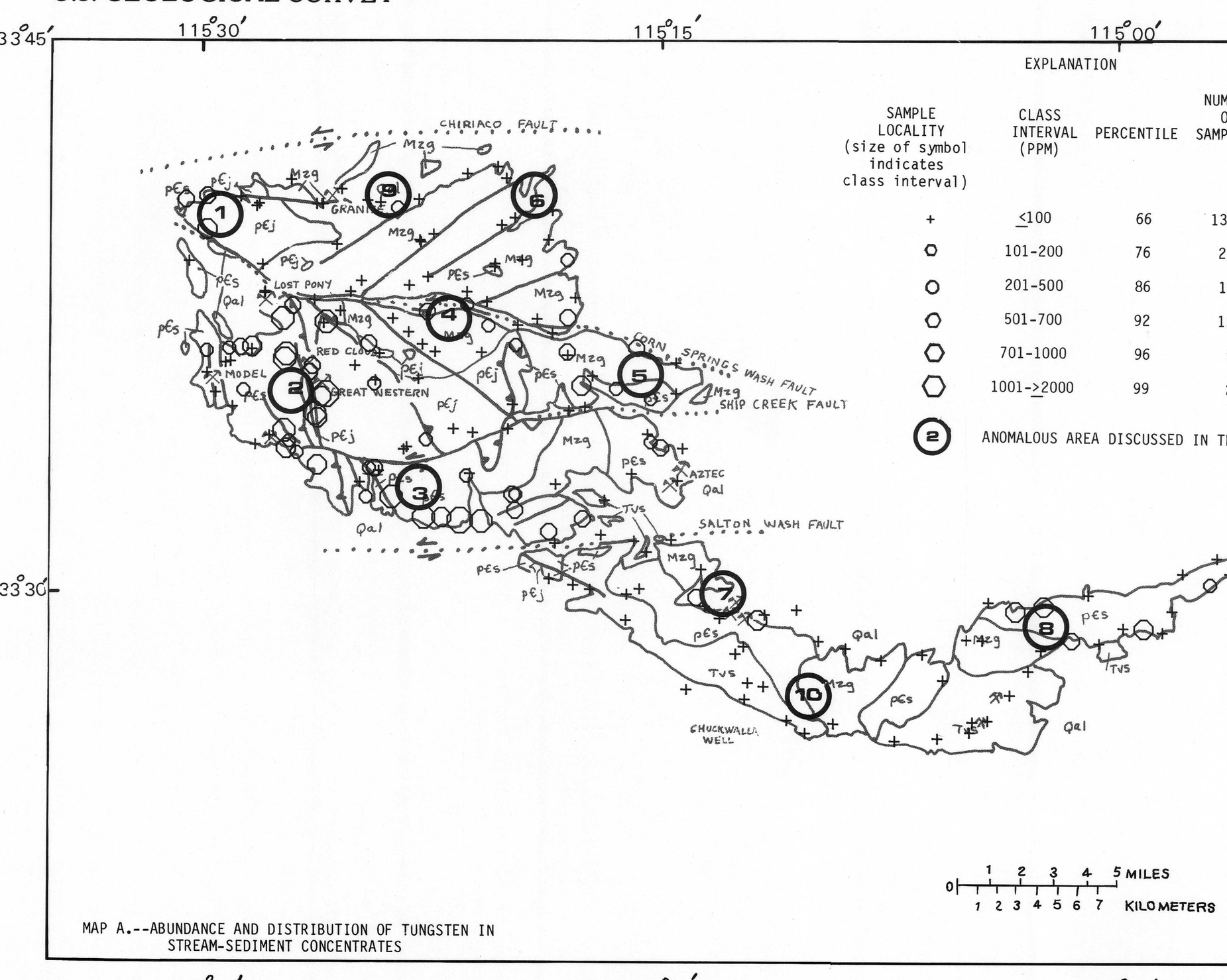
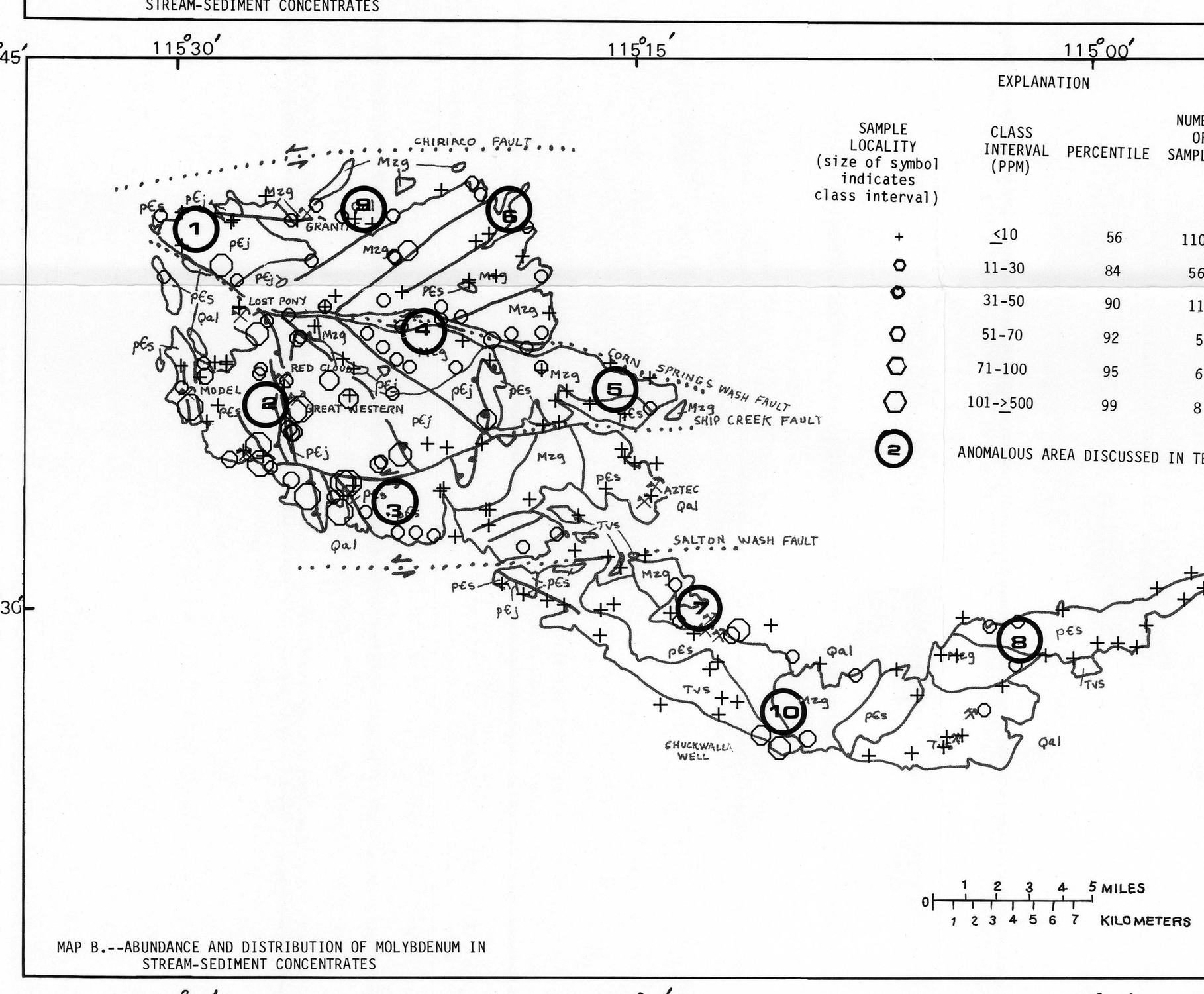
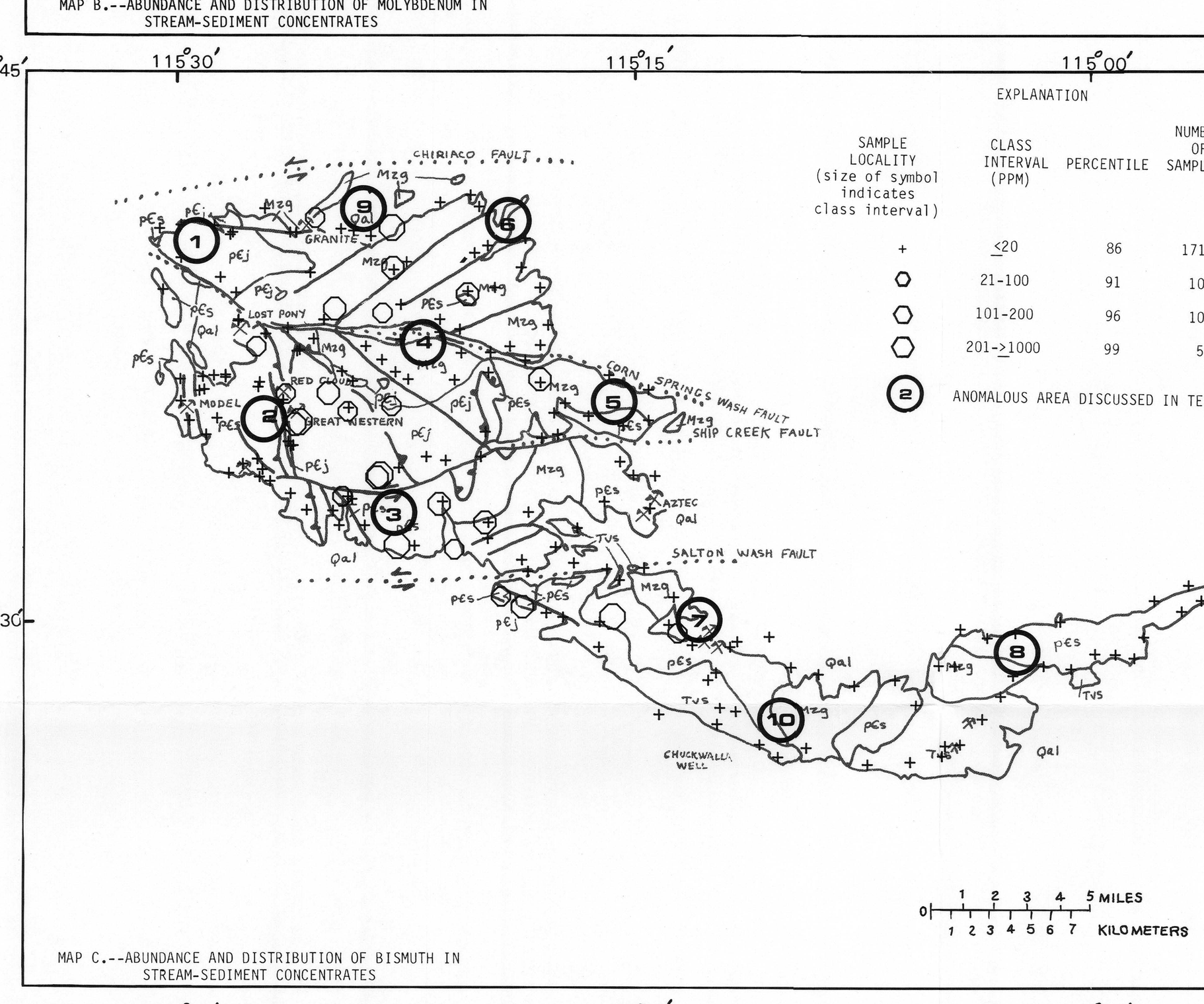


