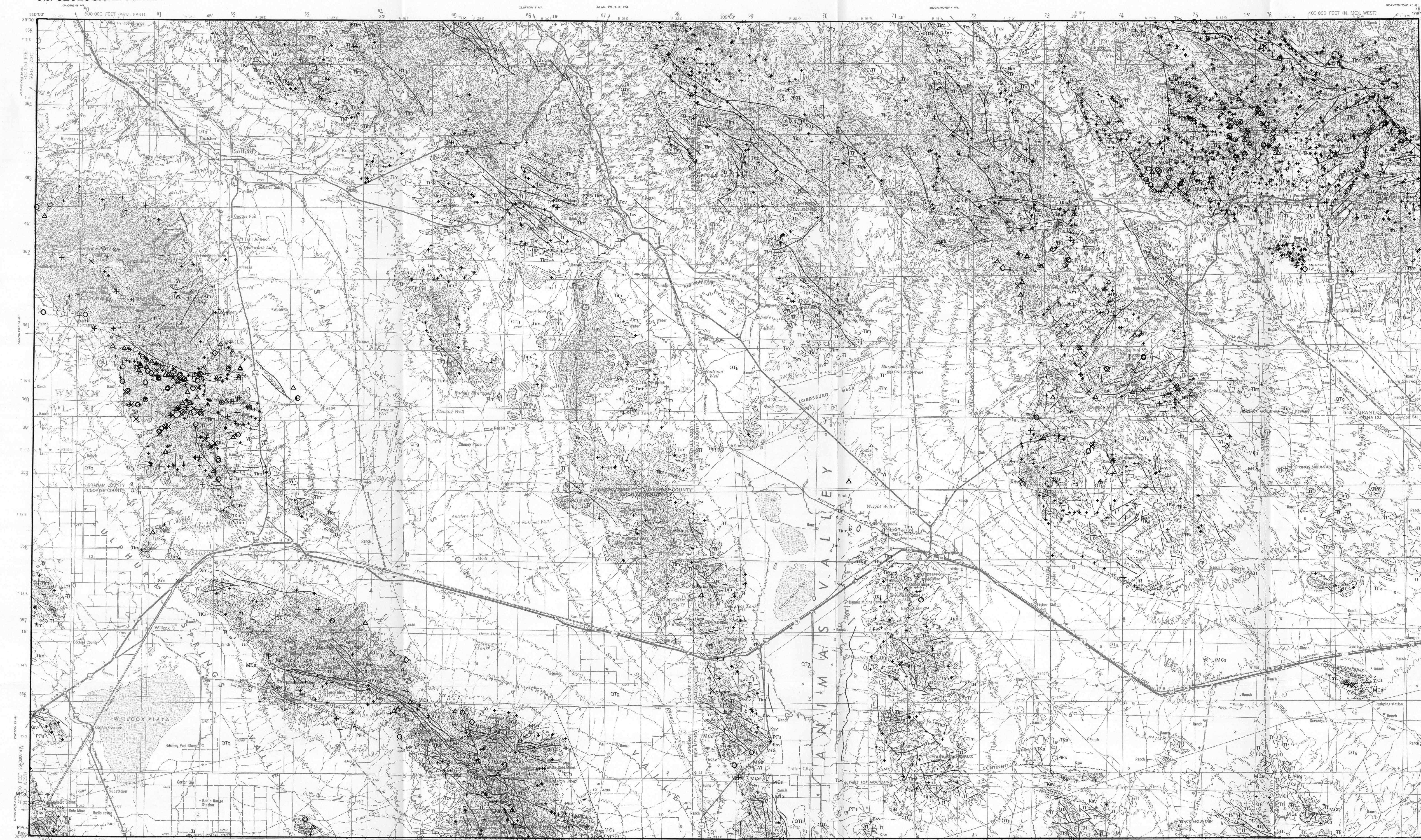
