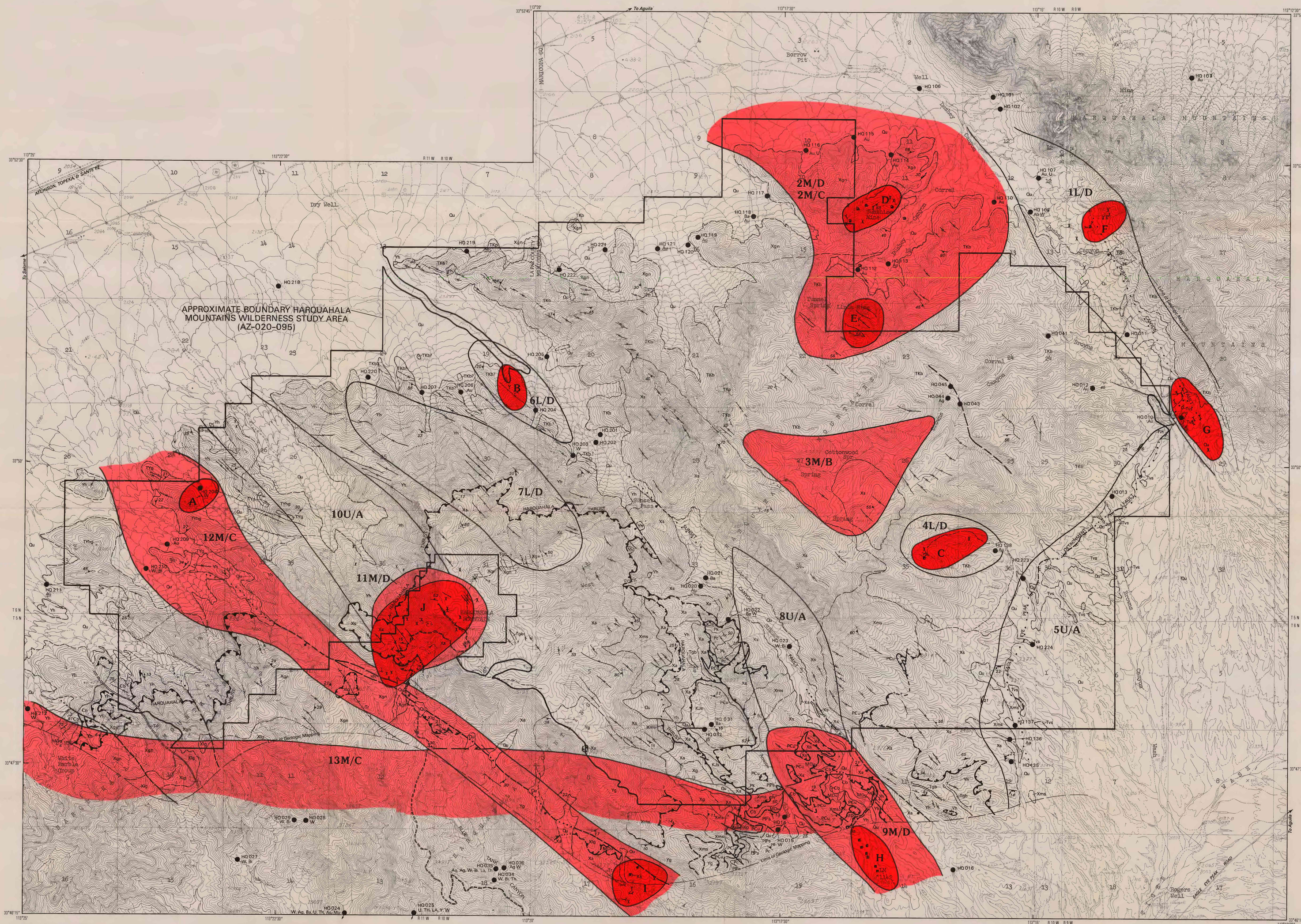
DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

BULLETIN 1701–C
PLATE 1



MINERAL RESOURCE POTENTIAL AND GEOLOGIC MAP OF THE HARQUAHALA MOUNTAINS WILDERNESS STUDY AREA, LA PAZ AND MARICOPA COUNTIES, ARIZONA