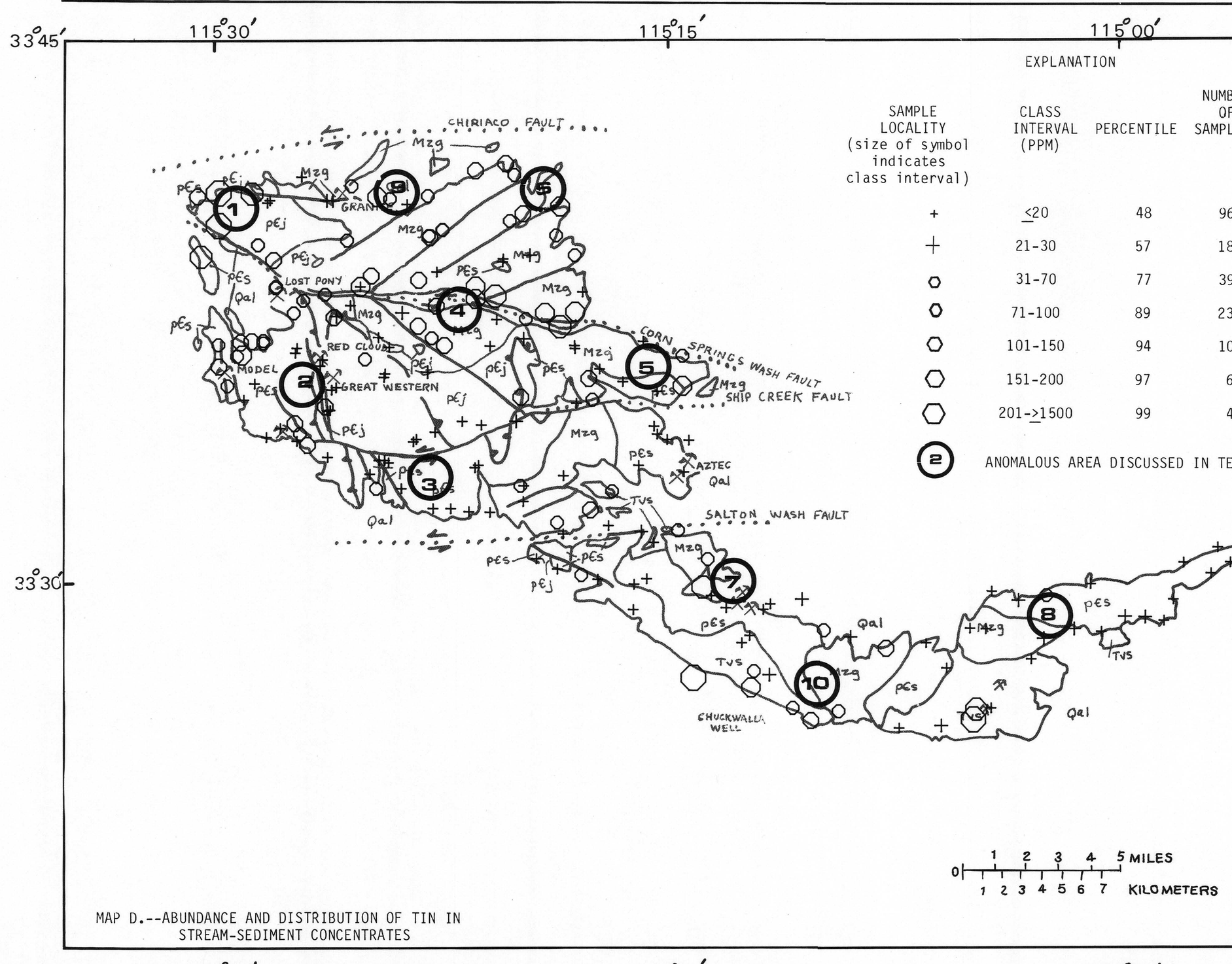
MAP A.--ABUNDANCE AND DISTRIBUTION OF TUNGSTEN IN STREAM-SEDIMENT CONCENTRATES



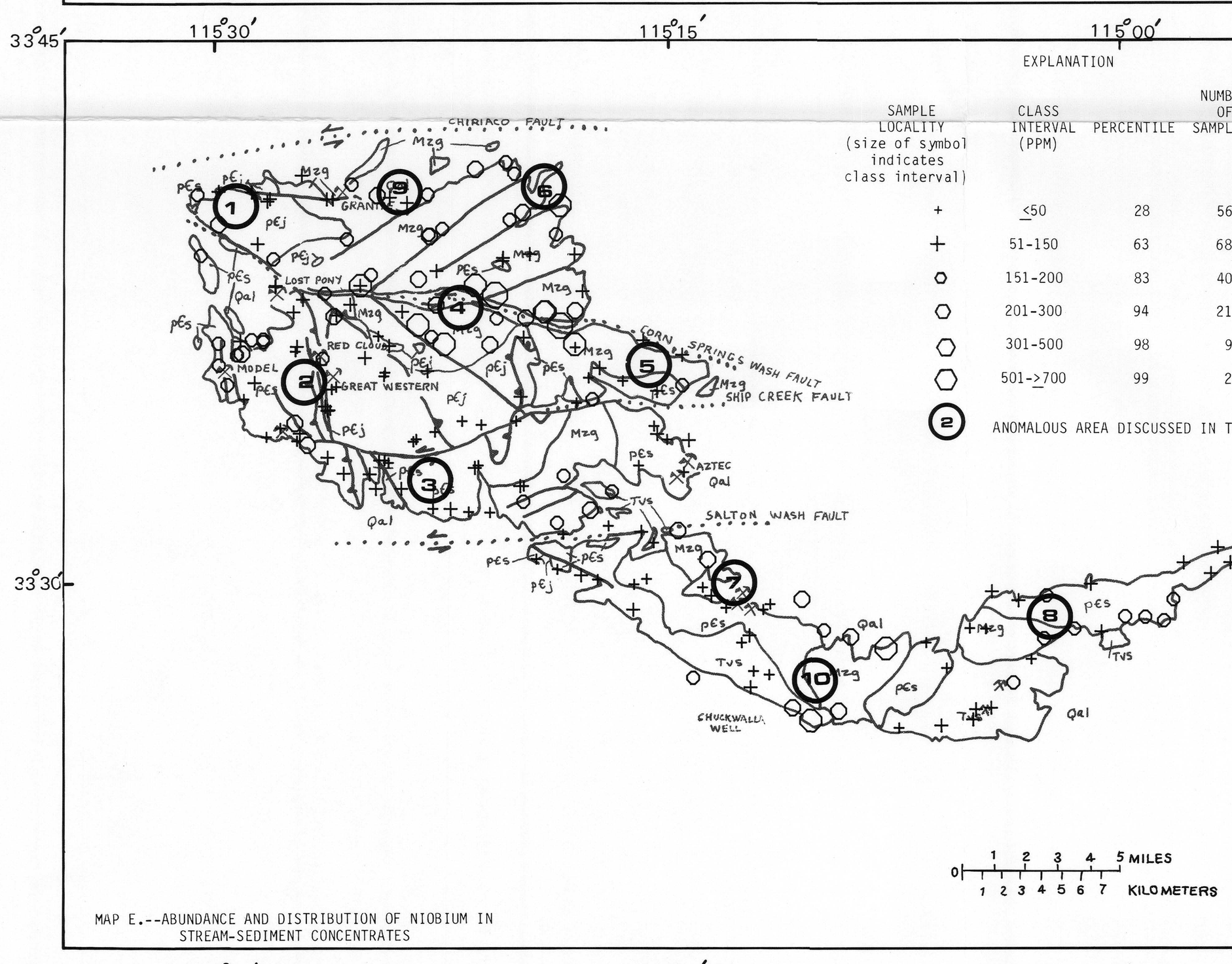
MAP B.--ABUNDANCE AND DISTRIBUTION OF MOLYBDENUM IN STREAM-SEDIMENT CONCENTRATES