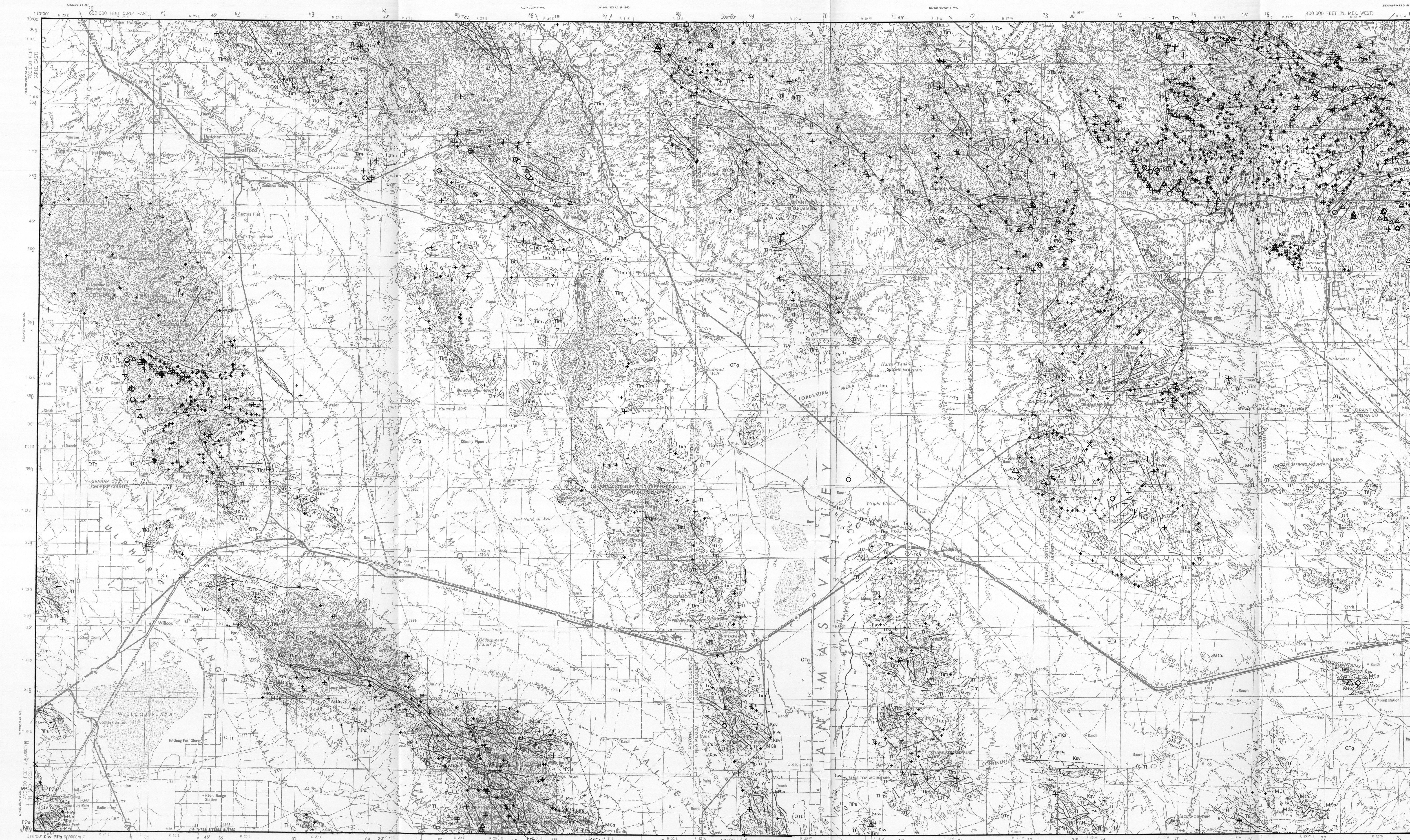


