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BLACK MOUNTAINS NORTH G-E-M

RESOURCES AREA

(GRA NO. AZ-05)

TECHNICAL REPORT

(WSAs AZ 020-009 and 020-010)

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Final Report

April 22, 1983

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ATTACHMENTS
(At End of Report)

CLAIM AND LEASE MAPS

Patented/Unpatented

Oil and Gas

MINERAL OCCURRENCE AND LAND CLASSIFICATION MAPS (Attached)

Metallic Minerals

Uranium and Thorium

Nonmetallic Minerals

Geothermal

LEVEL OF CONFIDENCE SCHEME

CLASSIFICATION SCHEME

MAJOR STRATIGRAPHIC AND TIME DIVISIONS IN USE BY THE U.S.
GEOLOGICAL SURVEY

EXECUTIVE SUMMARY

The Black Mountains North Geology-Energy-Minerals (GEM) Resource Area (GRA) includes the following Wilderness Study Areas (WSAs): AZ 020-009 and AZ 020-010.

The Black Mountains North GRA lies approximately 15 miles northwest of Kingman in the northwest portion of Arizona and is composed of an assemblage of Precambrian (greater than 600 million years old) basement rocks overlain by Tertiary (less than 60 million years old) volcanics. There are five mining districts in the GRA, and all are on the boundaries or outside the boundaries of the WSAs. From north to south they are the Virginia, Pilgrim, Portland, Union Pass and Katherine. All produced mainly gold from epithermal veins similar to those found in the Oatman district to the south. Combined production figures for the districts would be in the millions of dollars. The only strategic and critical mineral mined within the GRA was silver as a by-product of gold production in the Katherine district.

There are a few patented claims in the Portland mine area, at least one of which is in WSA AZ 020-009. In WSA AZ 020-010 there are two patented claims along the southeastern border.

Unpatented claims are found within both of the WSAs. Several claims are included in WSA AZ 020-009 adjoining the Virginia district in the north and the Portland mine area in the south. In WSA AZ 020-010 there are claims in three sections near the middle and four sections in the southern edge. Those claims in the south are also found in the vicinity of old prospects and workings in the WSA which are the outlying diggings of the Katherine district.

Oil and gas leases cover the federally owned mineral estate in the WSAs since this area is part of the Overthrust play. There are no geothermal leases in the WSAs.

In general the WSAs' metallic mineral potential ranges from high to low depending on proximity to known mining districts and geology. The majority of both WSAs have a low favorability for metallic mineral commodities along with a low confidence level. The Virginia district in the north has a high favorability with a high confidence level and may extend into the northern boundary area of WSA AZ 020-009. The high potential with a high confidence level of the Portland Mine area includes nearby portions of both WSAs. The southern edge of WSA AZ 020-010 borders a high potential area because of its proximity to the Katherine-Union Pass district. Nonmetallic resources grade from a moderate to a low favorability with a moderate to low confidence level. Oil and gas favorability is low with a minimal confidence level; and geothermal resources have a low to moderate favorability with a low confidence level. There is low favorability for uranium and thorium resources in the WSAs at a low level of confidence.

CHAPTER I

THE first part of the book is devoted to a general survey of the subject, and to a discussion of the various methods which have been employed in the study of the same.

The second part of the book is devoted to a detailed examination of the various methods which have been employed in the study of the subject, and to a discussion of the various results which have been obtained.

The third part of the book is devoted to a detailed examination of the various methods which have been employed in the study of the subject, and to a discussion of the various results which have been obtained.

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The twelfth part of the book is devoted to a detailed examination of the various methods which have been employed in the study of the subject, and to a discussion of the various results which have been obtained.

The geologic mapping within this GRA is generalized, so a more detailed geologic information would help in evaluating the mineral potential of the WSAs. Sampling and further industry contact would also be of assistance.

Uranium has a low potential with a low confidence level. Nonmetallic commodities such as perlite have areas of moderate favorability with a moderate confidence level. The majority of the areas in the WSAs have a low favorability with a low confidence level for the remainder of the nonmetallics except that the sand and gravel resources (saleable resources) exhibit a moderate favorability with a moderate confidence level in the areas of the WSAs covered with alluvium.

I. INTRODUCTION

The Black Mountain North G-E-M Resources area (GRA No. AZ-05) contains approximately 158,000 acres (641 sq km) and includes the following Wilderness Study Areas (WSAs):

WSA Name	WSA Number
Black Mountain North	AZ 020-009
Burns Springs	AZ 020-010

The GRA is located in Arizona within the Bureau of Land Management's (BLM) Kingman Resource Area, Phoenix district. Figure 1 is an index map showing the location of the GRA. The area encompassed is near 35°30' north latitude 114°30' west longitude and includes the following townships:

T 25 N, R 21,22 W	T 24 N, R 20-22 W
T 23 N, R 19-22 W	T 22 N, R 20,21 W
T 21 N, R 20,21 W	

The areas of the WSAs are on the following U. S. Geological Survey topographic maps:

15-minute:

Spirit Mountain	Davis Dam
-----------------	-----------

7.5-minute:

Spirit Mountain	Spirit Mountain NE
Spirit Mountain SE	Grasshopper Jct. NW
Davis Dam	Burns Spring

The nearest town is Kingman which is located approximately 15 miles southeast of the GRA. Access to the area is via U. S. Highway 93 east of the GRA and State Highway 68 (Union Pass Road) south of the GRA. Access within the area is via numerous east-west light duty and unimproved roads between Lake Mohave and U. S. Highway 93.