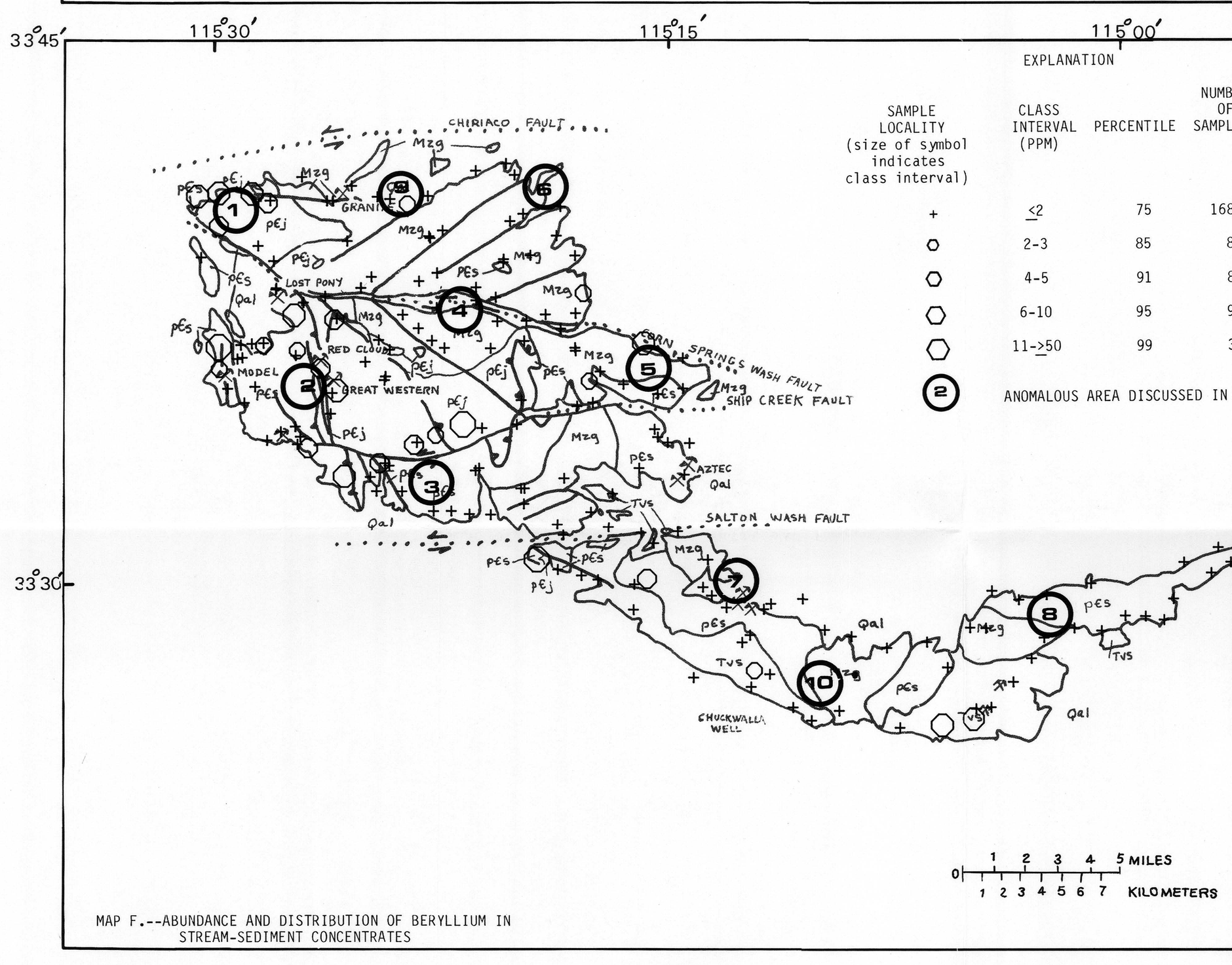
MAP C.--ABUNDANCE AND DISTRIBUTION OF BISMUTH IN STREAM-SEDIMENT CONCENTRATES



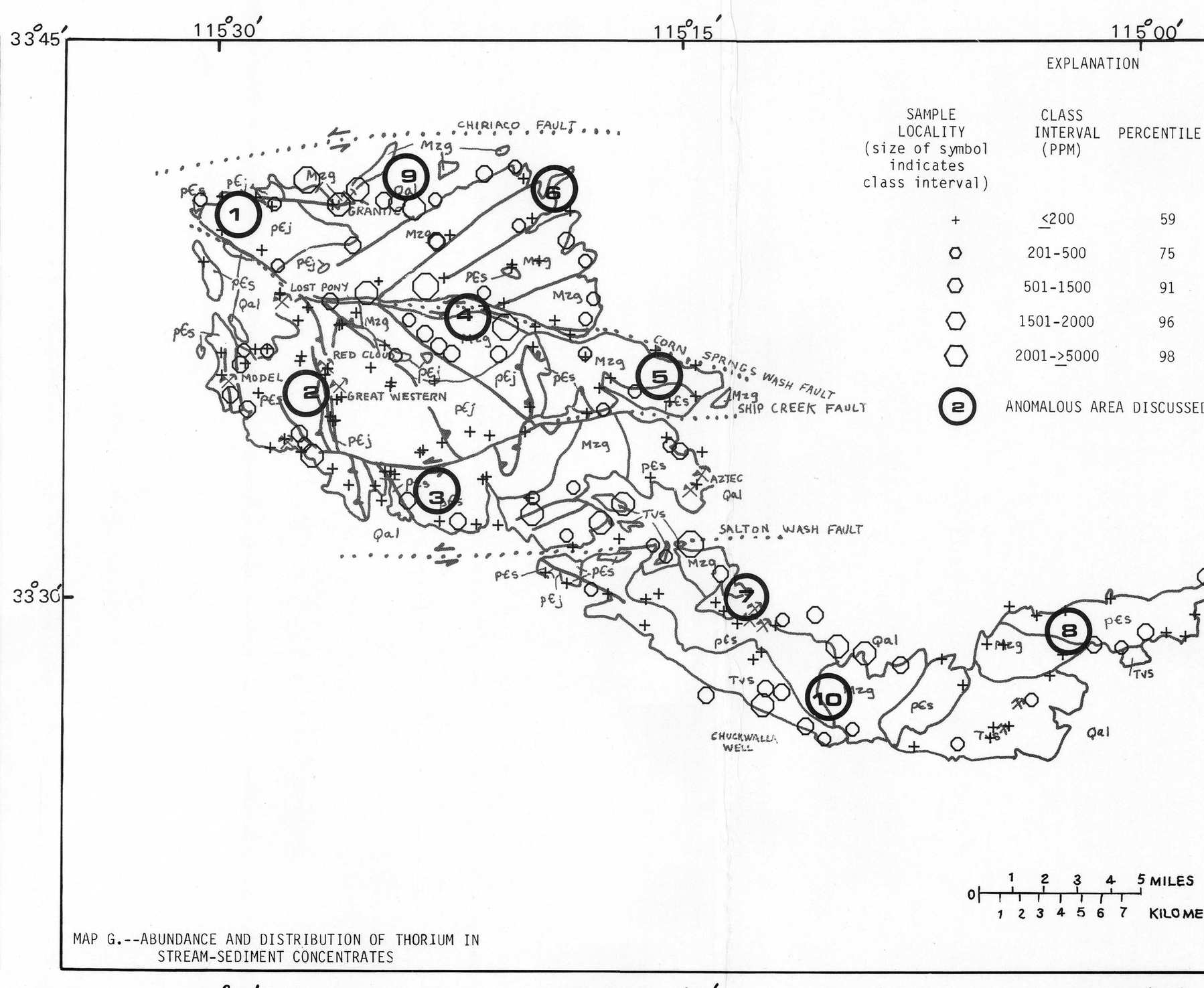
MAP D.--ABUNDANCE AND DISTRIBUTION OF TIN IN STREAM-SEDIMENT CONCENTRATES



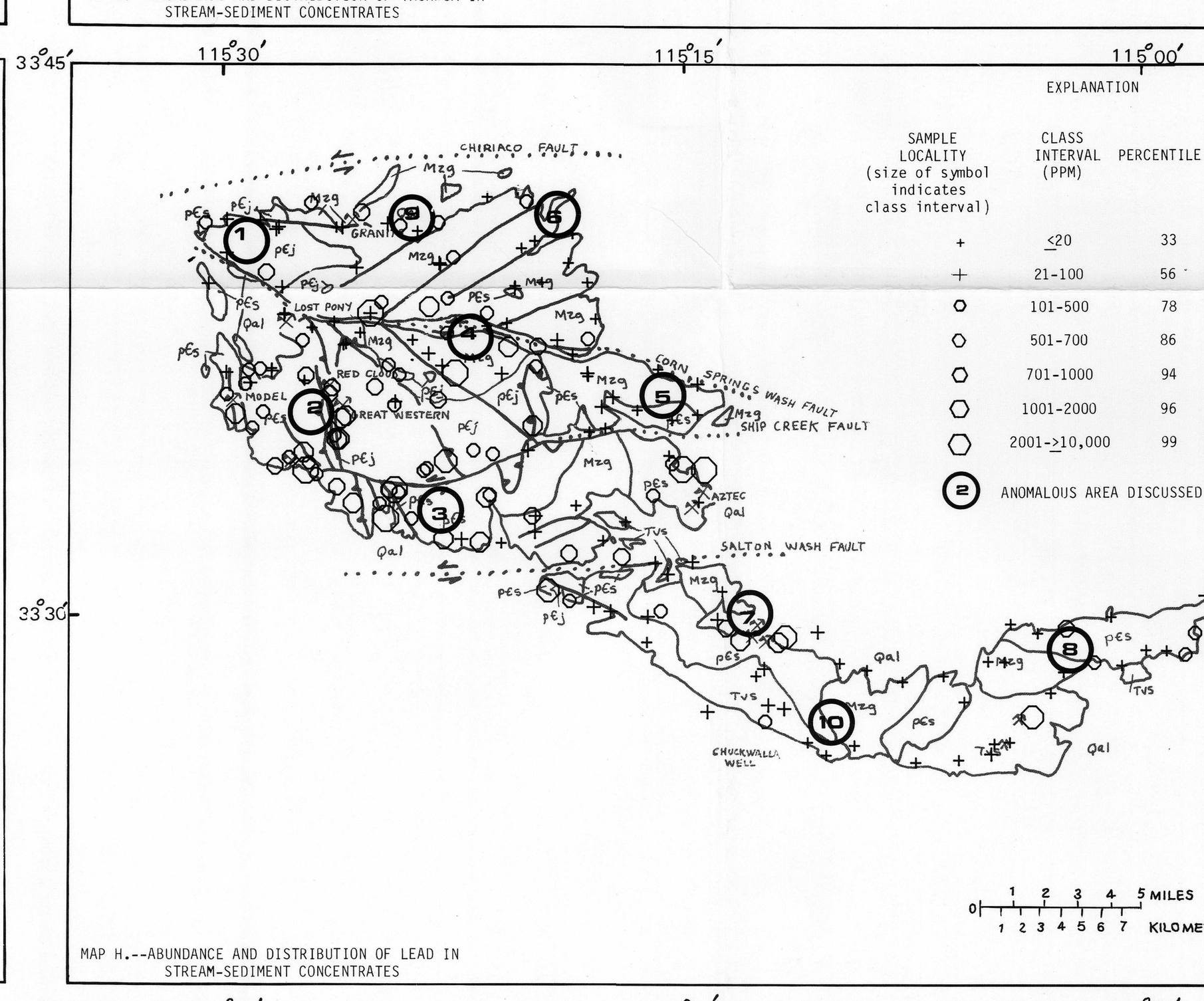
MAP E.--ABUNDANCE AND DISTRIBUTION OF NIOBIUM IN STREAM-SEDIMENT CONCENTRATES



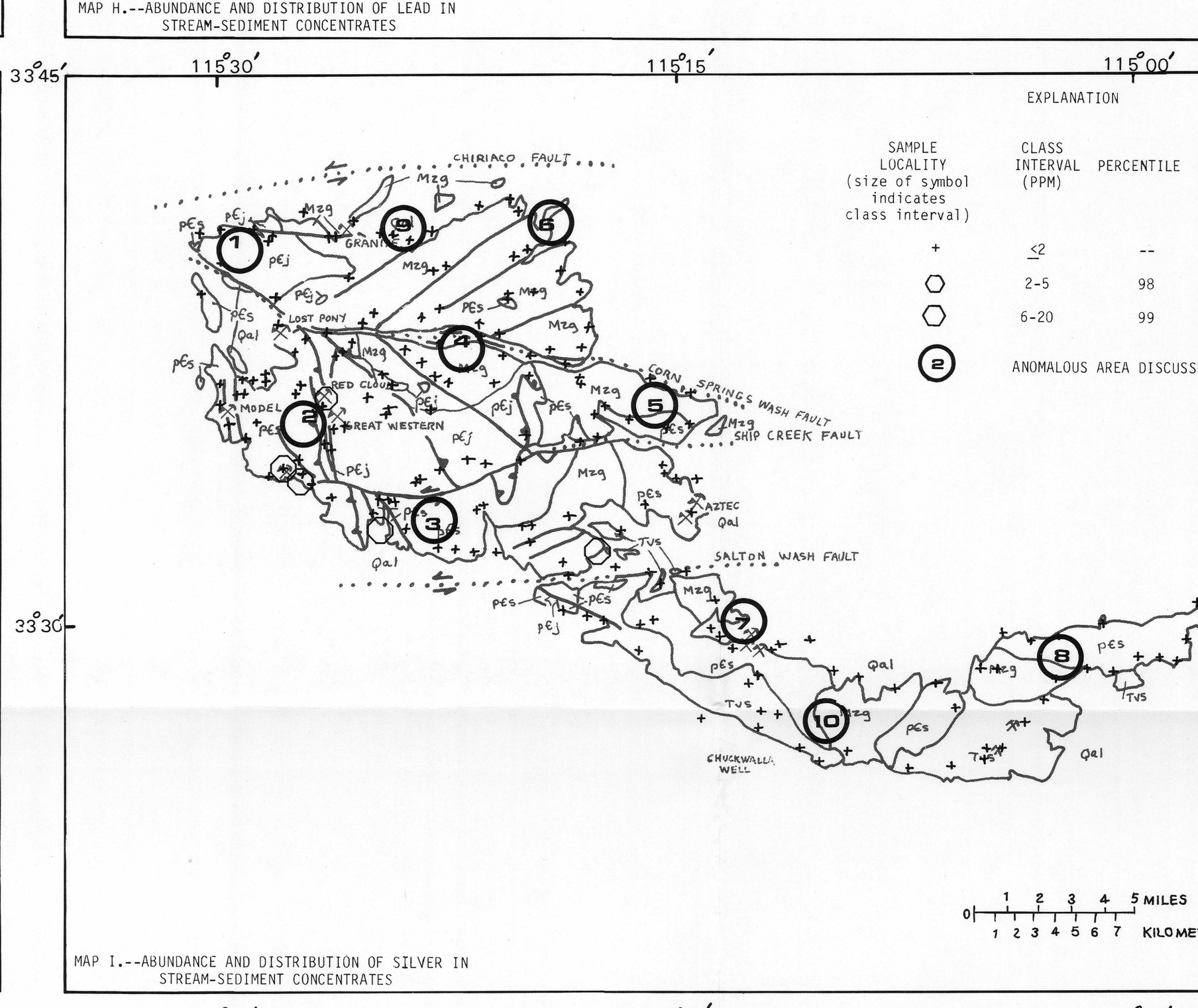
MAP F.--ABUNDANCE AND DISTRIBUTION OF BERYLLIUM IN STREAM-SEDIMENT CONCENTRATES



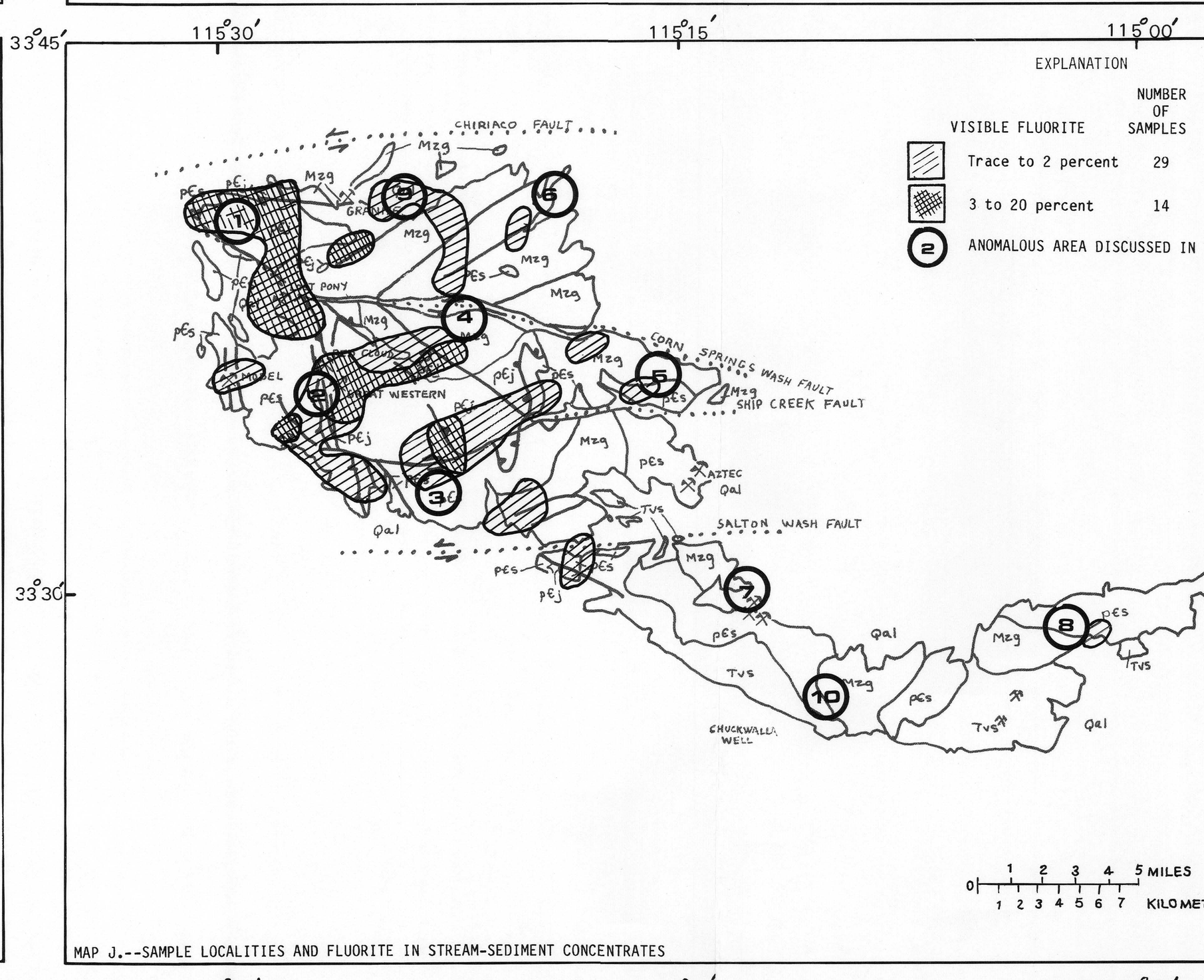
MAP G.--ABUNDANCE AND DISTRIBUTION OF THORIUM IN STREAM-SEDIMENT CONCENTRATES



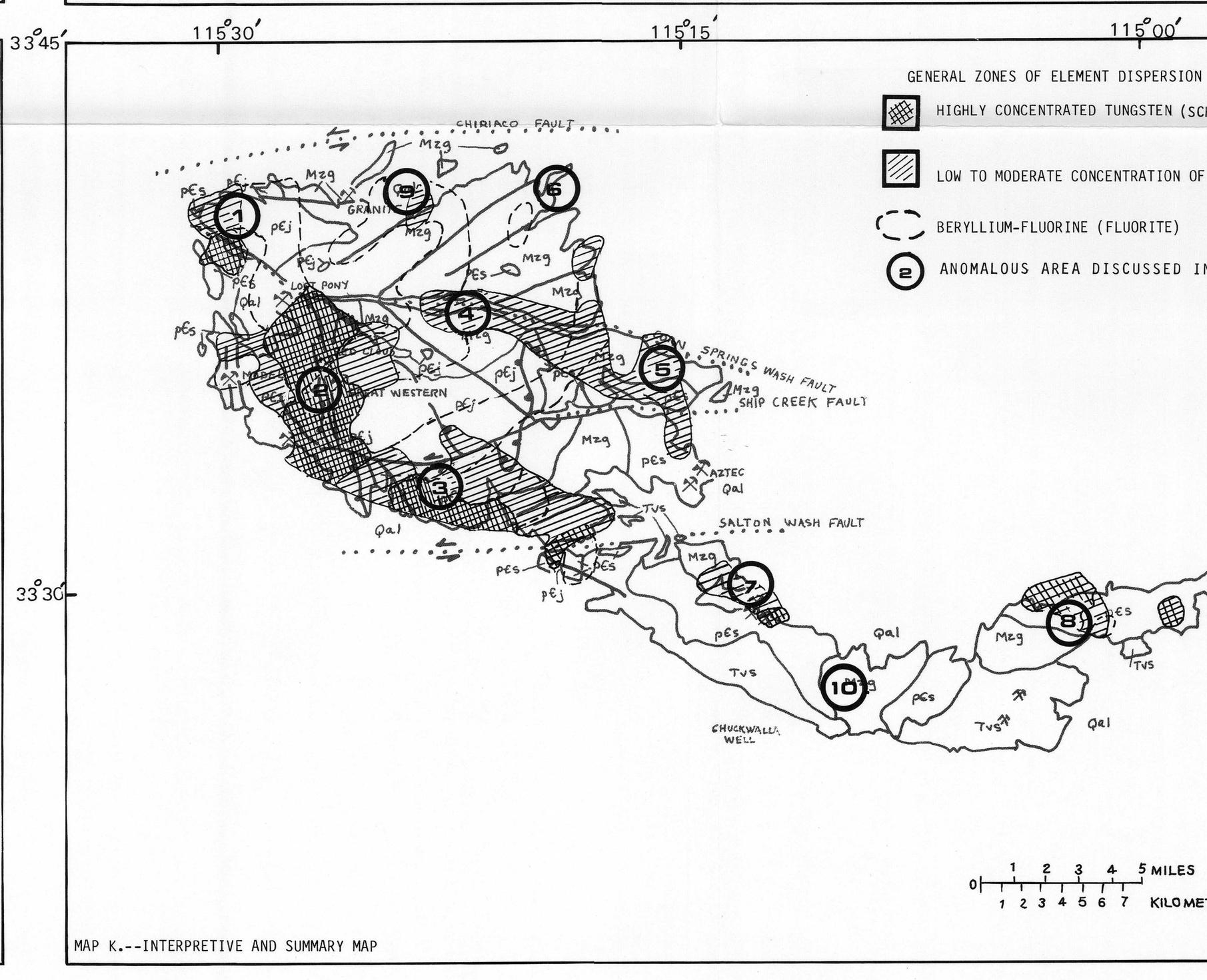
MAP H.--ABUNDANCE AND DISTRIBUTION OF LEAD IN STREAM-SEDIMENT CONCENTRATES



MAP I.--ABUNDANCE AND DISTRIBUTION OF SILVER IN STREAM-SEDIMENT CONCENTRATES



MAP J.--SAMPLE LOCALITIES AND FLUORITE IN STREAM-SEDIMENT CONCENTRATES



MAP K.--INTERPRETIVE AND SUMMARY MAP

EXPLANATION FOR GEOLOGIC BASE
(Shown in gray; modified from Powell and others, 1984)

Qal Alluvium (Quaternary)
Tvs Volcanic and sedimentary rocks (Tertiary)
Mzg Granitic and gabbroic rocks (Mesozoic)
P€s San Gabriel terrane (Precambrian)--Metasedimentary gneiss, orthogneiss, and syenite-mangerite-jotunite
P€j Joshua Tree terrane (Precambrian)--Granite gneiss
CONTACT
HIGH-ANGLE FAULT OR FRACTURE--Dotted where covered; arrows indicate relative movement
RED CLOUD THRUST FAULT--Sawteeth on upper plate
MINE

STUDIES RELATED TO WILDERNESS

Bureau of Land Management Wilderness Study Areas

The Federal Land Policy and Management Act (Public Law 94-579, October 21, 1976) requires the U.S. Geological Survey and the U.S. Bureau of Mines to conduct mineral surveys on certain areas to determine the mineral values, if any, that may be present. 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 Chuckwalla Mountains Wilderness Study Area (CDCA-348), California Desert Conservation Area, Riverside County, California.