Base from U.S. Geological Survey, 1954
Revised 1970

Geology simplified from Drewes and others (1985)

MAP A--BISMUTH IN THE NONMAGNETIC FRACTION



Base from U.S. Geological Survey, 1954
Revised 1970

Geology simplified from Drewes and others (1985)

MAP B--BERYLLIUM IN THE NONMAGNETIC FRACTION

This map is part of a folio of maps of the Silver City 1° x 2° quadrangle, New Mexico and Arizona, prepared under CUSMAP (Conterminous United States Mineral Assessment Program). Other publications in this folio are listed in the "Selected References" section.

EXPLANATION

Bismuth and beryllium concentrations

[Values in parts per million. Values shown in spectrographic class intervals as reported]

- + Undetected to 20
- + 30-70
- △ 100-200
- ○ 300-700
- × 1,000->2,000

[Note: The following "Correlation of Map Units", "Description of Map Units", and symbols are for the geologic base map shown in gray]

CORRELATION OF MAP UNITS

Units	Age
QTg, QTb	QUATERNARY
Tcv, Tf, Tim, Ti, TKi, TKa	TERTIARY
TKa, TKi, Ksv	CRETACEOUS
PPs	PERMIAN AND PENNSYLVANIAN
MЄs	MISSISSIPPIAN TO CAMBRIAN
Yd, Yi	MIDDLE PROTEROZOIC
Xm	EARLY PROTEROZOIC

DESCRIPTION OF MAP UNITS

QTg GRAVEL, SAND, SILT, AND CLAY (QUATERNARY AND TERTIARY)--Mainly alluvium on stream terraces, fan aprons, and pediments; colluvium on hill slopes; and lacustrine and eolian deposits in basins

QTb BASALT (QUATERNARY AND TERTIARY)--Basalt and basaltic andesite flows and small intrusions

Tcv CONGLOMERATE AND VOLCANIC ROCKS (TERTIARY)--Mainly coarse conglomerate and subordinate intercalated mafic to intermediate flows and felsic tuffs

Tim INTERMEDIATE TO MAFIC VOLCANIC ROCKS (TERTIARY)--Mainly flows, scoria cones, domes, and small intrusions. Locally includes small units of felsic volcanic rocks and volcaniclastic rocks

Tf FELSIC VOLCANIC ROCKS (TERTIARY)--Mainly flows, domes, and pyroclastic deposits. Locally includes small units of more mafic volcanic rocks and volcaniclastic rocks

Ti INTRUSIVE ROCKS (TERTIARY)--Includes granitic rocks in plutons and aphanitic and porphyritic rocks in plugs and dikes

TKi INTRUSIVE ROCKS (TERTIARY AND CRETACEOUS)--Includes granitic rocks, commonly porphyritic, in plutons, and porphyritic rocks and breccias in dikes, plugs, and small stocks

TKa ANDESITIC ROCKS (TERTIARY AND CRETACEOUS)--Flows and small intrusions. Locally includes small units of sedimentary rocks

Ksv SEDIMENTARY AND VOLCANIC ROCKS (CRETACEOUS)--Mainly shale, siltstone, sandstone, and conglomerate; includes some limestone and felsic to intermediate volcanic rocks. Mainly Lower Cretaceous Bisbee Group to the southwest and Upper Cretaceous Colorado Shale to the northeast. Includes Jurassic and Triassic rocks in extreme southwest corner of quadrangle

PPs SEDIMENTARY ROCKS (PERMIAN AND PENNSYLVANIAN)--Mainly limestone; includes some dolomite and sandstone. Chiefly Naco Group

MЄs SEDIMENTARY ROCKS (MISSISSIPPIAN TO CAMBRIAN)--Mainly limestone, dolomite, shale, quartzite, and sandstone; includes some conglomerate and arkose sandstone

Yd DIABASE (MIDDLE PROTEROZOIC)--Includes gabbro and metadiorite in dikes and irregular masses

Yi INTRUSIVE ROCKS (MIDDLE PROTEROZOIC)--Granitic rocks, commonly porphyritic or porphyroblastic, in plutons

Xm METASEDIMENTARY AND METAIGNEOUS ROCKS (EARLY PROTEROZOIC)--Includes Pinal Schist and unnamed gneisses

CONTACT

FAULT--Dotted where concealed

STRIKE AND DIP OF BEDS

5 Inclined

Vertical

STRIKE AND DIP OF FOLIATION--Includes primary flow foliation of volcanic rocks and secondary metamorphic foliation of metamorphic rocks

50 Inclined

Vertical

INTRODUCTION

These maps (Maps A and B) show the distribution and abundance of bismuth and beryllium in the nonmagnetic fraction of heavy-mineral concentrates from stream sediments collected in the Silver City 1° x 2° quadrangle, New Mexico and Arizona. Geochemical maps showing the distribution and abundance of nine other selected key elements and the mineral fluorite in the Silver City quadrangle are also part of this folio (Watts and Hassemer, 1980; Watts and others, 1986a-i). These maps contribute to the assessment of mineral resources within the Silver City 1° x 2° quadrangle by: (1) showing regional patterns of elements enriched in heavy-mineral concentrates, thereby providing clues to regional patterns of mineralization; (2) showing new areas containing enriched metals, not previously known from mining activity; and (3) providing supportive data to the interpretive and summary maps (Watts and Hassemer, 1986) and the mineral resource assessment (Richter and others, 1983). Background information that pertains to published components of the Silver City folio is also available (Richter and others, in press).

The text that accompanies each of these geochemical maps is intended to be brief, generalized, and descriptive. Interpretations and detailed discussions of the various element-enriched areas of the Silver City quadrangle are incorporated into the geochemical interpretive and summary maps mentioned above (Watts and Hassemer, 1986) that are also part of the Silver City folio.