Figure 2 outlines the boundaries of the GRA and the WSAs on a topographic base at a scale of 1:250,000.

Figure 3 is a geologic map of the GRA and vicinity, also at 1:250,000. At the end of the report, following the Land Classification Maps, is a geologic time scale showing the various geologic eras, periods and epochs by name as they are used in the text, with the corresponding age in years. This is so that the reader who is not familiar with geologic time subdivisions will

have a comprehensive reference for the geochronology of events.

This GRA Report is one of fifty-five reports on the Geology-Energy-Minerals potential of Wilderness Study Areas in the Basin and Range Province, prepared for the Bureau of Land Management by the Great Basin GEM Joint Venture.

The principals of the Venture are Arthur Baker III, G. Martin Booth III, and Dennis P. Bryan. The study is principally a literature search supplemented by information provided by claim owners, other individuals with knowledge of some areas, and both specific and general experience of the authors. Brief field verification work was conducted on approximately 25 percent of the WSAs covered by the study.

None of the WSAs in this GRA were field checked. An aerial reconnaissance was conducted of this GRA on October 22, 1982.

One original copy of background data specifically applicable to this GEM Resource Area Report has been provided to the BLM as the GRA File. In the GRA File are items such as letters from or notes on telephone conversations with claim owners in the GRA or the WSA, plots of areas of Land Classification for Mineral Resources on maps at larger scale than those that accompany this report if such were made, original compilations of mining claim distribution, any copies of journal articles or other documents that were acquired during the research, and other notes as are deemed applicable by the authors.

As part of the contract that resulted in this report, a background document was also written: Geological Environments of Energy and Mineral Resources. A copy of this document is included with the GRA File to this GRA report. There are some geological environments that are known to be favorable for certain kinds of mineral deposits, while other environments are known to be much less favorable. In many instances conclusions as to the favorability of areas for the accumulation of mineral resources, drawn in these GRA Reports, have been influenced by the geology of the areas, regardless of whether occurrences of valuable minerals are known to be present. This document is provided to give the reader some understanding of at least the most important aspects of geological environments that were in the minds of the authors when they wrote these reports.

FIGURE 1. GRA INDEX MAP OF REGION 3 1:3,168,000.

Kingman Sheet

Black Mountain North GRA AZ-05

Figure 2

E X P L A N A T I O N

<div>Qs</div> <div>Silt, sand, and gravel.</div>	<div>Qb</div> <div>Basalt Locally includes tuff and agglomerate.</div>	<div></div> <div>Dikes and plugs</div>	QUATERNARY
<div>QTs</div> <div>Sand, gravel, and conglomerate.</div>	<div>QTI</div> <div>Lake Deposits Siltstone, sandstone, and limestone.</div>	<div>QDb</div> <div>Basalt Locally includes tuff and agglomerate.</div>	
<div>Ts</div> <div>Sand, gravel, and conglomerate.</div>	<div>Tr</div> <div>Rhyolite Includes tuff and agglomerate</div>	<div>Ta</div> <div>Andesite Flows, tuff, and agglomerate</div>	
<div>TKs</div> <div>Sandstone, shale and conglomerate Includes some basalt.</div>	<div>Lg</div> <div>Granite and related crystalline rocks</div>	<div>D</div> <div>Dikes and plugs Rhyolitic to andesitic in composition.</div>	
<div>Ks</div> <div>Limestone conglomerate</div>	<div>Ka</div> <div>Andesite Flows, tuff, and agglomerate</div>	<div>Kr</div> <div>Gold Road volcanics Includes rhyolite, latite, and andesite. Locally contains volcanic glass.</div>	CRETACEOUS
	<div>RJc</div> <div>Glen Canyon group Includes in descending order, Navajo sandstone Kayenta formation, Moenave formation, and Wingate sandstone.</div>		
	<div>Rc</div> <div>Chinle formation</div>		
	<div>Rs</div> <div>Shinarump conglomerate</div>		
	<div>Rm</div> <div>Moenkopi formation</div>		TRIASSIC