INTRODUCTION

In March 1982, as part of the mineral resource investigations of the area, the U.S. Geological Survey conducted a reconnaissance geochemical survey of the Chuckwalla Mountains Wilderness Study Area (WSA), Riverside County, California. The survey involved collecting 196 heavy-mineral (panned) concentrates from stream sediment (the basis for these maps and the chief basis for the interpretations), the same number of sieved stream-sediment samples, and 25 samples of fresh, altered, or mineralized rocks. A broad regional geochemical framework for mineral resource evaluation was established by sampling a few miles beyond the boundaries of the WSA to include all of the Chuckwalla and Little Chuckwalla Mountains. These geochemical maps are therefore regional maps but of sufficient detail to allow valid conclusions about geochemical anomalies in the WSA.

The geochemical data were evaluated in three phases: (1) determining enrichment above background amounts for ore-forming and pathfinder (ore-associated) elements; (2) determining the dispersion patterns of the anomalous elements; and (3) relating the dispersion patterns to geologic environments favorable to ore deposition.

This report discusses and interprets geochemical results as they are seen at the reconnaissance stage. Analytical results for all samples collected are released in a U.S. Geological Survey Open-File Report (Adrian and others, 1985). A statistical summary of the data from heavy-mineral concentrates and sieved stream sediments is shown in table 1. The analytical results for selected elements in rock samples are shown in table 2.

Previous studies

The U.S. Bureau of Land Management did an early geochemical study of the Chuckwalla Mountains Wilderness Study Area that was used in a GEM Resources Area Report and a Management Summary of the mineral resource potential. This information, presumably gathered between 1978 and 1982, became available to the U.S. Geological Survey in 1982 and was reviewed by the author prior to this geochemical study. The U.S. Bureau of Land Management data compares well in both sample media used and analytical results obtained with that subsequently gathered, but is too general in scope for more than a cursory evaluation of the geochemistry. As a result, the general framework established by the U.S. Bureau of Land Management was expanded upon in the later work, but it was, however, decided to confine the geochemical evaluation to the U.S. Geological Survey data base.

Acknowledgments

Several full- and part-time members of the U.S. Geological Survey contributed to this geochemical study. Bruce Van Brunt and Nancy Thurman assisted in the field during the spring of 1982 and Julian Gray assisted in the office during 1982-1983. Field preparation of the samples prior to analysis were by John Unruh. Spectrographic analyses were by Betty Adrian and Gordon Day. Atomic-absorption analyses were by Al Meier. The analytical results are released in a separate report (Adrian and others, 1985).

GEOGRAPHIC SETTING

The Chuckwalla Mountains lie just south of Interstate Highway 10 at Desert Center, Riverside County, California, which is approximately 180 mi east-southeast of Los Angeles. The range is one of the eastern ranges of the Transverse Ranges of California (Powell, 1981) and covers an area of about 215 mi², mostly within a squarish block north of an unnamed east-draining wash that bisects the range (fig. 1). South of that wash, the range is narrow and trends southeast to Graham Pass where it merges with the east-west trending Little Chuckwalla Mountains.

The Chuckwalla Mountains rise abruptly from the desert floor to 4,504 ft at Black Butte and 4,216 ft at Pilot Mountain in the south-central part of the WSA. The northern block of the range is flanked by bajadas on all sides; the southern block is flanked by a bajada to the northeast. At the base of the range, on its northeast flank, the desert floor varies in elevation from about 900 to 1,600 ft, whereas on the southwest flank of the range, the desert floor varies from about 1,400 to 2,600 ft. The Chuckwalla Mountains are nearly transected by three major drainages--Corn Springs Wash, Ship Creek, and the unnamed wash that separates the northern and southern blocks of the range. These washes all drain to the east along the traces of east-west trending Cenozoic faults.

The Chuckwalla Mountains Wilderness Study Area consists of about 90 mi² in the northern block of the range. The WSA is split by a corridor along Corn Springs Wash with embayments into each segment that exclude from the WSA areas of numerous mines with past production of precious and base metals, prospects reflecting present day mining interest and the roads leading to them. These roads provide ready access to the WSA.

GEOLOGIC SETTING

Because of scale, the geologic base for the regional geochemical maps is simplified into four generalized geologic units, differing in age, lithology, and tectonic genesis. The geologic summary that follows from Powell and others (1984) refers to figure 2, which shows some of the geologic details of the Chuckwalla Mountains Wilderness Study Area at a larger scale than that of the simplified geology used as a base on the regional geochemical maps.

Pre-mid-Jurassic rocks comprise two lithologically distinct terranes within the crystalline basement complex of the eastern Transverse Ranges, which include the Chuckwalla, as well as the Orocopia, Eagle, Cottonwood, Hexie, Little San Bernardino, and Pinto Mountains of Riverside County, California (see fig. 1). These terranes are referred to as Joshua Tree (P€s) and San Gabriel (P€j) terranes by Powell (1981, 1982) for regions of southern California where their lithologic units were first described. The two terranes are superposed in the Chuckwalla Mountains along the Red Cloud thrust fault, a low-angle fault system of regional extent, which is exposed as a north to northwesterly zone to the south of Corn Springs Wash.

The structurally lower Joshua Tree terrane (P€j) consists of Precambrian granite capped by a paleoweathered zone, overlain nonconformably by undifferentiated orthoquartzite that interfingers westward with pelitic and feldspathic granofels and schist units and local dolomite. Near the Red Cloud thrust zone, the entire sequence comprising the Joshua Tree terrane was pervasively deformed to granite gneiss, stretched pebble conglomerate, lineated quartzite, and schist. The granite gneiss is extensively exposed in the Chuckwalla Mountains, whereas minor exposures of the paleoweathered zone, quartzite, and quartz-biotite-cordierite(?) granofels occur only in the southwest corner of the range.

Precambrian lithologic units of the San Gabriel terrane (P€s) in the Chuckwalla Mountains include amphibolite-grade metasedimentary gneiss intruded by granodioritic augen gneiss; both units are in turn underlain by retrograded granulitic gneiss; all are in turn intruded by syenite-mangerite-jotunite.

The Red Cloud fault zone was apparently developed in four sequential structural events, which are recognized in the Chuckwalla Mountains: (1) early thrusting that probably moved parallel to east-northeast mineral lineations recorded in both plates; (2) regional folding of the initial thrust surface around north-northeast-trending axes; (3) later thrusting that moved westward across a fold in the older thrust surface to produce a stacking of thrust plates of the Joshua Tree and San Gabriel terranes; (4) continued or renewed folding of both thrust faults with eventual overturning toward the southwest. All observations to date link these structural events to a single regional tectonic episode that resulted in allochthonous emplacement of the San Gabriel terrane westward over the Joshua Tree terrane.

Mesozoic plutonic rocks in the Chuckwalla Mountains comprise two batholithic suites, both of which intrude the Joshua Tree and San Gabriel terranes and the Red Cloud fault zone. The batholithic suites are combined in one unit (Mzg) on the simplified geologic base for these geochemical maps. Northwest-southeast-trending belts of plutonic lithologic units have been mapped within each suite. The older suite, which is Jurassic in age and lies to the northeast, consists of biotite- and alkali feldspar-bearing gabbro-diorite intruded by low-quartz monzogranite to quartz monzonite. The younger suite, which is of Cretaceous and (or) Jurassic age, includes hornblende-biotite-sphene granodiorite intruded by porphyritic monzogranite, intruded in turn by nonporphyritic monzogranite. Felsic, intermediate, and mafic dikes crosscut plutons of both batholithic suites in swarms. These dike swarms may have genetic relationships to the known mineral deposits and to some geochemical anomalies in the WSA. Unfortunately, because of scale, these dikes cannot be shown on the geologic base for the geochemical maps; they are shown on figure 2.

The rocks of the Chuckwalla Mountains are cut by several Cenozoic east-west-trending, left-lateral, strike-slip faults that have a cumulative westward displacement from south to north. The Chiriaco and Salton Wash faults bound the northern block of the Chuckwalla Mountains to the north and south, respectively, and the Corn Springs Wash and Ship Creek faults are found within the range; all faults are of the Cenozoic, strike-slip system. Geochemical evidence, such as offset anomaly clusters on opposite sides of faults, suggests that mineral deposits may have been slightly displaced laterally by the Cenozoic faulting.

MINES AND MINING ACTIVITY

Mining activity and prospecting has been extensive in the Chuckwalla Mountains. Prospects and mines range from small pits dug into altered zones or quartzose veins to developed mines of small to moderate past production (Lane, 1983, unpublished data; Powell and others, 1984). The mines have produced gold, silver and some lead, zinc, and tungsten, which are commonly localized in quartz veins near the propylitically altered mafic dikes that crosscut most rock units in the area; in some cases the quartz veins cut the mafic dikes as well (Powell and others, 1984).

Gold-bearing quartz veins on a shear within the Red Cloud fault zone connect the Red Cloud mine to the Great Western mine and were the source of considerable production in the past. Areas near the Red Cloud mine have been a particular focus of exploration activity for gold as late as 1982 (Lane, 1983, unpublished data; Powell and others, 1984). The sheared area of the Red Cloud fault zone, which is thousands of feet wide and a few miles in length, is highly altered, iron stained, and silicified within the mine areas.

The principal mines in the area are labeled on the geochemical maps to allow the reader to compare anomalies with areas of known mineralization. Virtually all of the drainage basins with mines in them were found to be anomalous in the stream-sediment concentrates in at least one element. Some drainage basins that are located across topographic divides from known mines are anomalous also. The geochemical anomalies are not, however, limited to the areas of mines.

METHODS

Sample collection, preparation and analysis

Methods for sample collection, preparation, and analysis used in this study are generally outlined below and are discussed in detail in another publication (Adrian and others, 1985). Because the methods influence interpretation of the data, they are briefly described here.

Alluvial samples were collected along the range fronts at the edge of bedrock outcrop where it meets with intermontane basin sediments. Samples were not collected within the intermontane basins or on the gravel-laden pediments of Pleistocene age. Large canyons were sampled on side and headward tributaries but not within the main canyons.

Recently active stream sediments were sampled across the full width of narrow alluvial channels and as random, deep scoops across wider channels. Ten-pound samples of stream sediment for heavy-mineral separation were collected in heavy cloth bags for later sequential processing by gold pan, heavy-liquid separation, and electromagnetic splitting. Smaller, whole stream-sediment samples weighing about one pound were collected and later sieved to <0.18 mm. All samples were pulverized to a fine, homogenous powder prior to semiquantitative analysis for 31 elements by six-step emission spectrography (Grimes and Marranzino, 1968; Adrian and others, 1985).

Rock samples were first crushed by jaw crusher, pulverized by vertical grinder with ceramic plates to a fine powder, and analyzed for 31 elements by emission spectrography and by atomic absorption for 7 elements (Adrian and others, 1985).

Mineral examination

All heavy-mineral concentrates were examined for mineral content using a stereomicroscope equipped with polarizer and analyzer in conjunction with short-wave ultraviolet light. Rock-accessory minerals, such as sphene, apatite, zircon, and sillimanite were seen in most samples in various proportions. Some samples contained as much as 99 percent yellow sphene. Other samples contained as much as 99 percent colorless, euhedral to rounded apatite. Some samples with 40 to 50 percent clear, euhedral apatite also contained as much as 50 percent zircon, some of which is a violet color (metamict?). Still other samples contain nearly 100 percent zircon.

The various proportions of rock-accessory minerals and rock-forming minerals are a function of the varied lithologies within the drainage basins. For example, sphene is typical of rocks lower in metamorphic grade than granulite facies; thus sphene most likely is derived from Jurassic or later plutons rather than high-grade Precambrian gneisses. From correlation with samples containing enriched ore or pathfinder elements, it can be inferred that some of the rocks containing sphene (that is, the Jurassic or younger rocks) also host some of the ore minerals.

Scheelite, which fluoresces a bright blueish white under ultraviolet light, is locally abundant, particularly in the zone of the Red Cloud fault system. Blue fluorescence indicates that molybdate content in the scheelite ranges from 0 to 0.5 percent (Smith, 1953). Higher amounts of molybdenum in scheelite cause a white to yellowish fluorescence not seen in these samples.