EXPLANATION OF IDENTIFIED RESOURCES AND MINERAL RESOURCE POTENTIAL

[No geologic terrane having high mineral resource potential for any commodity was identified by this study. Except as designated otherwise below, entire area has low mineral resource potential, with certainty level C, for gold, silver, and copper in small quartz-vein deposits. Entire area also has low mineral resource potential for copper, lead, zinc, gold, and silver in massive sulfide deposits and for pegmatite minerals, with certainty level D, and for placer gold, oil and gas, sand and gravel, and ornamental stone, with certainty level C]

A — **Areas having identified resources**—Letters refer to areas listed below and in table 1
- A. Gold, copper
- B. Gold, copper
- C. Gold
- D. Gold, copper
- E. Gold, silver
- F. Gold, silver, copper
- G. Silver, copper
- H. Gold, silver, copper
- I. Gold, silver, copper
- J. Gold, silver, copper

3 M/B, 12 M/C, 11 M/D — **Geologic terrane having moderate resource potential for commodities listed in table below, with certainty levels B, C, or D**—Number prefixes refer to areas listed in table below and in table 3. Numbered areas may surround lettered areas; if so, the lettered area has the same resource potential as the numbered area

1 L/D — **Geologic terrane having low resource potential for commodities listed in table below, with certainty level D**—Number prefixes refer to areas listed in table below and in table 3

10 U/A — **Geologic terrane having unknown resource potential**—Number prefixes refer to areas listed below and in table 3

CORRELATION OF MAP UNITS

DESCRIPTION OF MAP UNITS

Qu — **Surficial deposits, undivided (Holocene and Pleistocene)**—Alluvium, windblown sand, colluvium, talus debris, and landslide deposits are widely distributed in the study area and flank the Harquahala Mountains on all sides. Colluvium and talus debris are most abundant in steep canyons; alluvium and sand are most common away from the mountain front. Several geomorphic surfaces are present, and at least two ages of fanglomerate are present

Tr — **Rhyolite dikes (Miocene and Oligocene?)**—Light-gray to white, fine-grained, porphyritic rhyolite dikes along and northeast of Blue Tank Canyon appear on the basis of field relations to be the same age (Oligocene(?) and Miocene) as both the ductic and gabbroic dikes below

Td — **Dacite dikes (Miocene and Oligocene?)**—A tan to light-brown, fine-grained dacite dike west of the White Marble mine appears on the basis of field relations to be the same age (Oligocene(?) and Miocene) as the fine-grained gabbroic dikes below

Tgb — **Gabbroic dikes (Miocene and Oligocene?)**—Dark-green, fine- to medium-fine-grained, equigranular hornblende-plagioclase-epidote dikes are exposed throughout the Harquahala Mountains in a northwest-striking, high-angle swarm. Most of the dikes in the range are not shown on plate 1; an indication of the number of dikes is obtained by the density of dikes noted along ridge-top traverses southeast of Cottonwood Spring and northeast of Harquahala Mountain. The dikes are undeformed except in the Arrastre Gulch area, where some dikes that intrude marble show evidence of minor deformation. A dike from the southeast side of the area of plate 1 (dated by Shafiqullah and others (1980) gave the following results: K-Ar date of biotite, 22.1±1.3 Ma; K-Ar date of hornblende, 28.6±1.9 Ma. See Reynolds and others (1985) for a summary of geochronologic data in the Harquahala Mountains. Thin dikes are shown by single line containing an X

Tvs — **Volcanic and sedimentary rocks (Miocene and Oligocene?)**—Purple to black basalt, red conglomerate, and tan arkose, sandstone, and monolithologic breccia are exposed in the upper plate of the Eagle Eye Peak detachment fault west of Browns Canyon Wash. The volcanic and sedimentary rocks are similar to those in the Big Horn Mountains to the southeast (Allen, 1986; Capps and others, 1985) and are probably Miocene and Oligocene(?) in age

TKb — **Granite of Browns Canyon (Eocene or Late Cretaceous)**—Light-tan to light-gray, medium-grained, equigranular biotite granite containing accessory muscovite and garnet is exposed throughout the northeastern part of the study area, from Sunset Canyon to Dudley Canyon. The granite possesses a flow foliation in northern and western outcrops, but is relatively massive in the center and to the south. Small masses of granite extend west and northwest of Sunset Pass along the northeastern front of the range. The granite intrudes Early Proterozoic gneiss (Xgn), the granodiorite of Sunset Canyon (Xs), and the granodiorite of Harquahala Mountain (Yh). Mylonitic foliation is only locally developed in the granite along the Eagle Eye Peak detachment fault west of Browns Canyon Wash. Numerous small amphibolite and gneiss bodies in the granite are not shown on plate 1. Major- and minor-element chemistry of the granite of Browns Canyon is very similar to, but slightly more evolved than, the Tank Pass Granite (Reynolds, 1982) in the Harcuvar Mountains to the west. The two plutons' bodies are probably of a similar age