	Chinle formation	TRIASSIC
	Shinarump conglomerate
	Moenkopi formation
	Kaibab limestone <i>Includes Toroweap formation</i>	PERMIAN
	Coconino sandstone
	Hermit shale	
<p>SYMBOLS</p> <p> Contact, showing dip</p> <p> Fault, showing dip <i>Dashed where approximately located</i></p> <p> Thrust fault (T, upper plate)</p> <p> Axis of anticline</p> <p> Axis of syncline</p> <p> Strike and dip of beds</p> <p> Strike of vertical beds</p> <p> Mine</p>		Supai formation	PENNSYLVANIAN AND PERMIAN
	Callville limestone
	Redwall and Martin limestones
	Tonto group	CAMBRIAN MISSISSIPPIAN AND DEVONIAN
	Granite and related crystalline intrusive rocks
	Diorite porphyry
	Schist	OLDER PRECAMBRIAN
	Granite gneiss	

II. GEOLOGY

The Black Mountains North GRA is an assemblage of Precambrian basement rocks overlain by mid-Tertiary volcanics. The Precambrian consists of metamorphosed gneiss and schist with intercalated granitic assemblages. The Miocene volcanic rocks range in composition from basalt to rhyolite and cover the majority of the Black Mountains within the study area. Detrital Valley fill makes up most of the remaining section in the area.

The structure of the area is dominated by Basin and Range faulting which began during the Miocene. Much of the eastern slope of the Black Mountains is bounded by steep northerly-trending faults. The topography on the western side of the Black Mountains in this area is much more subdued with foothills giving way to gently dipping alluvium extending to Lake Mohave.

Recent geological mapping in the northwest part of Arizona is lacking and the only geologic map available which covers the GRA is Wilson and Moore's county map published in 1959 at a scale of 1:375,000. Many of the units on this map have subsequently been found to be radically different than when originally mapped, both in age and origin. Information on the geology is therefore sketchy and has had to be interpolated from various district reports and research material.

1. PHYSIOGRAPHY

The Black Mountains North GRA is located in the Basin and Range Province in west central Mohave county near the Nevada state border. The study area encompasses a central portion of the northwest-trending Black Mountains Range from the south slope of Mt. Perkins in the north, to Union Pass in the south. The Black Mountains lie between the Detrital Valley on the east and Lake Mohave on the west.

Elevations along the crest of the range average about 4,000 feet with the highest peak reaching 4,827 feet. The area is not typical Basin and Range and drainage is predominantly to the west into Lake Mohave rather than to enclosed basins. To the east the drainage is into Detrital Wash which flows north until it reaches Lake Mead near Bonnell Landing.

2. ROCK UNITS

The oldest rocks in the study area are an unnamed Precambrian granite outcropping outside the WSAs near Davis Dam, and Precambrian gneiss and schist which occur south of Mt. Perkins in a northwest-trending belt extending along the east side of WSA AZ 020-009.

Deposited unconformably over the Precambrian metamorphics is a series of Miocene volcanics which in the northern portion of the study area includes the Mount Davis sequence of Olivine basalt and rhyodacite, dacite lavas and flow breccias. It should be noted that on the Mohave County Map (1959) these volcanics are identified as Cretaceous and are not subdivided. A thick sequence of Miocene rhyolite and andesite was extruded in the east central part of the GRA. The andesite is reported to be dark red with a relatively fresh appearance.

A granitic plug was intruded into older Miocene volcanics during the Miocene at Mt. Perkins near the northern border of the GRA. Plugs, dikes, and sills of rhyolite and andesite outcrop sporadically throughout the study area.

Quaternary alluvial and fluvial deposits were the next rock units deposited with thousands of feet of detrital material accumulating in the Detrital-Sacramento Valley to the east.

Overlying these sediments and older volcanic sequences are Quaternary basalt flows which outcrop sporadically throughout the study area.

3. STRUCTURAL GEOLOGY AND TECTONICS

The oldest structure preserved in the study area is the northeast-trending steeply-dipping schistosity of the Precambrian schists. Jointing in the Precambrian rocks generally trends northwest with a steep to near vertical dip.

The Tertiary volcanic rocks contain fissures paralleling the northwest trend of the jointing in the underlying Precambrian rocks. Fissure filled vein deposits in the study area are often associated with northwest-trending andesite and rhyolite dikes.

Basin and Range faulting, starting in the Miocene, has obviously had an influence on the present day topography of typical basin and range block faulting. Along the western boundary of the Black Mountains there are steeply-dipping northerly-trending faults with large displacements.

4. PALEONTOLOGY

Two lithologies within the Black Mountains North GRA have slight potential for paleontological resources; fluviatile and lacustrine strata of latest Tertiary-early Quaternary age and occasional sedimentary lenses interbedded with felsic volcanics. No fossil localities have been recorded from within this GRA, however.

5. HISTORICAL GEOLOGY

During the Precambrian, granitic rocks were deformed and metamorphosed to gneiss and schist by tectonic processes and later Precambrian intrusives.

Sediments similar to those of the Grand Canyon were deposited during the Paleozoic, but were completely stripped away by a long period of erosion. The underlying Precambrian granitoid rocks were deeply dissected prior to the eruption of the oldest volcanics.