Samples with visible scheelite commonly contained visible fluorite. Locally fluorite is colored purple to violet; more generally, it is colorless. Usually the purple to violet fluorite was seen in only those samples with particularly large amounts of fluorite of both colors. It may be that the colored fluorite only formed when fluoride activity in the mineralizing solutions was at its highest. The purple to violet coloration is apparently the result of damage to the fluorite crystal structure by radioactive emanations (Berman, 1957, p. 191-203). The conclusion then might be that the most fluoride-rich, mineralizing solutions were also radioactive or precipitated radioactive minerals coexistent with the fluorite.

Anatase was noted in some samples. Anatase can be formed from the hydrothermal alteration of titanium-rich rocks. As a secondary mineral of titanium, anatase is commonly associated, though not restricted, to alkalic rocks, which are usually high in titanium (Herz, 1976, p. E1). As a result, the anatase can be an indicator of areas where the primary titanium minerals in rocks have been hydrothermally altered. Anatase was chiefly noted (1) within the Red Cloud fault zone, east and northeast of the Great Western mine a mile or so, (2) on the southeast and northwest ends of the Red Cloud fault zone, (3) in areas surrounding the Model mine, (4) south of the Granite mine, (5) east and southeast of Pilot Mountain and (6) east of Gulliday well. These are all areas with geochemical anomalies as well.

Of the minerals that occur in base- and precious-metal deposits, pyrite was the most abundant in the samples. Wulfenite and molybdite were tentatively identified in a very few samples.

Native gold was not seen in the samples, even in those collected downstream from mines that in the past have produced gold (Lane, 1983 unpublished data; Powell and others, 1984). Possible reasons are as follows: (1) gold placer operations and other surface disturbances of the alluvium downstream from the mines has removed most of the gold; (2) gold occurs as fine-grained particles and so observations would be obscured by other coarser grained rock minerals abundant in the samples; and (3) fine-grained gold was lost during panning or bromoform concentration.

Maps and Statistics

U. S. Geological Survey STATPAC (Statistical Package) programs (VanTrump and Miesch, 1977) were used to make histograms and other data summaries to aid preliminary evaluation. The maps were computer plotted using symbols to represent class intervals of reported analytical values.

For the purpose of map plots (maps A-K), the 50th percentile (median) value for each element is considered the geochemical threshold. The median value could not be used in the case of elements such as silver, whose abundance is mostly below the limits of analytical detection; the median value was censored and reported values represent a very low percentage of the number of samples. The various detection limits of the elements sought in spectrographic and atomic-absorption analyses are reported by Adrian and others (1985).

The plotting intervals used on the maps are based for each element on the reported value nearest to the 50th, 75th, 85th, 90th, 95th, and 99th percentiles. The percentile shown on the map explanations approximates the actual percentile of the reported upper value of the class interval as it is on the frequency distribution of the element. The locations of background values are shown by the plus sign (+). Although statistical populations representing the upper fluctuation of background values and the lowest anomalous values commonly overlap near the median value for each element, all values above the median are considered anomalous for the purposes of this report. Because of their low crustal abundance, several of the key elements found in the study area were usually undetected in heavy-mineral samples taken from unmineralized areas. This factor combined with mineralogic information is a subjective basis for recognizing anomalies. Table 1 contains a statistical summary of all data collected from stream-alluvium samples and shows the range of reported values.

RESULTS

Tungsten (map A), molybdenum (map B), bismuth (map C), tin (map D), niobium (map E), beryllium (map F), thorium (map G), lead (map H), silver (map I), and fluorine as the mineral fluorite (map J) are the key anomalous elements in the WSA. At least two elements belonging to the anomalous suite of elements occur in about ten general zones of 4 to 20 square miles area (shown on maps A-K). In general, the enriched elements are lithologically associated with metamorphic rocks of the San Gabriel terrane and granitoid rocks of the Mesozoic plutons. The distribution of these elements in heavy-mineral concentrates and the possible significance of their dispersion patterns are further discussed below. Other elements not shown on maps and results of rock sampling are also discussed.

Tungsten

A general, nearly continuous, north- to northwest-trending zone, at least 15 miles in extent contains stream alluvium rich in tungsten in the form of scheelite (map A). This anomalous zone coincides with the Red Cloud zone of low-angle thrust faults and shears that cut the southwest flank of the Chuckwalla Mountains. The anomaly pattern appears to be an overprint on metamorphic rocks of the San Gabriel terrane that should be intrinsically low in tungsten content. Therefore, the tungsten was probably introduced by primary mineralizing solutions from an extraneous source around specific loci. The tungsten at its bedrock source is probably deposited in shears and quartz veins and is focused around three general areas that contribute large amounts of tungsten to the alluvium of several small streams. The three areas shown on map A are as follows: area 1, the northwest corner of the WSA north of the Corn Springs Wash fault; area 2, a wide zone surrounding the Red Cloud and Great Western mines; and area 3, a zone on the southern edge of the WSA, south of the Ship Creek fault (Powell and others, 1984). Tungsten is strongly enriched in samples from areas 2 and 3 and moderately enriched in a few samples of area 1. Areas 2 and 3 contain outcrops of San Gabriel gneisses of Precambrian age, emplaced on the Red Cloud thrust fault and cut by mafic dikes, shears, and quartz veins. Area 1 contains outcrops of Joshua Tree metamorphic rocks cut by shears and quartz veins (Powell and others, 1984; Lane, 1983, unpublished data). The tungsten is apparently spatially associated with the mafic dikes (fig. 2; Powell and others, 1984).

Areas 4 and 5 (map A) are part of another northwest- to west-trending zone of tungsten anomalies. The zone of anomalies is mostly along the south side of Corn Springs Wash, in the south block of the Corn Springs Wash fault, but a few scattered anomalies occur north of the wash forming a tenuous northerly trend. The area contains swarms of Cretaceous or Tertiary latite to quartz latite dikes, west-trending swarms of propylitized mafic dikes, and northeast-trending cross faults (fig. 2; Powell and others, 1984). As in the Red Cloud fault zone, there is a spatial association of tungsten (scheelite) with the mafic dikes. The dikes appear to have been emplaced along a wide zone of tension and dilation that also may have facilitated the flow of mineralizing fluids.

Tungsten in alluvium was not found in the vicinity of areas 6 or 10 although some occurs in areas to the south of area 6 near area 5. In area 9 near the Granite mine, one sample was found to contain tungsten.

Other tungsten anomalies occur in areas 7 and 8 in the Little Chuckwalla Mountains. As with most tungsten anomalies in the WSA, those in the Little Chuckwalla Mountains are found in Precambrian San Gabriel terrane (P€s) but are near outcrop areas of Jurassic and (or) Cretaceous plutons (Mzg).

The scheelite throughout the WSA is probably derived from quartz veins, which is a common occurrence of tungsten mineralization. Commonly, the quartz veins in described occurrences elsewhere are in or near the apical zone (cusps or cupolas) of granitic bodies as described at Atolia, California (Kerr, 1946, p. 61-66). Because plutons are not exposed in any of the Precambrian terrane where tungsten occurs, it is inferred that if igneous affiliations exist for the tungsten-enriched areas they result from igneous bodies at depth. Therefore, the focal points of tungsten maxima along the Red Cloud fault zone, as a particularly strong example, may outline the surface projection of unexposed granitoid cusps, and the overburden of Precambrian metamorphic rocks may constitute roof pendants.

Local control over the deposition of scheelite may have been exercised by the abundant mafic dikes that occur near the mineralized quartz veins, perhaps in a similar manner to Silver Dyke, Nevada (Kerr, 1946, p. 34), where microscope studies revealed that scheelite preferentially formed from the destroyed fragments of calcium-bearing diorite distributed along a fracture zone. Tungsten is known to have a strong affinity for calcium.

Molybdenum

Molybdenum is particularly concentrated along the Red Cloud fault zone in the same general areas as tungsten (areas 1-3; map B). Lower concentrations of molybdenum occur south of the Corn Springs Wash fault, possibly in association with mafic and (or) quartz latite dikes (areas 4 and 5). Other molybdenum anomalies occur along the northern edge of the mountain front (area 6) in a linear zone that extends northward from Corn Springs Wash, possibly in association with quartz latite dikes and in a zone surrounding the Granite mine (area 9). Molybdenum anomalies occur in the Little Chuckwalla Mountains in areas 7, 8, and 10. A very prominent cluster of molybdenum anomalies occurs in area 10 in outcrop area of San Gabriel terrane metamorphic rocks (P€s).

Molybdenum occurs in generally low to moderate amounts (10 to 70 parts per million) in samples from outcrop areas of the Jurassic and (or) Cretaceous monzogranite (Mzg) (for example, area 4). This molybdenum is probably derived from accessory molybdenite (MoS_2) or its weathering products, contained interstitially or in veinlets within the granitoid plutons. Because molybdenum has such a strong affinity for sulphur, it enters molybdenite in rocks during magmatic crystallization to a far greater extent than it enters the crystalline lattices of silicate minerals (Rankama and Sahama, 1950, p. 626-627). Therefore, silicate-held molybdenum would be far below the detection levels of our analytical method.

Molybdenum is enriched in the sieved stream sediments (not shown on maps). The accumulation of molybdenum in stream sediments probably is the result of (1) the availability of molybdenum in some of the rocks; (2) the high mobility of molybdate anion in an alkaline soil environment prevalent in the desert (Pokalov and Orlov, 1974, p. 447-452; Titley, 1964, p. 199-204); and (3) the readiness of clay particles and iron hydroxides to adsorb molybdenum. Thus, from known molybdenum behavior, it can be inferred that the fine-grained sediments in the WSA contain minor amounts of molybdenum that has been (1) dispersed from the rocks during rainfall, and (2) adsorbed on clays or coprecipitated with iron-manganese oxyhydroxides on sand and clay grains during evaporation.

Bismuth

Clusters of bismuth anomalies are found in the vicinities of areas 2 and 3 but not in area 1 in the Red Cloud fault zone. Anomalies also occur northwest of Corn Springs Wash near the Granite mine (area 9) and in the western parts of the WSA, south of the Salton Wash fault (map C). The bismuth anomalies in area 3 are tightly clustered around the zone of intense tungsten and molybdenum dispersion. A tenuous pattern of bismuth dispersion has a northeasterly trend, possibly connecting areas 2 and 4 in a similar manner to molybdenum (and fluorite to be discussed later). Only one bismuth value occurs in area 7, but a general pattern of values trends westerly from area 7 a distance of about 6 miles. Bismuth is mostly absent from areas 1, 4, 5, 6, 8, and 10.

Bismuth enters rock-forming minerals to a very minimal degree (Rankama and Sahama, 1950, p. 739-740). Thus the detection of bismuth in heavy-mineral samples by emission spectrography at any level of concentration is considered anomalous. In the WSA, bismuth occurs in samples at levels of hundreds to thousands of parts per million (table 1), suggesting that ore minerals of bismuth may be present. However, the mineralogic source of bismuth was not positively identified. Geochemical and geologic associations suggest that bismuth occurs in an ore-forming, probably sulfide mineral such as bismuthinite or its secondary alteration products.

Tin

Tin is widespread in the WSA in amounts ranging from a few tens to a few hundreds of parts per million (map D). Tin is highly enriched in area 1 on the Red Cloud fault zone, in an area of Joshua Tree terrane metamorphic rocks (P€j). It is considered doubtful that the Joshua Tree gneisses are intrinsically enriched in tin, however. The tin was probably hydrothermally introduced in a crosscutting relationship. Tin is also enriched to the south of the Red Cloud mine (south of area 2) and in the vicinity of the Model mine. Tin is absent from areas 3 and 8 but prominent in areas 4, 5, 6, and 9 in areas of Mesozoic plutonic rocks (Mzg). In the Little Chuckwalla Mountains, tin shows a slight association with tungsten-enriched areas 7 and 8 but is more enriched in area 10 in association with bismuth and molybdenum anomalies. Most of the tin in the Little Chuckwalla Mountains, particularly some of the highest values, is associated with areas of middle Tertiary volcanic rocks (Tvs) (for example, area 10 and the cluster of high values about 5 miles to the east of area 10).

Tin can be leached from tin-rich granites by alteration and enrich the hydrothermal fluid that forms metallic ore deposits (Taylor, 1979, p. 210), which could account for its association with sulfide-forming elements in the areas of known mines (for example, the Model mine). The mineralogic source in the WSA of tin associated with sulfide deposits has not been determined. It is highly probable that the chief source of slightly enriched (30 up to perhaps 150 parts per million) tin in the heavy-mineral concentrates is rock-accessory sphene from the Jurassic and (or) Cretaceous plutons (Mzg). Sphene was found to be very abundant in microscopic scans of the samples, whereas cassiterite, a common source of tin in heavy-mineral concentrates when values range from hundreds to thousands of parts per million, was not observed. Some samples contain tin values high enough to be related to cassiterite, however; so it may be that some cassiterite was overlooked. Values possibly related to cassiterite, for example, were found in the Little Chuckwalla Mountains in area 10, an area covered by middle-Tertiary (Oligocene) volcanics (Tvs) and in area 1, in the northwest corner of the WSA, as discussed above.

The high tin values associated with the plutons (Mzg) are evidence that the rocks are more than normally enriched in tin. Tin is usually enriched in late magmatic differentiates of calcalkaline rocks, generally concentrating in the metasomatically altered (greisenized), apical zones of plutons as a result of pneumatolytic or hydrothermal activity (Taylor, 1979, p. 254-259; Reed, 1982, p. 55-61). The source of the tin anomalies may therefore be sought in areas where the cupola or high-level zones in the Mesozoic plutons (Mzg) are thought to be.

Niobium

Niobium, like tin, is particularly enriched along Corn Springs Wash in area 4 (map E) where it forms a strong northwest to westerly pattern. Niobium is only slightly enriched in the Red Cloud fault zone in areas 1 and 2; it is absent entirely from area 3 and very minor in area 5. Area 6 on the northern edge of the range is slightly enriched in niobium and, as with elements previously discussed in the area, may be related to latite-quartz latite dikes. Niobium is also slightly enriched at the Granite mine (area 9). In the Little Chuckwalla Mountains, niobium, like molybdenum, is enriched to the east southeast of area 7, 4 to 6 miles, and in area 10. Niobium in lesser amounts (less than 50 to 200 parts per million) occurs in area 8.