Geography and physiography

The Silver City 1° x 2° quadrangle covers approximately 8,050 mi^2 (20,650 km^2) in southwestern New Mexico and southeastern Arizona (fig. 1). It includes parts of Grant, Hidalgo, and Luna Counties in New Mexico, and Cochise, Graham, and Greenlee Counties in Arizona. Principal urban centers include Silver City and Lordsburg in New Mexico, and Safford and Willcox in Arizona. Interstate Highway 10, U.S. Highways 70, 80, 180, and 666, and numerous maintained State and county roads provide access to most of the quadrangle.

The quadrangle lies almost entirely within the southern Basin and Range province, an area of north- to northwest-trending mountain ranges and intervening basins (fig. 1). A small area in the northeastern part of the quadrangle, characterized by broad volcanic uplands, is in the transition zone between the Basin and Range and Colorado Plateaus provinces. The westerly flowing Gila River, and its tributaries, form the principal drainage system in the quadrangle; two large playa basins and other smaller central basin areas are drained internally. Elevations range from a low of 2,691 ft (820 m), where the Gila River leaves the northwest corner of the quadrangle, to a high of 10,686 ft (3,257 m), 22 mi (35 km) south on Mt. Graham in the Pinaleno Mountain range.

Geologic setting

The north- to west-northwest-trending block-faulted mountain ranges of the Silver City 1° x 2° quadrangle consist of diverse rocks ranging in age from Proterozoic through Cenozoic. The four main groups of rocks exposed in the ranges are, from oldest to youngest: (1) Proterozoic metamorphic and plutonic rocks; (2) Paleozoic and Mesozoic sedimentary rocks; (3) Cretaceous and early Tertiary volcanic and plutonic rocks; and (4) middle Tertiary volcanic and plutonic rocks. The mountain ranges are separated by structural and topographic basins filled with late Tertiary to Holocene sedimentary rocks and unconsolidated sediments.

SAMPLE COLLECTION, PREPARATION, AND ANALYSIS

Geochemical sampling of the Silver City 1° x 2° quadrangle was completed in 1981. The sample density of the drainage survey is highly variable over the Silver City quadrangle. Some of the highest numbers of samples per square mile were collected in the central mining region in the northeast corner of the Silver City 1° x 2° quadrangle, where sample density was as high as nine samples per square mile. That area was the subject of detailed studies of primary and secondary metal dispersion on a district scale and is the subject of other reports (Watts and others, 1978; Watts and others, 1984). Other areas identified as having anomalous element concentrations in the more widely spaced regional reconnaissance were further sampled in detail, as reflected by their high sample density.

The heavy-mineral samples were collected as composites from recently deposited sediment in the channels of ephemeral streams. The weight of the samples averaged about 11 lbs (5 kg) or roughly the amount of material that would fill a 16-in.-diameter gold pan. The samples were collected from the channels of streams where they issue from the range fronts, usually within about 100 ft (30 m) of the contact between bedrock outcrop and poorly consolidated to unconsolidated intermontane-basin-fill sediment. The major canyons in the mountain ranges were sampled on their headward and side tributaries but usually not in the main canyon.

In most cases the material analyzed consisted of two fractions (nonmagnetic and magnetic) of heavy (specific gravity greater than 2.8) minerals separated from the bulk alluvial sediments by density contrast (gold pan and heavy liquids) and relative magnetic susceptibility. In the case of bismuth and beryllium, however, the nonmagnetic fraction contained most of the detectable or enriched concentrations and therefore is the only fraction shown for these elements. Methods of collecting and preparing samples are discussed elsewhere (Watts and others, 1978; Watts and Hassemer, 1980; Watts and others, 1984). The samples were examined microscopically after initial preparation, and were then pulverized to a fine powder and analyzed for 30-31 elements by emission spectrography (Grimes and Marranzino, 1968; McDanal and others, 1983).

SAMPLE MINERALOGY

A knowledge of the mineralogic content of the samples is important in the interpretation of trace-element contents. Mineral phases in the samples indicate the geologic environment of the source area and sometimes provide additional geologic information than is known from geologic mapping. The heavy-mineral fractions will usually contain suites of minerals that characterize, by their variety, the rock types in the drainage basins, and by their ratios, the lithologic proportions contributing to the basin alluvium. Unusual trace-element contents in common rock minerals are often revealed by the spectrographic analyses. Some samples collected in the quadrangle also contained uncommon suites of minerals that may characterize unusual rock types or indicate specific types of mineralization and alteration in the drainage basin areas.