During the Miocene volcanism and intrusive activity was widespread throughout the study area. Thick sequences of basalt, rhyodacite, dacite, andesite and rhyolite were deposited. Rhyolite and andesite dikes often associated with mineralized quartz veins were intruded near the end of the Miocene.

A period of erosion followed with the accumulation of great thicknesses of Quaternary age detrital material in the structural lows and intermontane valleys. It is postulated by Lee (1908) that the Detrital Sacramento Valley was carved out by a large south flowing river. Sands and gravels similar to those deposited by aggrading streams are found along the entire length of the valley, supporting Lee's hypothesis.

Widespread basalt flows were extruded over the Quaternary gravels and older rocks.

1891

 

III. ENERGY AND MINERAL RESOURCES

A. METALLIC RESOURCES

1. Known Mineral Deposits

Five known mining districts are located in or partly in the Black Mountains North GRA. The following districts listed from north to south are: Virginia, Pilgrim, Portland, Union Pass and Katherine. They produced mainly gold from epithermal calcite-quartz-adularia veins similar to those found in the highly productive Oatman district to the south. The Katherine district was the major producer with a recorded production from 1893-1933 of \$2.19 million in gold and \$100,000 in silver. Production figures for the other districts are not available; however, combined estimates probably would not exceed several hundred thousand dollars.

The Virginia district, due east of Mount Davis and just north of WSA AZ 020-009 in the northern portion of the study area has produced an unknown quantity of gold from quartz-adularia and calcite veins in Tertiary rhyolite and andesite. The calcite veins strike northwest, dip southwest, do not have sharp wall rock contacts and grade into the country rock. The ore is free milling with the best values associated with specks of hematite which is distributed throughout the veins. The major mines within this district are the Golden Door, Klondyke, Dixie, and Dixie Queen. Recent drilling has been completed and a small tonnage gold heap leach is reportedly planned in the near future at the Dixie Queen mine (BLM files, Kingman).

The Pilgrim district, which is about 2 miles in length and trends northwestward is located about 9 miles west of Chloride in the eastern foothills of the Black Mountains just to the east of WSA AZ 020-010. The development of northwest-trending gold veins along a granite-rhyolite contact has taken place primarily at the Pilgrim and South Pilgrim mines. Twelve tons of \$100/ton ore are reported to have been shipped. Total production data, however, is not available.

An unknown amount of gold has been produced from the Portland mine located in T 23 N, R 21 W, Sec. 19, on the border between the two WSAs. Mineralization reportedly occurs along a thrust plane in Tertiary andesite. This mine has been compared to similar mineralized structures associated with the mines near Nelson to the northwest, across the river in Nevada. Anderson (1971) describes the structures at Nelson as complex low-angle zones of detachment in the volcanic rocks overlying the Precambrian basement complex.

THE JOURNAL OF THE
ROYAL ANTHROPOLOGICAL INSTITUTE

The Journal of the Royal Anthropological Institute is a quarterly publication of the Royal Anthropological Institute of Great Britain and Ireland. It is devoted to the publication of original research papers and reviews in all branches of anthropology, including physical anthropology, social anthropology, linguistics, and archaeology. The Journal is published by the Royal Anthropological Institute, 21, BEDFORD SQUARE, LONDON, W.C.1A 2E, U.K.

The Journal is published quarterly, in January, April, July, and October. The subscription price of the Journal (which includes postage) is £12.00 per annum in advance. Single issues are available for purchase at £3.00 each. The Journal is also available in microfilm and microfiche editions. The Journal is indexed and abstracted in a number of international journals and services.

The Journal is published by the Royal Anthropological Institute, 21, BEDFORD SQUARE, LONDON, W.C.1A 2E, U.K. The Institute was founded in 1871 and is a charitable organization. It is the largest and most active of the learned societies in the United Kingdom. The Institute's main activities are the promotion of research in anthropology and the organization of conferences and seminars. The Journal is one of the main publications of the Institute.

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The northwestern portion of the Union Pass district lies within the GRA boundary but south of WSA 010-010. Major mines of this district within the GRA are the Sheep Trail, Boulevard, and Tyro mines. These mines developed northwest to east-west trending quartz and calcite veins which cut Precambrian granite. Several of the veins reach a maximum length of 5,000 feet with the average width being about 30 feet. Ore containing quartz and hematite gangue was very rich, and reportedly contained \$50/ton in gold in the early 1900s.

The eastern edge of the Katherine district (formerly the western extension of the Union Pass district) is located in the southwest corner of the GRA south of WSA AZ 020-010. It was a major producer of gold and silver from northwest-trending veins in Precambrian granite, at or near the granite-Tertiary volcanic contacts and within structures cutting the rhyolite flows and tuffs. The veins occupy fault fissures or fractures which show several stages of mineralization beginning with quartz and closing with calcite. The later stages of mineralization carried the highest concentrations of gold. Major mines in the district are: Katherine, Black Dyke, Illinois, Big Four, Treasure Vault, and Roadside.