Much of the mineralogic discussion concerning tin applies equally to niobium, which is a common associate of tin in granitoid rocks enriched in rare metals, particularly those rocks with alkalic affinities (Parker and Adams, 1973; Taylor, 1979, p. 104).

Like tin, niobium commonly accumulates in sphene and other rock-accessory minerals such as zircon (Rankama and Sahama, 1950, p. 606-607). The anomalous amounts of niobium in concentrations of a few tens to perhaps 150 parts per million suggest that niobium is present in rock-accessory minerals. Amounts of niobium greater than 150 parts per million that occur in area 4 could also have a pneumatolytic or hydrothermal origin as described above for tin in possible greisens. The areal distribution of niobium enrichment is close to that of the Mesozoic plutons (Mzg), suggesting them as the source of the niobium-rich accessory or alteration minerals. In area 10 and in lesser levels of enrichment in area 8, however, the niobium may be related to accessory minerals in the Tertiary volcanic rocks (Tvs).

Beryllium

The highest beryllium values are in the Red Cloud fault zone (areas 1-3; map F). In areas 1 and 2, the beryllium is clustered around the central locus of anomalies. In area 3, rather than a rounded cluster, the pattern is linear. This linear pattern of beryllium is associated with fluorite and lead (to be discussed) and trends northeasterly from the Red Cloud fault zone, past Pilot Mountain (see fig. 1 for location) to a termination south of Corn Springs Wash. The linearity of the beryllium pattern suggests that it may be related to a conduit followed by mineralizing (metasomatic?) fluids.

Beryllium is also enriched near the Model mine along with tin, niobium, and lead, and near the Granite mine (area 9). Beryllium is notably absent from anomaly areas 4, 6, 7, and 8. In the Little Chuckwalla Mountains, beryllium is highly enriched in two samples about 6 miles east of area 10 in Tertiary volcanic rocks (Tvs) and present in only one sample in area 10, which is also an area of Tertiary volcanic rocks.

As will be seen from comparison of beryllium distribution with that of fluorite, patterns of dispersion are very similar. The association of beryllium with fluorite stems chiefly from the fact that beryllium is transported in fluorine complexes and is deposited when fluorine activity is lowered by the precipitation of fluorite (Griffitts, 1982, p. 65).

High-density minerals of beryllium were not observed in mineralogic scans of the samples though they could have been overlooked. The geologic association of most of the high beryllium values (10 to 50 parts per million) suggests that high beryllium occurs in either contact metasomatic zones or in greisenized cusps of the plutonic rocks (Mzg), which is a common occurrence of several high-density beryllium minerals in similar environments elsewhere in the world (Griffitts, 1982, p. 62-66). Beryllium values from about 2 to 5 parts per million probably reflect its presence in rock-accessory minerals, possibly those derived from the Mesozoic plutons.

A sieved stream-sediment sample (CW-35; lat 33°29′35″; long 115°22′55″) collected just north of Corn Springs Canyon was reported to contain 50 parts per million beryllium, which is well into the anomalous range. Because the beryllium occurs in sieved sediment, it may be present in a low-density mineral such as beryl, which is a typical mineral of greisens and pegmatites (Griffitts, 1982, p. 63-64).

Thorium

Thorium (map G) is highly concentrated (values > 1500 parts per million) in samples near the Granite mine (area 9), in a cluster south of the Corn Springs Wash fault (area 4), in samples on both sides of the Salton Wash fault, in areas of Mesozoic plutonic rocks (Mzg) east of area 3 in areas east of area 7. Less-enriched amounts of thorium (200 to 1000 parts per million) occur in most areas defined as anomalous. For example, thorium is associated with a known area of mineralization at the Model mine. A linear, north trend of thorium anomalies in a dispersion pattern nearly identical to that of tungsten, molybdenum, beryllium, and fluorite extends between anomalous areas 5 and 6. In the Little Chuckwalla Mountains, thorium is most prominent in area 10 but is found also in slightly lesser amounts in area 8 in Tertiary volcanic rocks (Tvs).

Thorium is a radioactive element found typically in rock-accessory minerals and in veins in granitic and alkalic rocks (Staatz and Olson, 1973, p. 47). There are a number of ore minerals of thorium possible in the geologic environment of the WSA, but none were seen in the mineralogic scans. The rock-accessory minerals such as zircon can accommodate thorium and may be the source of the thorium anomalies. Samples with the highest thorium values were also very high in lanthanum, which would suggest the presence of monazite, a phosphate mineral rich in both lanthanum and thorium, typically found in heavy-mineral placers derived from high-grade metamorphic and related igneous terranes (Staatz and Olson, 1973, p. 471). Monazite, however, was not seen in the samples, so the mineralogic source of lanthanum and thorium is probably elsewhere.

From the distribution of the thorium anomalies many of the highest values of thorium are apparently derived from the granitoid plutons (Jurassic or Cretaceous; Mzg), probably those formed during the more alkalic phases for which thorium has an affinity.

Lead

Lead (map H) is similar in its distribution to the other key elements, being particularly associated with the zones of alteration and mineralization associated mines and prospects (see Lane, 1983; Powell and others, 1984). Throughout the WSA, the highest lead contents occur in San Gabriel metamorphic terrane (P€s). In the Red Cloud fault zone, lead is strongly enriched in areas 2 and 3 and only slightly anomalous in a few samples in area 1. South of Corn Springs Wash lead anomalies are strong (area 4) and have the same northwest to westerly trend as tungsten. Near the Granite mine (area 9), lead is slightly anomalous; in area 6, along the northern range front, lead is scarce. Lead is highly anomalous (thousands of parts per million) in drainages near the Aztec mines on the eastern edge of the Chuckwalla Mountains, but is at background levels in samples from area 5, about 2 miles to the north. In the Little Chuckwalla Mountains, lead is clustered around area 7 and in scattered samples in the vicinity of area 8; both areas contain outcrops of San Gabriel terrane metamorphic rocks. In area 10, where Tertiary volcanic rocks outcrop, lead is at background levels in all but one sample.

Some of the scattered lead values of low to moderate anomaly to background contrast (100 to perhaps 500 parts per million) could be, but may not be, radiogenic lead resulting from the radioactive decay of thorium in such rock-accessory minerals as zircon. The source of these thorium-lead-rich accessory minerals appear to be certain phases of the Mesozoic (Mzg) granitoid plutons. In known mineralized areas and at high levels of concentration, lead anomalies probably reflect ore minerals of lead, which are sparingly soluble in the weathered zone, usually heavy, and highly susceptible to mechanical dispersion into the drainage-basin alluvium.

Silver and Gold

Silver and gold are geochemically similar, and they are found in association in the Chuckwalla Mountains (Lane, 1983). Neither silver or gold were found to be very abundant in the stream-sediment concentrates.

The problems in collecting gold in the samples and then seeing it under the microscope have been previously discussed. In addition, the analytical sensitivity and precision of spectrographic analyses are also poor. However, from rock data, and the distribution of gold-producing mines relative to the geochemical anomaly patterns, one might speculate that if the analytical and sampling methods for gold were better, its distribution pattern would be similar to tungsten.

Silver (map I) was found in drainage sediments in areas 2 and 3, and there is an isolated silver anomaly north of the Salton Wash fault in the southern part of the WSA. The silver anomalies are probably related to primary or secondary ore minerals of silver. The secondary minerals of silver are relatively insoluble in the weathering zone and are high in density, making alluvium rich in these minerals susceptible to gold-pan concentration. However, if the minerals are very fine grained they could have been lost during panning.

Two heavy-mineral samples outside the boundaries of the WSA contain detectable gold. Sample number CW-109C (lat 33°27′25″; long 115°14′12″), about one mile northwest of Chuckwalla well, contained a gold value reported as <20 parts per million. Sample CW-120C (lat 33°29′21″; long 115°13′07″), to the north in the next drainage basin northeast of Chuckwalla Spring, contained 20 parts per million gold. At the time of sampling, some gold placer operations were going on near Chuckwalla Spring.

Sieved stream sediments anywhere in the sampled area showed no gold in the spectrographic analyses. Samples of sieved sediment are subject to dilution from barren material that would effectively mask clastic gold grains.

Fluorite

The distribution of detrital fluorite in alluvium is concluded to reflect areas of fluorine-metasomatized rocks and (or) hydrothermal vein deposits containing fluorite. The strongest fluorite mineralization (map J) apparently occurs in the Red Cloud fault zone in area 2 near the Red Cloud and Great Western mines, and in the northwestern corner of the WSA (area 1). Fluorite also shows a northeast-trending pattern similar to beryllium in the vicinity of area 2 (near the Red Cloud and Great Western mines). Locally, during sampling, veinlets that contain fluorite were noted in outcrops of sheared bedrock within the Red Cloud fault zone (sample CW-229R, table 2).

Other elements

A few elements found enriched in the WSA are not shown on maps, either because the anomalies are not widespread, or the relationship enrichments of the element may have to metallic-mineral resources is not clear. Some elements normally associated with metallic-sulfide deposits are distinguished in the area not by abundance but by unusually low concentrations (copper and zinc are the chief examples).

Barium, manganese, and strontium locally reach anomalous levels of concentration in heavy-mineral concentrates (thousands of parts per million). Sulphates and possibly carbonates of barium and strontium and high-valence oxides of manganese are the most likely sources of these anomalous concentrations.

Although minerals of copper have been observed at the mines and in outcrop (for example, bornite and chalcopyrite; Lane, 1983, unpublished data; Powell and others, 1984), the reconnaissance geochemical survey indicates that copper enrichment is not widespread or common. Zinc, though present was not widely observed in the mines nor abundantly found in the geochemical reconnaissance. It is possible that intensive leaching has removed copper from the weathered zone making it inaccessible to detection by the stream-sediment reconnaissance methods. However, the necessary leaching would require large amounts of pyrite to supply acidity, and the presence of water (pyrite may be locally abundant; water generally is not). A more attractive conclusion, supported by geologic and climatic environment and geochemical associations, is that copper was never a significant constituent of the primary mineralization system, which is a common feature of granite-molybdenite mineralization systems (Theobald, 1982, p. 48) related to silicic, plutonic rocks similar to those in the WSA.

Rock samples

Bedrock sampling was not extensive or systematic enough to be of great use in this geochemical evaluation. However, analyses of some of the samples contribute an insight into the trace elements that were mobilized during hydrothermal mineralization.

Evidence suggests that molybdenum mineralization and possible greisen(?) alteration have affected the younger monzogranite (KJg on fig. 2). Table 2 shows that high molybdenum values were found in quartz veins and in limonite associated with altered monzogranite in samples CW-185R, 186R, and 187R. The zone where these samples were collected outcrops about 2 mi north of Corn Springs Wash. The outcrops are extensively fracturing, quartz veined, and iron stained, and located near a northeast-trending fault zone. Coarse muscovite, developed along margins of the quartz-limonite veins, is suggestive of greisen-type alteration, which is further supported by the elevated above normal contents of such typical greisen elements as boron and beryllium (sample CW-186R). These are, however, limited observations of one small area.

Slight enrichments of zinc, arsenic, and mercury were found in iron-stained, pyritic gneiss from near Corn Springs Wash (sample CW-032R) and in pyritic stringers within a phase of the Mesozoic pluton near Gulliday well (CW-075R). Zinc and arsenic were also found in a relatively fresh appearing, gneissic rock sample (CW-182R) collected near a contact with a quartz latite dike on Ship Canyon; the enriched metal contents may indicate that hypogene leakage occurred along dike-host rock contacts. The rocks most noticeably enriched in the selected elements shown in table 2 were collected near mines. Slightly metal-rich rocks were also collected in fault or shear zones at some distance from known deposits such as the sample of cataclasite from the Corn Springs fault zone (sample CW-227R); it contains enriched amounts of mercury, zinc, and arsenic. The highest concentrations for most of the selected elements were found in sample CW-213R, which was collected at a prospect south of Corn Springs Wash; it was the only sample with notable amounts of gold and copper.

SUMMARY AND CONCLUSIONS

This reconnaissance geochemical study has shown that a number of key ore-forming and pathfinder elements, that include tungsten, molybdenum, bismuth, beryllium, tin, niobium, lead, silver, and fluorine (fluorite), are concentrated in high amounts in drainage-basin alluvium. Of these anomalous elements, tungsten in stream-sediment concentrates is probably the most diagnostic indicator of the intensive zones of mineralization. The tungsten dispersion patterns geographically encompass and extend beyond areas of known gold-silver and base-metal mineralization and possibly delineate the maximum areal extent of hydrothermal metallization. Most, if not all, deposits in the area may be part of one large, interrelated hydrothermal system with probable genetic ties to Jurassic and (or) Cretaceous or possibly even Tertiary igneous activity. The deposition of metals comprising the system of mineralization was apparently structurally controlled. Subsequently, the primary dispersion patterns in the host rock appear to have been displaced as much as 2 miles east or west by Cenozoic, left-lateral faulting. An uncertain portion of the deposited metals may be present in the subsurface.

Map K summarizes the inferred dispersion of some of the key elements of the mineralization system. The patterns of element dispersion are derived from the single-element maps by drawing lines around and shading in the anomalous drainage areas. The patterns appear to delineate the general configuration of the primary mineralization system.

The north- to northwest-trending zone of low- and high-angle thrust faults, high-angle crossfaults, and alteration (Powell and others, 1984), referred to as the Red Cloud fault zone in this report, is the chief locus for significant element anomalies in the WSA. Scattered silver and (from mine information) gold are also associated with the Red Cloud fault zone, but they are less easy to relate directly to that locus. Rock samples collected in the zone (Lane, 1983, unpublished data) indicate that gold and silver are part of the suite of elements that characterize the mineralization. Anomalies along the Red Cloud fault zone are probably derived from quartz veins and may have their source in materials and energy supplied by one or more unexposed igneous cupolas.