Microscopic scans of the samples prior to their pulverization showed that the most abundant minerals in the nonmagnetic fraction, regardless of geologic terrane, are zircon, sphene, and apatite. Barite and carbonate minerals, commonly coated by manganese oxide or containing black inclusions, occur in both volcanic and pre-Tertiary terranes (for example, the Silver City Range), whereas fossils and aggregate grains (intergrowths) of various minerals such as quartz and hematite are indicative of samples from Paleozoic terrane. Concentrates from regionally metamorphosed Proterozoic rocks exposed by uplift and deep erosion contain abundant sphene and muscovite and lesser amounts of sillimanite and garnet. Samples from contact metasomatized zones (skarn) in all types of pre-Tertiary terrane usually contain abundant light-green to colorless minerals of the epidote group (iron poor) usually in conjunction with other calc-silicate minerals such as tremolite and diopside. During these studies, observations of the skarn assemblage in samples has been used to infer the existence of previously unknown skarn zones.

Invariably, samples from mineralized areas contain pyrite that is occasionally abundant and is usually altered slightly to limonite; some samples contain fluorite and (or) barite. Alluvium in many mineralized areas contains a variety of primary and secondary ore minerals of copper, lead, zinc, and silver. Stream sediment derived from many of the middle Tertiary volcanic centers was noted to contain cassiterite, fluorite, barite, hematite, minor pyrite, and occasional uranium-thorium minerals.

The magnetic fraction of samples from most geologic terranes contains limonitic and hematitic aggregates. Volcanic and plutonic igneous terranes produce biotite, hornblende, various pyroxene minerals, sphene, and garnet. Green epidote (iron rich) is typically found in samples from contact metasomatic or propylitized zones. The chief constituents of the magnetic fraction in mineralized areas are (1) the various oxides of iron (for example, limonite) as pseudomorphs after pyrite, (2) some of the more magnetic ore minerals (such as chalcopyrite), and (3) often manganese oxide minerals and oxyhydroxides. In samples from areas covered by middle Tertiary volcanic rocks, the magnetic fraction generally contains amorphous oxyhydroxides and oxide minerals of manganese and iron and occasional epidote and minor pyrite related to propylitization.

INTERPRETIVE IMPLICATIONS OF THE HEAVY-MINERAL FRACTIONS

Spectrochemical and mineralogic data have been considered together in evaluating the relative roles of ore-forming, rock-accessory, and rock-forming minerals as sources of unusually enriched trace elements in the stream-sediment concentrates. Each mineralogic residence site for unusually high trace-element content can have its own implications with regard to possible mineral deposits.

The two heavy-mineral fractions (nonmagnetic and magnetic) have complementary but somewhat different implications with regard to element dispersion; some of the implications may not apply directly to the element(s) shown on this map but usually will apply indirectly. Thus, one or more of the factors listed below probably account for element enrichments in the two fractions.

In the nonmagnetic fraction, high concentrations of ore and pathfinder elements can be attributed to the presence in the drainage basin of (1) primary and secondary ore minerals and gangue minerals in exposed mineral deposits; (2) gangue minerals (for example, barium in barite) in possible zoned leakage halos on the vertical or lateral periphery of base-, precious-, or rare-metal deposits; (3) rock-accessory minerals with trace-element contents that are usually derived from the various igneous rocks (for example, tin in sphene) and are the result of lattice replacements or exsolved phases; and (4) non-sulfide ore minerals such as fluorite and cassiterite indicative of possible base- and precious- or rare-metal deposits (for example, deposits of tin, molybdenum, and beryllium in association with the middle Tertiary volcanic centers).

In the magnetic fraction, high element contents are mostly associated with the various oxides and oxyhydroxides of iron and manganese. The sources of these element-enriched detrital grains are diverse but undoubtedly include: (1) outcropping zones of limonitic gossan favored by fractured or otherwise permeable, pyritic bedrock; (2) altered zones where manganese and iron oxides were brought to the surface by convection currents of heated, oxygenated meteoric and (or) magmatic water (geothermal activity); (3) manganese and iron oxides deposited at springs of normal temperature as a result of surface oxidation; (4) outcropping mineral deposits that include metal-rich magnetic minerals; (5) intergrowths of sulfide phases with ferromagnesian minerals from outcrops; and (6) in-situ minerals coated by limonite precipitated from metal-rich soil solutions.