2. Known Prospects, Mineral Occurrences and Mineralized Areas

Prospect pits, short adits, and shallow shafts are found in the general vicinity of the five mining districts described in the previous section. These prospects are usually on strike or extensions of known gold producing structures.

The following prospects outside of the main districts but within WSA AZ 020-010 have been identified on the Mineral Location Information Maps compiled by Coe & Van Loo Consulting Engineers, Inc. for the Arizona Department of Mineral Resources or on USGS topographic maps of the area:

Prospect	Location
Burns 1 & 2	T 22 N, R 20 W, Sec. 4
Crazy Stick	T 22 N, R 21 W, Sec. 26
Gold Chain Mine	T 22 N, R 21 W, Sec. 27
Unknown Shaft & Adit	T 22 N, R 21 W, Sec. 34

No other specific geologic or production information concerning the above listed prospects is available.

3. Mining Claims

Unpatented claims are predominantly found in the vicinity of the major mining districts. In the Virginia district, several hundred claims have been located by Claude Jolls, et al., in the north, and Occidental Minerals in the southern portion of the district. Some of these claims fall within the northern portion of WSA AZ 020-009.

In the Pilgrim district, Third Planet Resources has located most of the unpatented lode claims.

In the Katherine and Union Pass districts the majority of unpatented lode and placer claims have been located by Crown Resources, Ernest Holstein et al., and Freeport Mining Co. Some of these claims extend into the southern portion of WSA AZ 020-010. Patented claims are found in 5 sections in the Union Pass district and in 3 sections in the Katherine district.

Asarco Mining Co. has a block of claims covering the Portland Mine and portions of sections around it. Several patented claims are also found in the sections to the east and west of the Portland mine.

An isolated block of lode claims covering Secs. 1, 2 and 3 of T 22 N, R 21 W has been staked by Ernest Holstein, but it is unknown what commodity is being explored. The claims in Sections 1 and 3 are within WSA AZ 020-010.

In T 22 N, R 20 W, Secs. 4 & 9, there are patented claims, but no mine or prospect information concerning this property is available.

4. Mineral Deposit Types

The predominant type of mineral deposits found within the study area is gold-bearing epithermal calcite-quartz-adularia veins similar to those found in the highly productive Oatman District to the south. Five gold mining districts within the GRA produced over 2 million dollars at old gold prices from underground mines. Because the Katherine and Union Pass districts were the largest producers and contain veins similar to those found in the other districts, the following discussion will focus mainly on deposits within these two districts.

Northwest-trending auriferous vein deposits in the Union Pass and Kathrine districts are found in Precambrian granite, at or near Precambrian granite-Tertiary volcanics contacts and within structures cutting rhyolite flows and tuffs. The veins occupy fault fissures or fractures in the enclosing rocks. The ores are believed to have been deposited by ascending hydrothermal solutions closely

associated with Tertiary volcanism.

Five stages of mineralization, each of which has a distinct type of quartz, can usually be recognized. In the earlier stages silver predominates over gold, while in the last stage, the gold exceeds the silver. The gold is commonly alloyed with silver forming electrum, and hypogene coarse gold is rarely found in these two districts. Supergene gold occurs as wires and loose flakes in vugs with iron and manganese oxides.

Veins found within shear zones in granite are often a series of quartz stringers. The Katherine Mine produced gold ore locally rich in silver from high grade, closely spaced stringers. At some places, however, the vein filling was solid quartz and calcite more than ten feet wide. The granite wallrock is somewhat silicified.

At the Golden Door mine south of WSA AZ 020-010 in the Virginia district, minor gold production has come from widely silicified quartz-calcite breccia zones found along the crests of anticlines in Tertiary andesite. Extensive recent exploration has been conducted in this area. Large zones of silicification have been drilled to test the potential for a large tonnage lowgrade gold mine amenable to open-pit.

5. Mineral Economics

There is potential for additional gold and silver production from epithermal vein type deposits within the GRA. Because most of the past-producing epithermal veins are narrow, costly underground development and production of the ore would be necessary. As pointed out by Clifton (1980), American exploration groups are more interested in longer term, larger tonnage open-pit operations that are less labor intensive than underground operations. However smaller targets may be amenable to development by smaller operators.

In the Golden Door mine area, large silicified zones are being explored for low-grade, high tonnage gold potential amenable to open-pit mining techniques. Although specific data concerning similar deposits is not available, the geologic environment appears suitable for their occurrence.

Major mining companies including Freeport, Occidental Minerals and Crown Resources have large blocks of claims in and surrounding the major mining districts. It is possible that these companies are also prospecting for large tonnage, low grade gold open-pit hot springs type deposits which could be found higher in the geothermal system which produced the vein deposits.