Subparallel to the Red Cloud fault zone, an east-west- to northwest-trending zone of tungsten, molybdenum, and lead anomalies occurs south of Corn Springs Wash. As with the Red Cloud fault zone, the bedrock sources for the metal anomalies are probably quartz veins in close association with the numerous mafic dikes of east-west to northwest trend. In contrast to the Red Cloud fault zone, fluorite is not as abundant nor, for the most part, are most anomalies as intense.

An additional directional component to element dispersion patterns in Corn Springs Wash is north to northeasterly. Linear patterns of molybdenum, tungsten, tin, and fluorine (fluorite), to name a few elements, trend north from Corn Springs Wash through the outcrop area of Mesozoic plutonic rocks (Mzg). Some of these anomalies may reflect metals deposited in faults and fractures and along latite-quartz latite dikes.

Anomalies of tin, niobium, thorium, and molybdenum within outcrop area of the Jurassic and (or) Cretaceous granitoid rocks may have their source in rock-accessory and ore minerals possibly from exposures of altered (greisenized) cusps. Concentrations of these elements are often found in apical (cusp) zones of plutons (Taylor, 1979, p. 254-259; Reed, 1982, p. 55-61). Rock samples discussed earlier (samples CW-185R, 186R, and 187R) suggest that greisenized zones may exist locally in the younger monzogranite (Mzg on geochemical maps and Kjg on fig. 2).

Left-lateral displacement on the Corn Springs Wash and Ship Creek faults appears to have affected the dispersion patterns of the elements associated with the Red Cloud fault zone. Assuming the Red Cloud trend of anomalies and geologic structure to have once been a continuous, north- to northwest-trending anomalous zone, area 3 may represent the position of anomalies prior to Cenozoic, left-lateral fault movement, if area 3 is assumed to have been relatively stationary. Dispersion patterns in areas 1 and 2 may be westward displacements on the north blocks of the Corn Springs Wash and Ship Creek faults, respectively (or eastward displacements of south blocks), if area 1 is assumed stationary. If these inferences are valid, displacements of the initial, primary dispersion patterns westward in north fault blocks could be as much as 2 miles.

Finally, the three tungsten-molybdenum-fluorine-rich areas in the Red Cloud fault zone (areas 1-3, maps A, B, J, and K) may contain areas of stockwork molybdenum mineralization at moderate to shallow depth (within 1000 feet). This conclusion is based on analogy with numerous descriptions of granite-molybdenite (Climax-type) systems elsewhere in the western United States (Wallace and others, 1978, p. 357, 363, and 364; Sharp, 1978, p. 373-376; Mutschler and others, 1981, p. 879-880; Theobald, 1982, p. 47-48), particularly with regard to vertical and lateral zonation of minerals and elements. The zonal pattern usually consists of (1) a pipelike body of fluorite terminating above the main molybdenum zone and extending toward the surface a distance of several hundred feet (Theobald, 1982, p. 48); (2) tungsten in an enveloping zone above and overlapping around and within the main molybdenum ore zone; and (3) base- and precious-metal anomalies at the surface. The overlapping patterns of molybdenum, tungsten, and fluorite near area 2 and area 3 suggest that the postulated molybdenum ore zone may lie at a relatively shallow depth (possibly within 1000 feet). In area 1, because of weaker anomaly signals, a postulated molybdenum ore zone may be at greater depth (possibly slightly more than 1000 feet).

The above interpretations notwithstanding, it must be emphasized that Climax-type deposits have not been discovered in the surrounding region; therefore, regional models are unavailable for comparison. Consequently, other ore-deposit models are possible.

REFERENCES

Adrian, B. M., Day, G. W., and Watts, K. C., 1985, Analytical and sample locality map of results for stream-sediment and heavy-mineral-concentrate samples from the Chuckwalla Mountains Wilderness Study Area (CDCA-348), Riverside County, California: U.S. Geological Survey Open-File Report 85-293, 36 p.
Berman, Robert, 1957, Some physical properties of naturally irradiated fluorite: American Mineralogist, v. 42, p. 191-203.
Beus, A. A., and Grigorian, S. V., 1977, Geochemical exploration methods for mineral deposits: Wilmette, Illinois, Applied Publishing, Ltd., 287 p.
Griffitts, W. R., 1982, Diagnostic features of fluoride-related beryllium deposits in Erickson, R. L., (ed.), Characteristics of mineral deposit occurrences: U.S. Geological Survey Open-File Report 82-795, p. 62-66.
Grimes, D. J., and Marranzino, A. P., 1968, Direct-current and alternating-current spark emission spectrographic field methods for the semiquantitative analysis of geologic materials: U.S. Geological Survey Circular 591, 6 p.
Herz, Norman, 1976, Titanium deposits in alkalic igneous rocks: U.S. Geological Survey Professional Paper 959E, p. E1-E6.
Kerr, Paul F., 1946, Tungsten mineralization in the United States: Geological Society of America Memoir 15, 241 p.
Mutschler, F. E., Wright, E. G., Ludington, Steve, and Abbott, J. T., 1981, Granite molybdenite systems: Economic Geology, v. 76, no. 4, p. 874-897.
Parker, R. L., and Adams, J. W., 1973, Niobium and tantalum in Brobst, D. A., and Pratt, W. F., (eds.), United States Mineral Resources: U.S. Geological Survey Professional Paper 820, p. 443-454.
Pokalov, V. T., and Orlov, V. G., 1974, Behavior of molybdenum in the oxidation zone: Geochemical International, p. 447-452 (D. Gottfried, translator, Geokhimiya No. 4, pp. 616-622).
Powell, R. E., 1981, Geology of the crystalline basement complex, Eastern Transverse Ranges, southern California: Constraints on regional tectonic interpretation: California Institute of Technology, Pasadena, Ph.D. thesis, 441 p.
Powell, R. E., 1982, Crystalline basement terranes in the southern Eastern Transverse Ranges, California in Cooper, J. D., compiler, Geologic excursions in the Transverse Ranges: Guidebook for the 78th Annual Meeting of the Cordilleran Section of the Geological Society of America, Anaheim, California, April 19-21, 1982, p. 109-151.
Powell, Robert E., Watts, Kenneth C., and Lane, Michael E., 1984, Mineral resource potential of the Chuckwalla Mountains Wilderness Study Area, Riverside County, California: U.S. Geological Survey Open-File Report 84-674, 25 p.
Reed, Bruce L., 1982, Tin greisen occurrence model in Erickson, R. L., (ed.), Characteristics of mineral deposit occurrences: U.S. Geological Survey Open-File Report 82-795, p. 55-61.
Rankama, Kalervo, and Sahama, T. G., 1950, Geochemistry: Chicago, Illinois, University Chicago Press, 912 p.
Sharp, J. E., 1978, A molybdenum mineralized breccia pipe complex, Redwell Basin, Colorado: Economic Geology, v. 73, no. 3, p. 369-382.
Smith, O. C., 1953, Identification and qualitative analysis of minerals: Van Nostrand Company, Princeton, New Jersey, 385 pp.
Staatz, M. H., and Olson, J. C., 1973, Thorium in Brobst, D. A., and Pratt, W. F., (eds.), United States Mineral Resources: U.S. Geological Survey Professional Paper 820, p. 468-476.
Taylor, R. G., 1979, Geology of tin deposits: New York, Elsevier Scientific Publishing Company, 543 p.
Titley, S. R., 1964, Some behavioral aspects of molybdenum in the supergene environment: American Institute of Mining and Metallurgical Engineers Transactions, v. 229, p. 199-204.
Theobald, P. K., 1982, Characteristics of the Colorado-type (climax-type) molybdenum deposits readily recognized at the surface in Erickson, R. L., (ed.), Characteristics of mineral deposit occurrences: U.S. Geological Survey Open-File Report 82-795, p. 47-48.
VanTrump, G., Jr., and Miesch, A. T., 1977, The U.S. Geological Survey RASS-STATPAC system for management and statistical reduction of geochemical data: Computers and Geoscience, v. 3, p. 475-488.
Wallace, S. R., MacKenzie, W. B., Blair, R. G., and Muncaster, N. K., 1978, Geology of the Urad and Henderson molybdenite deposits, Clear Creek County, Colorado, with a section on a comparison of these deposits with those of Climax, Colorado: Economic Geology, v. 73, no. 3, p. 325-368.

Table 1.--Statistical summary of data from heavy-mineral concentrate and sieved stream-sediment samples, Chuckwalla Mountains Wilderness Study Area, California

[Leaders (---) indicate no value available or statistically invalid value was computed; N, not detected; L, detected below the limit of determination; and G, greater than the highest reporting value]

Element	Sample type[1]	Data based on qualified values: Number of samples N	L	G	Number of values reported	Range of values[3] (in ppm)	Geometric mean	Geometric deviation	Arithmetic mean	Standard deviation	25	50	75	85	90	95	99
Fe	1	0	0	0	196	0.15 - 5	5	1	0.89	0.71	0.5	0.7	1	1.5	1.5	2	5
	2	0	0	0	184	2 - 20	6.3	1.4	6.7	3.3	5	5	10	10	10	10	20
Mg	1	0	2	0	194	0.05 - 10	10	---	0.28	0.72	0.1	0.2	0.3	0.5	0.5	0.7	0.85
	2	0	0	0	184	0.5 - 2	---	---	1.3	0.46	1	1	2	2	2	2	2
Ca	1	0	0	0	196	0.5 - 50	---	---	15	14	7	10	20	30	30	50	50
	2	0	0	0	184	0.2 - 2	---	---	1.1	0.35	1	1	1	1	2	2	2
Ti	1	0	0	70	126	0.2 - 2	---	---	1.4	0.62	1	2	>2	>2	>2	>2	>2
	2	0	0	0	184	0.2 - 1	---	---	0.58	0.24	0.5	0.5	0.5	1	1	1	1
Mn	1	0	0	0	196	100 - 2,000	464	1.8	546	319	300	500	700	700	1,000	1,000	1750
	2	0	0	0	184	200 - 3,000	856	1.4	911	371	700	700	1,000	1,000	1,000	2,000	2,000
Ag	1	190	1	0	5	5 - 20	---	---	---	---	---	---	---	---	---	---	10
	2	182	0	0	2	0.5 - 1	---	---	---	---	---	---	---	---	---	---	0.5
As	1	196	0	0	0	---	---	---	---	---	---	---	---	---	---	---	---
	2	184	0	0	0		---	---	---	---	---	---	---	---	---	---	---
Au	1	194	1	0	1	20	---	---	---	---	---	---	---	---	---	---	---
	2	184	0	0	0		---	---	---	---	---	---	---	---	---	---	---
B	1	0	128	0	68	20 - 100	24	1.5	26	16	<20	<20	<20	20	20	40	70
	2	0	1	0	183	10 - 70	20	1.6	23	13	15	20	30	30	50	50	60
Ba	1	0	4	8	184	50 - 10,000	479	2.9	888	1364	200	500	1,000	1,500	2,000	7,500	>10,000
	2	0	0	0	184	100 - 1,000	468	1.4	491	140	500	500	500	500	700	700	1,000
Be	1	137	14	0	45	2 - 70	11	2.4	11	15	---	---	<2	3	5	10	50
	2	0	3	0	181	1 - 50	---	---	1.7	3.6	1	1	2	2	2	2	3
Bi	1	157	4	0	35	20 - 2,000	113	3.9	285	453	---	---	---	---	85	200	1,250
	2	184	0	0	0	---	---	---	---	---	---	---	---	---	---	---	---
Cd	1	196	0	0	0	---	---	---	---	---	---	---	---	---	---	---	---
	2	184	0	0	0	---	---	---	---	---	---	---	---	---	---	---	---
Co	1	57	45	0	94	10 - 1,500	---	---	29	154	---	<10	10	10	15	20	50
	2	1	0	0	183	10 - 70	---	---	19	911	15	15	20	20	30	30	50
Cr	1	4	94	0	98	20 - 2,000	---	---	57	200	<20	20	20	50	70	70	150
	2	0	0	0	184	20 - 300	---	---	81	46	50	70	100	100	100	200	250
Cu	1	46	93	0	57	10 - 200	19	2.1	27	32	<10	<10	10	15	20	40	100
	2	0	0	0	184	10 - 100	18	1.4	20	12	15	15	20	20	20	50	85
La	1	2	13	3	178	100 - 2,000	---	---	415	335	150	300	500	700	700	1,000	>2,000
	2	0	0	0	184	20 - 1,000	---	---	133	121	70	100	150	200	200	300	600
Mo	1	66	23	0	107	10 - 1,500	30	2.6	62	160	---	10	30	50	60	100	500
	2	174	0	0	10	5 - 50	11	2.5	16	18	---	---	---	---	---	5	33
Nb	1	16	16	0	164	50 - 1,000	151	1.9	188	138	50	150	200	300	300	500	700
	2	5	128	0	51	20 - 50	22	1.3	23	7.5	<20	<20	20	20	20	20	50
Ni	1	92	53	0	51	10 - 70	---	---	14	9	---	<10	10	10	15	15	25
	2	0	0	0	184	5 - 100	---	---	27	11	20	30	30	30	30	50	50
Pb	1	10	26	0	160	20 - 50,000	167	5.2	856	4,079	20	85	500	700	1,000	2,000	7,500
	2	1	0	0	183	10 - 1,000	32	2.0	44	78	20	30	50	50	70	85	200
Sb	1	196	0	0	0	---	---	---	---	---	---	---	---	---	---	---	---
	2	0	1	0	183	---	---	---	---	---	---	---	---	---	---	---	---
Sc	1	10	21	0	165	10 - 100	---	---	26	14	10	20	30	30	30	50	70
	2	0	0	0	184	5 - 50	---	---	18	5.8	15	15	20	20	20	25	50
Sn	1	82	12	0	102	30 - 2,000	82	2.3	140	287	---	30	70	100	150	200	1,350
	2	137	40	0	7	10 - 20	12	1.3	12	3.9	---	---	<10	<10	<10	<10	13
Sr	1	171	14	3	8	300 - 2,000	662	1.8	775	537	---	---	---	---	<200	400	>10,000
	2	2	0	0	182	100 - 500	240	1.4	255	101	200	200	300	300	500	500	500
V	1	0	0	0	196	20 - 1,000	---	---	201	166	70	150	200	300	500	500	700
	2	0	0	0	184	20 - 500	---	---	123	81	100	100	150	200	200	200	500
W	1	103	14	0	79	100 - 10,000	361	2.6	627	1,165	---	---	200	500	700	1,000	2,000
	2	184	0	0	0	---	---	---	---	---	---	---	---	---	---	---	---
Y	1	0	0	0	196	150 - 5,000	---	---	183	918	700	1,000	1,500	2,000	2,000	3,000	5,000
	2	0	0	0	184	20 - 500	---	---	78	75	50	50	100	100	100	200	500
Zn[2]	1	193	1	0	2	700	---	---	---	---	---	---	---	---	---	---	600
	2	0	176	0	8	200 - 300	210	1.2	---	---	---	---	---	---	---	---	200
Zr	1	0	0	178	18	1,000 - 2,000	1,852	1.2	1889	323	>2,000	>2,000	>2,000	>2,000	>2,000	>2,000	>2,000
	2	0	0	1	183	150 - 1,000	---	---	606	303	300	500	1,000	1,000	1,000	1,000	1,000
Th	1	82	19	3	92	200 - 5,000	669	2.4	975	916	---	<200	500	1,500	1,500	2,000	>5,000
	2	166	7	0	11	100 - 200	111	1.3	114	32	---	---	---	---	---	100	125

(Columns 25-99: Percentile distribution based on total number of samples analyzed. Columns "Number of values reported" to "Standard deviation": Data based on unqualified values.)