TKp — **Pegmatite dikes (Eocene or Late Cretaceous)**—Pink to tan, coarse-grained potassium feldspar-albite-quartz-muscovite pegmatite dikes related to the granite of Browns Canyon (TKb) are restricted to the southeastern part of the area of the granite, predominantly along Sunset Canyon and north and west of Sunset Pass. The dikes range in thickness from 2 to 12 ft, cut discordantly across older metamorphic fabrics, and discordantly intrude the Harquahala thrust fault. The southeast border of the granite of Browns Canyon is actually a zone of intense pegmatite injection. A Rb-Sr whole rock-muscovite date of 69 Ma (Eocene) was determined by Conoco Minerals Company (W.A. Rehrig, unpub. data, 1984) for a pegmatite northwest of Sunset Pass. Small bodies of pegmatite are shown by a dotted outline pattern or a dotted line pattern

TYg — **Granitic rocks of unknown age (Eocene or Middle Proterozoic)**—Light-gray, medium-fine-grained, equigranular, foliated to undeformed biotite granite to granodiorite containing accessory muscovite is exposed along the northwest front of the range, from near the White Marble mine to northwest of Harquahala Mountain. The granite intrudes the Middle Proterozoic granodiorite of Harquahala Mountain and is cut by pegmatite dikes (unit TKp) related to the granite of Browns Canyon

TYhg — **Granodiorite of Harquahala Mountain and granitic rocks of unknown age, undivided (Eocene or Middle Proterozoic)**—Unit consists of mixture of granodiorite of Harquahala Mountain (unit Yh) and granitic rocks of uncertain age (unit TYg) and is restricted to the northwestern edge of the Harquahala Mountains

KJs — **Metasedimentary rocks, undivided (Cretaceous and (or) Jurassic)**—Gray, fine-grained quartz-feldspar-biotite schist, muscovite schist, muscovite-quartz-feldspar-staurolite-garnet schist, and epidote-feldspar schist of probable Jurassic and (or) Cretaceous age is exposed in upper Arrastre Gulch, where it structurally underlies Kaibab Limestone. Probable rare sandstone, siltstone, sparse conglomerate, and calcareous sandstone. The schist may be correlative to the basal part of the McCoy Mountains Formation (Harding and Coney, 1985) or to Triassic units present farther northwest on the Colorado Plateau

Pk — **Kaibab Limestone (Lower Permian)**—Gray to white, coarsely crystalline marble that originally was dolomite and cherty limestone is exposed in the upper reaches of Arrastre Gulch, where it structurally overlies upside-down Cretaceous and (or) Jurassic metasedimentary rocks, and south of West Fork, where it structurally underlies upside-down Coconino Sandstone

Pc — **Coconino Sandstone (Lower Permian)**—White, vitreous quartzite of the Coconino Sandstone is exposed south of Arrastre Gulch, where it tectonically underlies the Supai Formation, and south of West Fork, where it tectonically overlies Kaibab Limestone

PPs — **Supai Formation (Lower Permian to Lower Pennsylvanian)**—Tan to reddish-brown interbedded quartzite, mica schist, and hematite schist of the Supai Formation originally were sandstone, siltstone, and calcareous siltstone, respectively. The upside-down Supai is exposed in the Arrastre Gulch area

MDu — **Redwall Limestone (Upper and Lower Mississippian) and Martin Formation (Upper Devonian), undivided**—The Martin Formation consists of tan to white, coarsely crystalline, tremolite-bearing marble that originally was a dolomite and siliceous limestone. The Redwall Limestone is a tan to white-sndy-gray, coarsely crystalline marble interbedded with chert lenses and originally was a cherty dolomite and limestone. The unit is mapped in the Arrastre Gulch area, and some areas near Arrastre Gulch, but the marble lithologies are included in undivided Paleozoic rocks (unit PCu) in much of the Arrastre Gulch area