The major use of gold is for storing wealth. It is no longer used for coinage because of monetary problems, but many gold "coins" are struck each year for sale simply as known quantities of gold that the buyer can keep or dispose of relatively easily. The greatest other use of gold is in jewelry, another form of stored wealth. In recent years industrial applications have become increasingly important, especially as a conductor in electronic instrumentation. In the United States and some other countries gold is measured in troy ounces that weigh 31.1 grams -- twelve of which make one troy pound. Annual world production is about 40 million ounces per year, of which the United States produces somewhat more than one million ounces, less than one-fourth of its consumption, while the Republic of South Africa is by far the largest producer at more than 20 million ounces per year. World production is expected to increase through the 1980s. For many years the price was fixed by the United States at \$35 per ounce, but after deregulation the price rose to a high of more than \$800 per ounce and then dropped to the neighborhood of \$400 per ounce. At the end of 1982 the price was \$460.50 per ounce.

The major uses of silver are in photographic film, sterlingware, and increasingly in electrical contacts and conductors. It is also widely used for storage of wealth in the form of jewelry, "coins" or bullion. Like gold it is commonly measured in troy ounces, which weigh 31.1 gram grams, twelve of which make one troy pound. World production is about 350 million ounces per year, of which the United States produces about one-tenth, while it uses more than one-third of world production. About two-thirds of all silver is produced as a byproduct in the mining of other metals, so the supply cannot readily adjust to demand. It is a strategic metal. Demand is expected to increase in the next decades because of growing industrial use. At the end of 1982 the price of silver was \$11.70 per ounce.

B. NONMETALLIC MINERAL RESOURCES

1. Known Mineral Deposits

There are no reported nonmetallic mineral deposits in the GRA or included WSA. Sand and gravel is present, however, in the alluvial materials in both the WSA and GRA.

2. Known Prospects, Mineral Occurrences and Mineralized Areas

Perlite is one of the few nonmetallic minerals reported to occur within the GRA and is found in siliceous Tertiary volcanics. In WSA AZ 020-009 perlite occurs sporadically in the western half of T 24 N, R 21 W. In WSA AZ 020-010

perlite is reported to occur in Sec. 31, T 24 N, R 20 W, and in two other localities two to three miles east of the WSA.

Zeolites are reported in silicic volcanic tuffs near Union Pass outside the GRA and along Cottonwood Road in the northern part of the GRA, but no occurrences are reported in the WSAs. Similar geology, however, is found in the WSAs. Sand and gravel is found in the alluvium in both WSAs but no active material sites are known to be present.

3. Mining Claims, Leases and Material Sites

There are no claims within the WSAs which are known to be staked for nonmetallic mineral resources. Outside the WSAs some of the claims south of the Pilgrim district may be for perlite, however.

Sand and gravel material sites are located in the GRA but not in the WSAs.

4. Mineral Deposit Types

Perlite occurs in silicic volcanic rocks throughout the GRA, sometimes associated with latite. The perlite occurs as phases of flows or as tuff breccias.

5. Mineral Economics

Perlite occurs in the GRA but the quality and extent of the occurrences are unknown. Perlite is a rather widespread nonmetallic resource in parts of the Basin and Range province and the economics of these occurrences would not only depend on quality and quantity but also on the market for perlite and transportation costs.

The most common use of sand and gravel is as "aggregate" - as part of a mixture with cement to form concrete. The second largest use is as road base, or fill. About 97 percent of all sand and gravel used in the United States is in these applications in the construction industry. The remaining three percent is used for glassmaking, foundry sands, abrasives, filters and similar applications. The United States uses nearly one billion tons of sand and gravel annually, all of it produced domestically except for a very small tonnage of sand that is imported for highly specialized uses. Since construction is by far the greatest user of sand and gravel, the largest production is near sites of intensive construction, usually metropolitan areas. Since sand and gravel are extremely common nearly everywhere, the price is generally very low and mines are very close to the

point of consumption -- within a few miles as a rule. However, for some applications such as high-quality concrete there are quite high specifications for sand and gravel, and acceptable material must be hauled twenty miles and more. Demand for sand and gravel fluctuates with activity in the construction industry, and is relatively low during the recession of the early 1980s. Demand is expected to increase by about one third by the year 2000. In the early 1980s the price of sand and gravel F.O.B. plant averaged about \$2.50 per ton but varied widely depending upon quality and to some extent upon location.

C. ENERGY RESOURCES

Uranium and Thorium Resources

1. Known Mineral Deposits

There are no known uranium or thorium deposits within the GRA or adjacent to it.

2. Known Prospects, Mineral Occurrences and Mineralized Areas

Radioactive occurrences are shown on the Uranium Land Classification and Mineral Occurrence Map, included at the back of the report.

There are no known uranium or thorium occurrences within the GRA. There is one uranium occurrence near the southwest boundary of the GRA, the Secret Pass claim. Uranium bearing minerals occur in a pegmatite there, probably of Precambrian age (Luning and others, 1981). No other uranium occurrences are noted surrounding the GRA.

