical comparator, the concentrations are classed in terms of intervals whose limits increase logarithmically, in accordance with human visual perception. In practice, concentrations are reported as decimal multiples or sub multiples of 1, 1.5, 2, 3, 5, or 7, a sequence of numbers representing midpoints of the six concentration intervals. The lower and upper limits of determination for each element analyzed are given in tables 1 and 2 of Part A.

### GEOCHEMICAL DATA

The results of the chemical analyses for each of the samples, together with their respective geographical coordinates, are compiled in tables 1, 2, and 3 of

Part B, and are also recorded on the accompanying diskette (Part C). The data are tabulated in three separate files representing: 1) the c-3 magnetic fraction of the heavy-mineral concentrates (PERUGXC3. DIF), 2) the >0.25-mm, <1.0-mm fraction of the stream sediment samples, (PERUGXSD. DIF), and 3) the outcrop samples (PERUGXRK. DIF). All three data files are in data interchange format (DIF) and can be imported into most spreadsheet and database application software. The analytical data of the c-1 and c-2 magnetic fractions of the heavy-mineral concentrates are not included here; these fractions were analyzed only for a 75-sample pilot study, which indicated that these two fractions provided substantially lower anomaly-to-background ratios and substantially shorter downstream dispersion trains than did the c-3 fraction.

The first column in each of the three analytical data tables contain a 7-character sample number in which the first two characters are letters identifying the drainage basin from which that sample was collected. The three numerals that follow represent the chronological sequence of site collection in the drainage basin. The following letter indicates the sample medium, and the seventh and final character, a numeral, indicates the chronological sequence of sample collection at the site. Thus, the sample number PI070C2, signifies the second concentrate sample collected at the 70th sample site in the Río Pisco drainage basin. (Two samples were collected at every tenth site so that analytical and sampling consistency could be checked by analysis of variance).

The second and third columns of the tables contain the longitude and latitude respectively, of the sample site, in decimal degrees. The fourth column indicates the sample medium analyzed; the fifth, sixth, and seventh columns show the report number, name(s) of the analytical chemist(s), and the date of analysis, respectively; and the remaining columns contain the concentrations of the elements determined, in percent or parts-per million as indicated.

The values indicating concentrations of the elements determined are shown as multiples or sub multiples of numerals in the sequence, 1, 1.5, 2, 3, 5, or 7. However, the letters G, L, and N commonly appear in the tables in lieu of numerical concentrations. The letter G, indicates that the concentration of the element determined is above the upper limit of determination shown for that element in table 1 or 2. Likewise, the letter, L, indicates that the element was detected, but its concentration was below the lower limit of determination shown for that element in table 1 or 2. The letter N, indicates that the element was sought, but not detected at the lower limit of determination shown in table 1 or 2.

#### REFERENCES CITED

Grimes, D.J., and Marranzino, A.P., 1968, Direct-current arc emission spectrographic field methods for the semiquantitative analysis of geologic materials: U.S. Geological Survey Circular 591, 6 p.

Vidal, Cesar E., 1980, Mineral deposits associated with the Peruvian Coastal Batholith and its volcanic country rocks: Ph.D. dissertation, University of Liverpool, England, 284 p.

**Table 1. -- Limits of determination for the spectrographic analysis of rocks, and stream sediments based on a 10-mg sample.**

Elements	Lower determination limit	Upper determination limit
	Percent	
Iron (Fe)	0.05	20
Magnesium (Mg)	0.02	10
Calcium (Ca)	0.05	20
Titanium (Ti)	0.002	1
	Parts per million	
Manganese (Mn)	10	5,000
Silver (Ag)	0.5	5,000
Arsenic (As)	200	10,000
Gold (Au)	10	500
Boron (B)	10	2,000
Barium (Ba)	20	5,000
Beryllium (Be)	1	1,000
Bismuth (Bi)	10	1,000
Cadmium (Cd)	20	500
Cobalt (Co)	10	2,000
Chromium (Cr)	10	5,000
Copper (Cu)	5	20,000
Lanthanum (La)	50	1,000
Molybdenum (Mo)	5	2,000
Niobium (Nb)	20	2,000
Nickel (Ni)	5	5,000
Lead (Pb)	10	20,000
Antimony (Sb)	100	10,000
Scandium (Sc)	5	100
Tin (Sn)	10	1,000
Strontium (Sr)	100	5,000
Vanadium (V)	10	10,000
Tungsten (W)	20	10,000
Yttrium (Y)	10	2,000
Zinc (Zn)	200	10,000
Zirconium (Zr)	10	1,000
Thorium (Th)	100	2,000