STATISTICS AND MAP GENERATION

The statistical distribution of the data is shown on the histogram (fig. 2). The frequency distributions of the two elements in the heavy-mineral concentrates are superimposed on each other on the histogram to facilitate their comparison, which is useful for interpretations. The symbols used on the maps correspond to class intervals of reported element concentrations as shown on the histogram.

The maps were computer plotted. The plotting symbol (+) represents the lowest class interval of reported element concentrations, which is regarded as the background range of element concentrations. These element contents are mostly derived from normal rock-forming and rock-accessory minerals and their weathering products, which compose the bulk of heavy-mineral concentrates. The remaining class intervals shown are ranges of element concentrations regarded as high background or weakly anomalous to highly anomalous as a result of either unusual trace-element substitutions in rock-forming minerals or the presence of ore-forming minerals; increasing trace-element content is indicated by increasing size of symbol.

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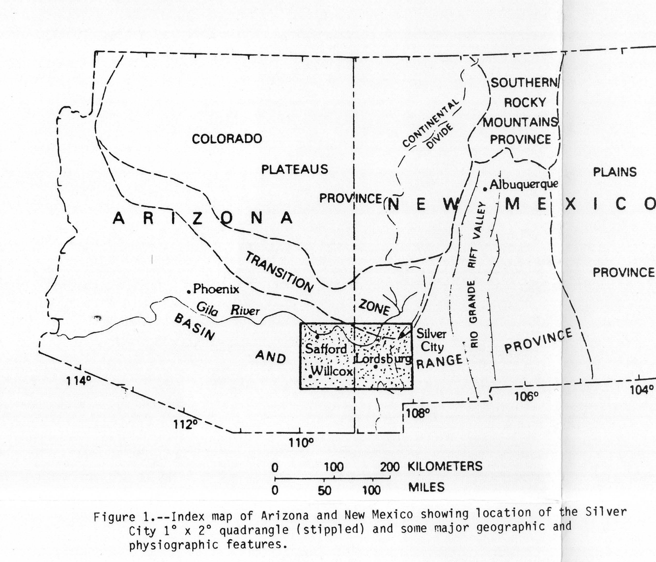

Figure 1.--Index map of Arizona and New Mexico showing location of the Silver City 1° x 2° quadrangle (stippled) and some major geographic and physiographic features.

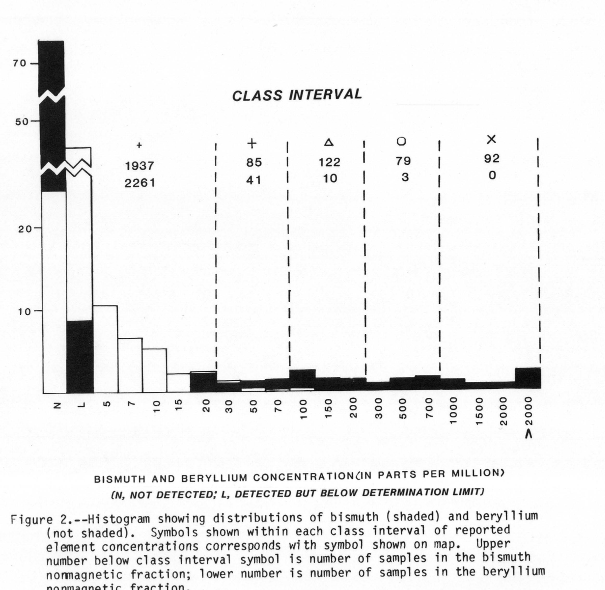

Figure 2.--Histogram showing distributions of bismuth (shaded) and beryllium (not shaded). Symbols shown within each class interval of reported element concentrations corresponds with symbol shown on map. Upper number below class interval symbol is number of samples in the bismuth nonmagnetic fraction; lower number is number of samples in the beryllium nonmagnetic fraction.

SCALE 1:250 000

CONTOUR INTERVAL 200 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

GEOCHEMICAL MAPS SHOWING DISTRIBUTION AND ABUNDANCE OF BISMUTH AND BERYLLIUM IN THE NONMAGNETIC FRACTION OF STREAM-SEDIMENT CONCENTRATES, SILVER CITY 1° X 2° QUADRANGLE, NEW MEXICO AND ARIZONA

By
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1986

INTERIOR—GEOLOGICAL SURVEY, RESTON, VIRGINIA—1986
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