3. Mining Claims

There are no known uranium or thorium claims or leases within the WSAs or the GRA.

4. Mineral Deposit Types

Deposit types cannot be discussed for the GRA as there are no known uranium or thorium occurrences within the GRA and only one uranium occurrence in pegmatite near the southwest border of the GRA.

5. Mineral Economics

The GRA apparently has no economic value for uranium or

 

thorium as there are no known radioactive mineral occurrences within the GRA.

Uranium in its enriched form is used primarily as fuel for nuclear reactors, with lesser amounts being used in the manufacture of atomic weapons and materials which are used for medical radiation treatments. Annual western world production of uranium concentrates totaled approximately 57,000 tons in 1981, and the United States was responsible for about 30 percent of this total, making the United States the largest single producer of uranium (American Bureau of Metal Statistics Inc., 1982). The United States ranks second behind Australia in uranium resources based on a production cost of \$25/pound or less. United States uranium demand is growing at a much slower rate than was forecast in the late 1970s, because the number of new reactors scheduled for construction has declined sharply since the accident at the Three Mile Island Nuclear Plant in March, 1979. current and future supplies were seen to exceed future demand by a significant margin and spot prices of uranium fell from \$40/pound to \$25/pound from January, 1980 to January, 1981 (Mining Journal, July 24, 1981). At present the outlook for the United States uranium industry is bleak. Low prices and overproduction in the industry have resulted in the closures of numerous uranium mines and mills and reduced production at properties which have remained in operation. The price of uranium at the end of 1982 was \$19.75/pound of concentrate.

Thorium is used in the manufacture of incandescent gas mantles, welding rods, refractories, as fuel for nuclear power reactors and as an alloying agent. The principal source of thorium is monazite which is recovered as a byproduct of titanium, zirconium and rare earth recovery from beach sands. Although monazite is produced from Florida beach sands, thorium products are not produced from monazite in the United States. Consequently, thorium products used in the United States come from imports, primarily from France and Canada, and industry and government stocks. Estimated United States consumption of thorium in 1980 was 33 tons, most of which was used in incandescent lamp mantles and refractories (Kirk, 1980b). Use of thorium as nuclear fuel is relatively small at present, because only two commercial thorium-fueled reactors are in operation. Annual United States demand for thorium is projected at 155 tons by 2000 (Kirk, 1980a). Most of this growth is forecast to occur in nuclear power reactor usage, assuming that six to ten thorium-fueled reactors are on line by that time. The United States and the rest of the world are in a favorable position with regard to adequacy of thorium reserves. The United States has reserves estimated at 218,000 tons of ThO_2 in stream and beach placers, veins and carbonatite deposits (Kirk, 1982); and probable cumulative demand in

the United States as of 2000 is estimated at only 1800 tons (Kirk, 1980b). The price of thorium oxide at the end of 1981 was \$16.45 per pound.

Oil & Gas Resources

There are no known oil or gas deposits, hydrocarbon shows in wells or as surface seeps in the region. There are numerous Federal oil and gas leases of record throughout the area, including within the two WSAs (see Oil and Gas Lease Map). There is no oil and gas occurrence and land classification map for this report.

Geothermal Resources

There are no known geothermal deposits, prospects, or occurrences within the two WSAs in the GRA. Fully 10 miles to the southeast (see Geothermal Occurrence and Land Classification Map) are two wells of unknown depth in Sacramento Valley which have surface discharge temperatures of 36° and 37°C. There are no Federal geothermal leases in the region, and no geothermal lease map is included with this report.

Geothermal resources are utilized in the form of hot water or steam normally captured by means of drilling wells to a depth of a few feet to over 10,000 feet in depth. The fluid temperature, sustained flow rate and water chemistry characteristics of a geothermal reservoir determine the depth to which it will be economically feasible to drill and develop each site.

Higher temperature resources (above 350°F) are currently being used to generate electrical power in Utah and California, and in a number of foreign countries. As fuel costs rise and technology improves, the lower temperature limit for power will decrease appreciably -- especially for remote sites.

All thermal waters can be beneficially used in some way, including fish farming (68°F), warm water for year around mining in cold climates (86°F), residential space heating (122°F), greenhouses by space heating (176°F), drying of vegetables (212°F), extraction of salts by evaporation and crystallization (266°F), and drying of diatomaceous earth (338°F).

Unlike most mineral commodities remoteness of resource location is not a drawback. Domestic and commercial use of natural thermal springs and shallow wells in the Basin and Range province is a historical fact for over 100 years.

Development and maintenance of a resource for beneficial use

may mean no dollars or hundreds of millions of dollars, depending on the resource characteristics, the end use and the intensity or level of use.

D. OTHER GEOLOGICAL RESOURCES

There are no other known geological resources in this GRA.