**Table 2.--Limits of determination for the spectrographic analysis of heavy-mineral concentrates based on a 5-mg sample**

Elements	Lower determination limit	Upper determination limit
Percent		
Iron (Fe)	0.1	50
Magnesium (Mg)	0.05	20
Calcium (Ca)	0.1	50
Titanium (Ti)	0.005	2
Parts per million		
Manganese (Mn)	20	10,000
Silver (Ag)	1	10,000
Arsenic (As)	500	20,000
Gold (Au)	20	1,000
Boron (B)	20	5,000
Barium (Ba)	50	10,000
Beryllium (Be)	2	2,000
Bismuth (Bi)	20	2,000
Cadmium (Cd)	50	1,000
Cobalt (Co)	10	5,000
Chromium (Cr)	20	10,000
Copper (Cu)	10	50,000
Lanthanum (La)	50	2,000
Molybdenum (Mo)	10	5,000
Niobium (Nb)	50	5,000
Nickel (Ni)	10	10,000
Lead (Pb)	20	50,000
Antimony (Sb)	200	20,000
Scandium (Sc)	10	200
Tin (Sn)	20	2,000
Strontium (Sr)	200	10,000
Vanadium (V)	20	20,000
Tungsten (W)	100	20,000
Yttrium (Y)	20	5,000
Zinc (Zn)	500	20,000
Zirconium (Zr)	20	2,000
Thorium (Th)	200	5,000

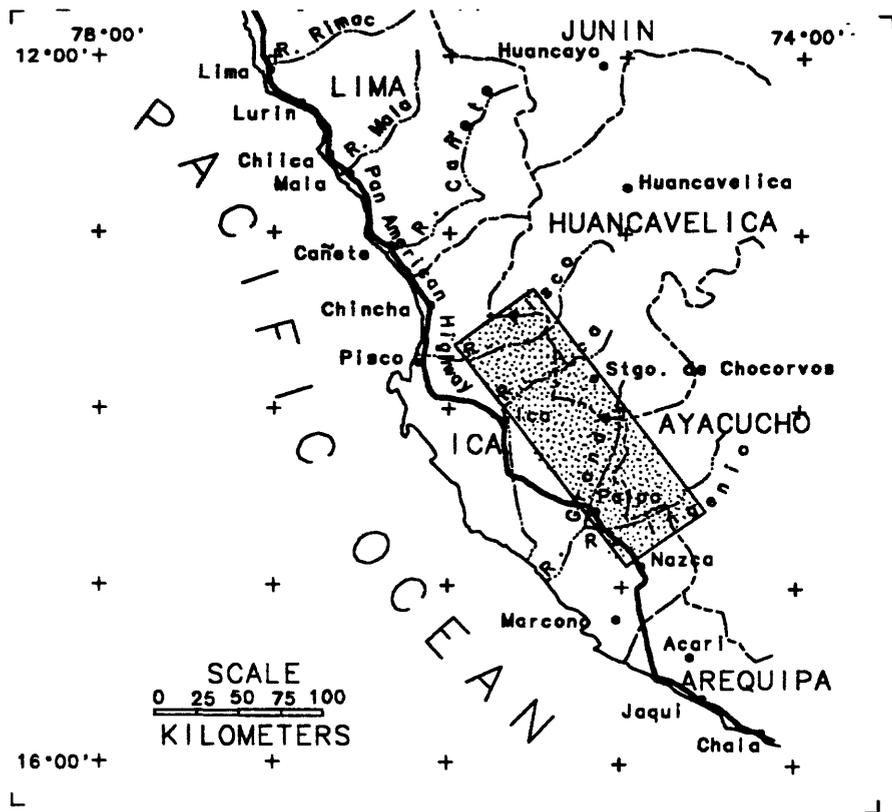


Figure 1. Index map of southwestern Peru showing the approximate boundaries of the Sur Medio study area (shaded).