Cb — **Abrigo Formation (Upper and Middle Cambrian) and Bolsa Quartzite (Middle Cambrian)**—Bolsa Quartzite consists of white to light-tan feldspathic schist, quartzite, and conglomerate that originally were sandy siltstone, quartzite, and conglomeratic sandstone, respectively. The Abrigo Formation consists of gray to brown, fine-grained quartz-biotite-epidote schist that originally was an interbedded shale and sandstone. Both units are exposed in the White Marble mine area, where the depositional contact of Bolsa on granodiorite of Harquahala Mountain is retained, and in the Arrastre Gulch area, where the original depositional contact is now highly deformed. The Bolsa and Abrigo are upside down in most exposures in the study area, as are many of the Paleozoic units

All Paleozoic units have been tectonically thinned in almost all exposures; estimates of original thickness are not possible. Metamorphic grade of the Paleozoic units decreases from lower amphibolite facies in the northeastern part of the outcrop area near Arrastre Gulch (Richard, unpub. data, 1986; Hardy, 1984) to greenschist facies near the White Marble mine, in the southwest, farther south in the Harquahala Mountains, near Socorro Peak (Varga, 1977), the Paleozoic strata are virtually unmetamorphosed

PCu — **Kaibab Limestone (Permian), Coconino Sandstone (Permian), Supai Formation (Permian and Pennsylvanian), Redwall Limestone (Mississippian), Martin Formation (Duvonian), Abrigo Formation (Cambrian), and Bolsa Quartzite (Cambrian), undivided**—Paleozoic rocks ranging from the Cambrian Bolsa Quartzite to the Permian Kaibab Limestone are exposed in tectonically thinned lenses along the Harquahala thrust fault in the Arrastre Gulch area and northeast of Sunset Canyon. The lenses consist of quartzite, marble, and schist, and represent various sandstone and quartzite, limestone and dolomite, and siltstone units, respectively, of the Paleozoic strata

Yg — **Granite (Middle Proterozoic?)**—Tan to gray, medium-grained, slightly porphyritic, undeformed to weakly deformed biotite granite containing potassium feldspar phenocrysts is exposed northeast of Sunset Canyon and along the steep ridge leading up to Harquahala Mountain from the south. This unit actually is composed of a number of texturally variable granitic bodies that are too small to show at the scale of plate 1. The granite intrudes Early Proterozoic gneiss (unit Xgn), schist (unit Xms), granitic rocks (unit Xg), and granodiorite of Sunset Canyon (unit Xs) and is in tectonic contact with leucogranite (unit Xlg) and schist. The granite is finer grained and less porphyritic than the granodiorite of Harquahala Mountain, but is chemically very similar to it (Richard, unpub. data, 1986); this granite may also be Middle Proterozoic

Yh — **Granodiorite of Harquahala Mountain (Middle Proterozoic?)**—Tan to gray, coarse-grained, very porphyritic, foliated biotite granodiorite to granite containing potassium feldspar augen that were once phenocrysts is exposed extensively along the northwest flank of the range, in steep cliffs northwest of Harquahala Mountain, and in low hills along Arrastre Gulch and on the northeast side of Sunset Canyon. This granodiorite intrudes the granodiorite of Sunset Canyon (Xs) and amphibolite (Xa), is unconformably overlain by the Eagle Eye Peak detachment fault, and is in tectonic contact along the Harquahala thrust fault with a variety of Early Proterozoic rock units. Small exposures of granodiorite are noted in the upper reaches of Arrastre Gulch. Foliation in the granodiorite is believed to have formed in Mesozoic time because fabric in the granodiorite also cuts the Bolsa Quartzite at White Marble mine (and other Paleozoic units). Major- and minor-element chemistry of the granodiorite is similar to 1,400-Ma granitic rocks in the Hualapai Mountains near Kingman, Ariz. (Keizer, 1976; Logsdon and Heinrichs, 1980) and throughout the southwestern United States (Anderson, in press). Rb-Sr whole-rock data from Conoco Minerals Company (W.A. Rehrig, unpub. data, 1983) indicate that the pluton is no older than 1,450 Ma. The small body of the granodiorite of Harquahala Mountain northeast of Sunset Canyon and west of Browns Canyon Wash is intermixed with Early Proterozoic granite rocks (Xg), but no separate bodies of the granitic rocks are shown on plate 1