[1]Sample type: 1, panned, heavy-mineral concentrate; 2, stream sediment sieved to <0.18 mm.
[2]Zinc data on sieved stream sediment may not be valid at values recorded as L.
[3]Single value under range column is the only value reported for the elements gold and zinc.

Table 2.--Analytical results for selected elements in rock samples, Chuckwalla Mountains Wilderness Study Area, California
[Analyses are by atomic-absorption spectroscopy for Au, Hg, Zn, As, Sb, Cd, and Bi; emission spectrography for Cu and Mo. All values in parts per million; limits of detection are Au .05; Hg .02; Zn 5; As 5; Sb 1; Cd 0.2; Bi 2; Cu 5; Mo 5; N, not detected; and L, detected below the limit of determination]

Sample number	Location Latitude	Longitude	Au	Hg	Zn	As	Sb	Cd	Bi	Cu	Mo	Field description of sample
CW-032R	33 40 32	115 28 17	N	0.02	35	10	3	N	N	15	N	Fault or shear zone trending E-W in Fe-stained pyritic gneiss.
CW-075R	33 32 17	115 19 49	N	0.02	50	10	5	N	2	10	N	Granodiorite containing stringers of pyrite.
CW-181R	33 38 59	115 20 53	N	N	10	10	N	N	L	5	N	Quartz latite dike.
CW-182R	33 38 59	115 20 53	N	N	90	20	N	N	N	10	N	Granodiorite near contact with quartz latite dike.
CW-184R	33 39 06	115 20 48	N	N	20	20	N	N	L	10	N	Felsic dike.
CW-185R	33 38 43	115 22 36	N	N	110	10	1	0.2	6	15	50	Quartz veins in monzogranite (greisen?); contains pyrite, coarse muscovite on vein margins.
CW-186R[1]	33 38 42	115 22 36	N	0.02	70	25	2	L	N	50	300	Spongy limonite in 6-inch fracture cutting bleached granite.
CW-187R	33 38 42	115 22 36	N	0.02	10	5	N	N	N	15	70	Altered monzogranite; sheared, iron-stained, and bleached.
CW-188R	33 39 47	115 22 54	N	0.02	65	5	N	L	L	50	N	Mafic dike.
CW-189R	33 39 47	115 22 54	N	L	5	5	N	N	N	5	N	Granite about 5 ft from contact with mafic dike; abundant muscovite and pyrite.
CW-190R	33 40 00	115 25 11	N	N	75	L	N	L	N	20	N	Biotite granite.
CW-191R	33 40 02	115 25 07	N	N	10	N	N	N	N	L	N	Biotite-poor granite.
CW-192R	33 40 05	115 25 30	N	N	10	5	N	N	N	L	N	Felsic dike; light grayish green, weathers reddish brown.
CW-193R	33 40 05	115 25 30	N	N	15	L	N	N	N	5	N	Quartz monzonite; highly jointed, weathers brown.
CW-195R	33 36 27	115 24 59	N	N	65	5	N	L	N	5	N	Latite dike; dark gray, contains biotite.
CW-196R	33 37 32	115 18 06	N	N	30	L	N	L	N	10	N	Quartz monzonite.
CW-197R	33 37 32	115 18 06	N	N	70	N	1	L	N	50	N	Diorite; porphyritic with coarse hornblende blades.
CW-213R	33 37 16	115 20 54	0.45	0.02	30	15	2	0.4	2	2000	N	Quartz breccia; vein striking N. 10° W.; stained yellow-brown.
CW-214R	33 37 16	115 20 54	N	N	45	5	N	N	N	10	N	Granite porphyry; forms wallrock to above vein.
CW-218R	33 37 53	115 21 54	N	0.04	10	10	N	L	N	5	N	Quartz latite, fine grained; forms irregular intrusive body.
CW-222R	33 38 15	115 23 18	N	L	10	5	1	N	N	5	N	Cataclasite; gritty, quartzose; in Corn Springs Wash fault zone.
CW-225R	33 38 30	115 24 42	0.05	0.30	15	25	2	L	2	5	10	Limonitic gossan at prospect.
CW-227R	33 38 13	115 25 12	N	0.02	15	10	1	0.2	L	20	N	Cataclasite; highly sheared, limonite-mottled granite.
CW-229R	33 35 54	115 26 24	N	0.02	25	40	2	0.2	N	5	N	Sheared gneiss; iron-stained, contains green fluorite.
CW-230R	33 36 48	115 27 07	N	L	15	100	N	N	N	10	N	Gneissic breccia; stained yellow brown, pyritic.

(Au through Mo: Element content)

[1]Sample also contains 50 ppm B and 10 ppm Be, which indicates an enrichment in these elements.

KW/MF/Chuckwalla/2/20 revised

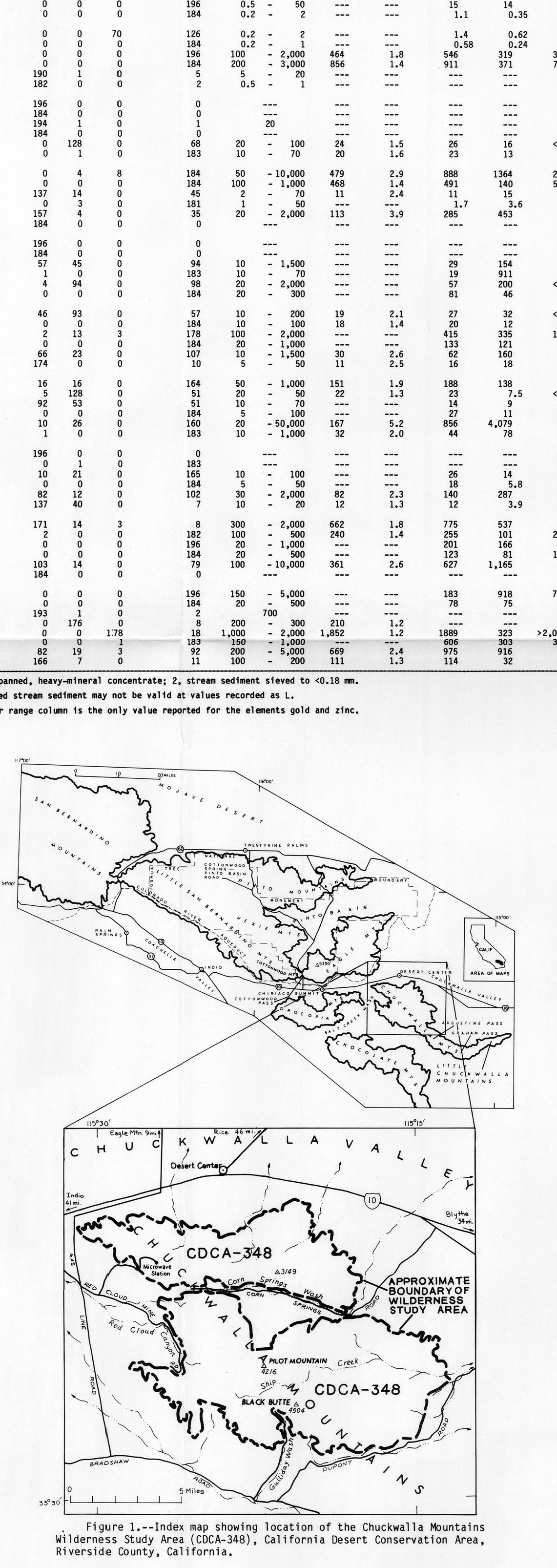
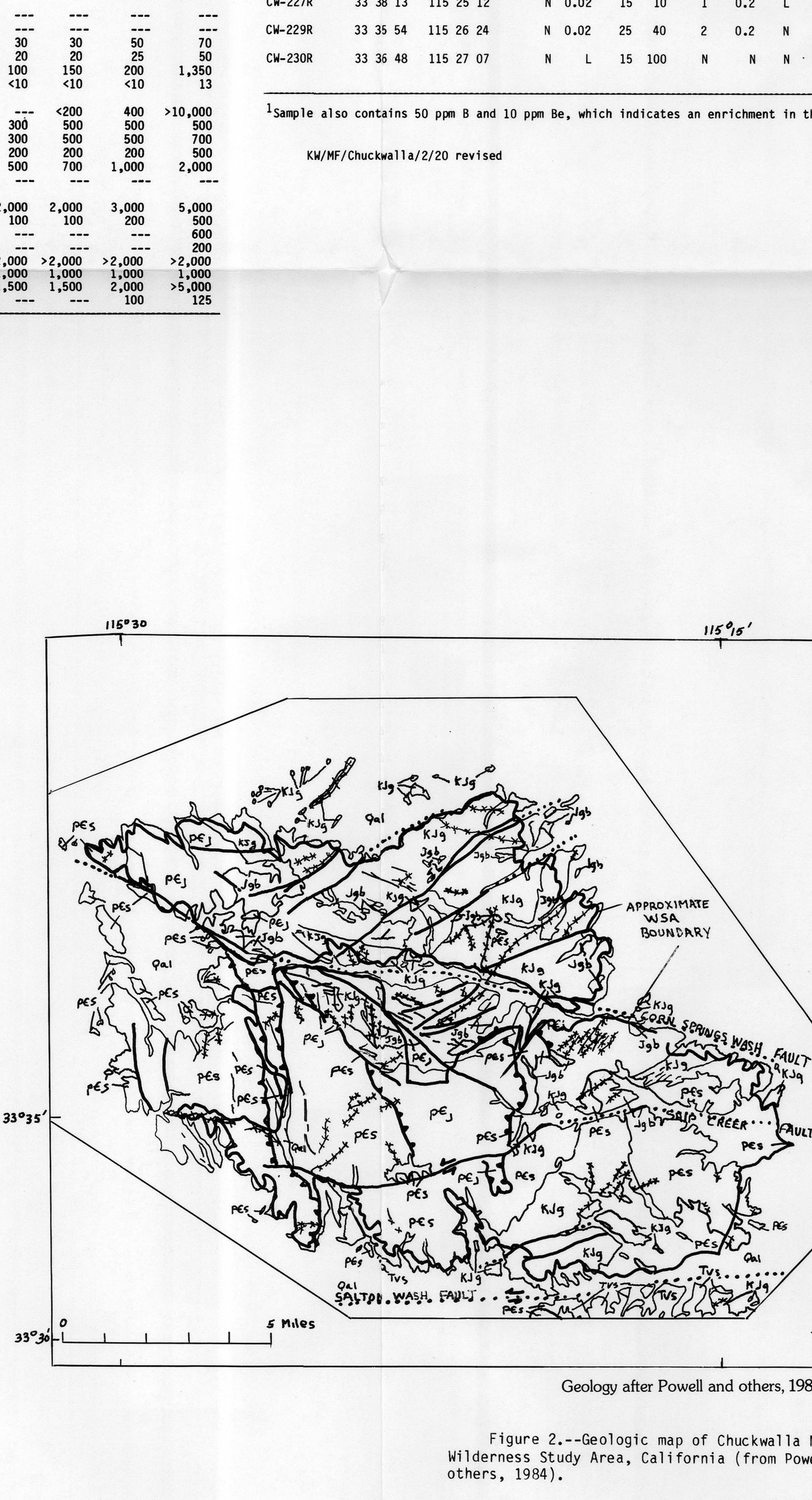


Figure 1.--Index map showing location of the Chuckwalla Mountains Wilderness Study Area (CDCA-348), California Desert Conservation Area, Riverside County, California.



Geology after Powell and others, 1984

EXPLANATION
Qal Alluvium (Quaternary)
Tvs Volcanic and sedimentary rocks (Tertiary)
KJg Granitic rocks (Cretaceous and (or) Jurassic)
Jgb Gabbro (Jurassic)
P€s San Gabriel terrane (Precambrian)--Metasedimentary gneiss, orthogneiss, and syenite-mangerite-jotunite
P€j Joshua Tree terrane (Precambrian)--Granite gneiss
CONTACT
HIGH-ANGLE FAULT OR FRACTURE--Dotted were covered; arrows indicate relative movement
RED CLOUD THRUST FAULT--Sawteeth on upper plate
FELSIC DIKES (Tertiary, Cretaceous, and (or) Jurassic)
MAFIC DIKES (Tertiary, Cretaceous, and (or) Jurassic)

Figure 2.--Geologic map of Chuckwalla Mountains Wilderness Study Area, California (from Powell and others, 1984).

MAPS AND INTERPRETATION OF GEOCHEMICAL ANOMALIES, CHUCKWALLA MOUNTAINS WILDERNESS STUDY AREA, RIVERSIDE COUNTY, CALIFORNIA

By
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1986

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