Xlg — **Leucocratic granite (Early Proterozoic)**—White to light-gray, fine- to medium-grained muscovite granite intrudes feldspathic gneiss (unit Xgn) east of the White Marble mine and is in tectonic contact with Middle Proterozoic granitic rocks (unit Yg) and Early Proterozoic amphibolite (unit Xa) along the steep ridge northeast of Blue Tank Canyon. The leucocratic granite has a weak flow foliation in most exposures. The Early Proterozoic age of the granite is indicated by its intrusion of an Early Proterozoic muscovite granite near Bagdad, Ariz. (DeWitt, unpub. data, 1986). Small bodies of pegmatite just south of Harquahala Mountain that are related to muscovite granite are shown by a dotted line pattern

Xg — **Granitic rocks (Early Proterozoic)**—Dark-gray, medium-grained, moderately to intensely foliated biotite granite to granodiorite is exposed west of Arrastre Gulch, where it intrudes amphibolite and mica schist. Biotite granodiorite may be a border phase of the granodiorite of Sunset Canyon (unit Xs) or may be a separate body. An Early Proterozoic age is inferred by the deformed nature of the granodiorite

Xs — **Granodiorite of Sunset Canyon (Early Proterozoic)**—Light-gray to tan, fine- to medium-fine-grained, leucocratic biotite granodiorite is exposed in a large area in the center of the range, from Harquahala Mountain on the northwest to 2 mi northeast of Sunset Canyon. The granodiorite has a compositional banding defined by flow foliation in most outcrops. An Early Proterozoic syntectonic age is inferred from the intense flow foliation and chemical similarity of the rock to deformed granodioritic units in the central Bradshaw Mountains and Congress area of Arizona (DeWitt, 1986). The large body of granodiorite centered on Harquahala Mountain southwest of Sunset Canyon contains much gneiss and minor muscovite schist, ranging in size from tens to hundreds of feet thick, that are not shown on plate 1. The small body of granodiorite (unit Xs) at the head of Browns Canyon northeast of Sunset Canyon is intermixed with mica schist (unit Xms). The small body of the granodiorite of Sunset Canyon northeast of Sunset Canyon and west of Browns Canyon Wash is intermixed with Early Proterozoic granitic rocks (Xg) but no separate bodies of the granitic rocks are shown on plate 1

Xa — **Amphibolite (Early Proterozoic)**—Dark-green, medium-grained amphibolite and amphibolite-plagioclase schist and gneiss are exposed south of West Fork and north of Arrastre Gulch and in the far southeastern part of the study area, northeast of Blue Tank Canyon. Compositional banding is locally preserved in some areas, but most of the amphibolite is massive and could have been derived from basaltic flows or gabbroic sills. Bodies of amphibolite too small to be shown at the scale of plate 1 are present in many of the Early and Middle Proterozoic granitic rocks and the Late Cretaceous or Eocene granite of Browns Canyon

Xgn — **Feldspathic gneiss (Early Proterozoic)**—White to light-colored, medium-grained, compositionally banded quartz-feldspar-biotite gneiss is well exposed west of the Sunshine mine in the southeastern part of the study area and east of the White Marble mine in the southwestern part of the area. The unit includes minor amphibolite and biotite-amphibole-epidote gneiss and was derived from a mixture of granitic rocks and metamorphosed sedimentary rocks, predominantly siltstone and sandstone. Near the Sunshine mine the gneiss has a northeast-striking, high-angle foliation characteristic of Early Proterozoic rocks in much of northcentral Arizona. Foliation in the southern exposures of gneiss trends more northerly. The gneiss is not in contact with other Early Proterozoic metamorphic rocks

Xms — **Mica schist (Early Proterozoic)**—Light-tan to gray, fine- to medium-grained quartz-biotite-muscovite-feldspar schist is exposed along the ridge top northeast of Blue Tank Canyon, in steep cliffs southwest of Sunset Canyon, and in low-relief hills west of Browns Canyon Wash. The schist was derived from silty and shaly sedimentary rocks. Amphibolite is in contact with the schist southwest of Sunset Canyon, but age relations of the two are unclear. Contacts of the schist and Middle Proterozoic granitic rocks northeast of Blue Tank Canyon may be in part tectonic

—?— **Contact**—Dashed where approximately located, dotted where concealed, queried where location uncertain

—?— **Fault**—Dashed where approximately located, dotted where concealed, queried where location uncertain. Bar and ball on downthrown side

—?— **Low-angle or detachment fault**—Dashed where approximately located, dotted where concealed. Hachures on upper plate

—?— **Thrust fault**—Dashed where approximately located, dotted where concealed, queried where location uncertain. Barbs on upper plate

Strike and dip of bedding

Strike and dip of overturned bedding

Strike and dip of Cretaceous and (or) Jurassic or Proterozoic foliation and trend of lineation

Strike and dip of Tertiary mylonitic foliation and trend of lineation

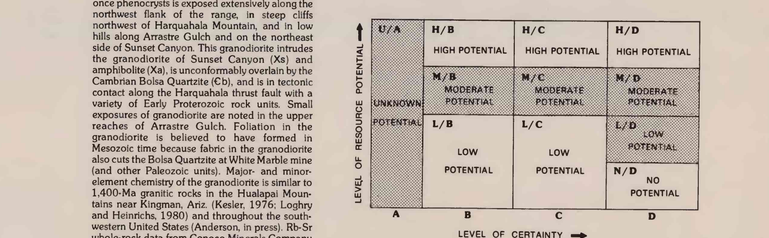
Strike and dip of flow foliation in granite of Browns Canyon

Dike
- Gabbroic (unit Tgb)
- Rhyolite (unit Tr)

Small bodies of pegmatite

Surface openings—Showing sample numbers
- Prospect pit
- Adit
- Shaft
- Trench

HQ029 Au, Bi, W — **Stream-sediment sample locality and number**—Elements present in highly anomalous concentrations listed beneath sample number and underlined. Stream-sediment sample localities shown in sec. 13, T. 5 N., R. 11 W. are actually outside the map area, downstream in the direction indicated by the arrows



LEVELS OF RESOURCE POTENTIAL

- H High mineral resource potential
- M Moderate mineral resource potential
- L Low mineral resource potential
- U Unknown mineral resource potential
- N No known mineral resource potential

LEVELS OF CERTAINTY

- A Available data not adequate
- B Data indicate geologic environment and suggest level of resource potential
- C Data indicate geologic environment, give good indication of level of resource potential, but do not establish activity of resource-forming processes
- D Data clearly define geologic environment and level of resource potential and indicate activity of resource-forming processes in all or part of the area

Diagram showing relationships between levels of mineral resource potential and levels of certainty. Shading shows levels that apply to this study area

Summary of areas having mineral resource potential in and adjacent to the Harquahala Mountains Wilderness Study Area

[Level of potential/level of certainty explained below; commodities listed in order of relative importance; commodities not underlined are considered to be byproducts or trace metals that could be recovered if deposits containing gold were mined; where variable sizes of deposits are shown, the most probable size is listed first; size of deposits listed below; c, less than]

Map area	Name	Resource potential	Level of potential/ level of certainty	Commodities (listed in order of importance)	Size, type of deposit
1	Dudley Canyon	Low	L/D	Au, Ag, Cu, Zn	Small, vein
2	Sunshine	Moderate	M/C	Au, Ag, Cu, Zn	Small, vein
		Moderate	M/C	Au, Ag, Cu, Zn	Small-medium, disseminated
3	Upper Browns Cyn.	Moderate	M/B	Au, Ag, Cu	Small, vein
4	Crown Prince	Low	L/D	Au, Ag, Cu, Pb, Zn	Small, vein
5	Browns Canyon Wash	Unknown	U/A	Au, Ag, Mo, Cu	Medium, vein or disseminated
6	NW. of Sunset Pass	Low	L/D	Au, Cu	Small, vein
7	N. of West Fork Arrastre Gulch	Low	L/D	Au, W, Ag	Small, vein
8	NW. of Arrastre Gul.	Unknown	U/A	Au, W, Ag	Small, vein
9	Arrastre Gulch	Moderate	M/D	Au, Cu, Pb, Zn, Ag	Small, vein
10	N. Harquahala Mtn.	Unknown	U/A	Au, W, Ag	Small, vein
11	Harquahala Mtn.	Moderate	M/D	Au, Cu, Ag	Small, vein
12	Blue Tank Canyon	Moderate	M/C	Au, Cu, Ag, Pb, Zn	Small, vein
13	White Marble Mine	Moderate	M/C	Au, W, Ag	Small-medium, skarn or replacement

Small vein deposit = <10,000 tons
Medium-size vein deposit = 10,000–250,000 tons
Medium-size replacement or skarn deposit = 10,000–500,000 tons

Small replacement or skarn deposit = <10,000 tons
Medium-size disseminated deposit = 200,000–10,000,000 tons