E. STRATEGIC AND CRITICAL MINERALS AND METALS

A list of strategic and critical minerals and metals provided by the BLM was used as a guideline for the discussion of strategic and critical materials in this report.

The Stockpile Report to the Congress, October 1981-March 1982, states that the term "strategic and critical materials" refers to materials that would be needed to supply the industrial, military and essential civilian needs of the United States during a national emergency and are not found or produced in the United States in sufficient quantities to meet such need. The report does not define a distinction between strategic and critical minerals.

The only strategic and critical mineral historically produced in the Black Mountain North GRA is silver. Silver worth \$100,000 has been produced as a secondary commodity from gold mines within the Katherine district. Because highgrade silver values contained within the narrow veins are spotty, silver production would be feasible only as a by-product of gold production.

IV. LAND CLASSIFICATION FOR GEM RESOURCES POTENTIAL

Land classification areas are numbered starting with the number 1 in each category of resources. Metallic mineral land classification areas have the prefix M, e.g. M1-4D. Uranium and thorium areas have the prefix U. Nonmetallic mineral areas have the prefix N. Oil and gas areas have the prefix OG. Geothermal areas have the prefix G. Sodium and potassium areas have the prefix S. The saleable resources are classified under the nonmetallic mineral resource section. Both the Classification Scheme, numbers 1 through 4, and the Level of Confidence Scheme, letters A, B, C, and D, as supplied by the BLM are included as attachments to this report. These schemes were used as strict guidelines in developing the mineral classification areas used in this report.

Land classifications have been made here only for the areas that encompass segments of the WSA. Where data outside a WSA has been used in establishing a classification area within a WSA, then at least a part of the surrounding area may also be included for clarification. The classified areas are shown on the 1:250,000 mylars or the prints of those that accompany each copy of this report.

In connection with nonmetallic mineral classification, it should be noted that in all instances areas mapped as alluvium are classified as having moderate favorability for sand and gravel, with moderate confidence, since alluvium is by definition sand and gravel. All areas mapped as principally limestone or dolomite have a similar classification since these rocks are usable for cement or lime production. All areas mapped as other rock, if they do not have specific reason for a different classification, are classified as having low favorability, with low confidence, for nonmetallic mineral potential, since any mineral material can at least be used in construction applications.

Geologic mapping of the WSAs consists of Wilson and Moore's (1959) Mohave County map at a scale of 1:375,000 and Longwell's (1963) reconnaissance geologic map. Neither of these maps are detailed in geology or structure and neither address mineralization. These maps are not sufficiently detailed for the purpose of assessing mineral potential. Other available information describing the adjacent mining districts is adequate but geologic detail within the WSAs is inadequate. Overall our confidence level in the available information is moderate to high.

1. LOCATABLE RESOURCES

a. Metallic Minerals

WSA AZ 020-009

M1-4D. This is a high favorability with a high confidence level. This classification area includes the mines and prospects of the Virginia district which has past gold production. The classification borders the very northern part of the WSA. The boundary of this area is approximate and could be further delineated with detailed geologic mapping and sampling.

M2-4D. This is a high favorability with a high confidence level. This classification area includes the Portland mine area. The Portland mine was a gold producer along a shallow fault plane in andesite. The boundary of this area is approximate and could be further delineated with detailed geologic mapping and sampling.

M3-2B. This classification area includes the remaining outcrop area within the WSA. There are no reported mineral occurrences but this area is identified as having a low favorability with a low confidence level for the following reasons:

1. This classification area is along strike from the mining districts and in a broad sense is in the same structural regime as the mining districts.
2. The host geology is similar to that found in the adjacent mining districts where mineralization is found in Tertiary units or along the Tertiary-Precambrian contacts.
3. There are some unpatented claims along the northern boundary of the WSA, adjacent to the Virginia district.
4. There are intrusives in the WSA which could be hosts to mineralization not exposed at the surface.
5. The nature of the underlying Pre Tertiary rocks is unknown, and additional mineralization could be found at the volcanic-Precambrian contacts at depth.

The B confidence level is because all the data is indirect evidence.

M4-2A. This classification area is for low favorability with a very low confidence level and includes the alluvium within the WSA both on the east and west flanks of the

The first part of the chapter discusses the basic concepts of the theory of functions. It begins with a definition of a function and then discusses the properties of functions. The second part of the chapter discusses the properties of the real numbers. It begins with a definition of the real numbers and then discusses the properties of the real numbers.

The third part of the chapter discusses the properties of the complex numbers. It begins with a definition of the complex numbers and then discusses the properties of the complex numbers. The fourth part of the chapter discusses the properties of the vector spaces. It begins with a definition of the vector spaces and then discusses the properties of the vector spaces.

The fifth part of the chapter discusses the properties of the linear transformations. It begins with a definition of the linear transformations and then discusses the properties of the linear transformations. The sixth part of the chapter discusses the properties of the matrices. It begins with a definition of the matrices and then discusses the properties of the matrices.

The seventh part of the chapter discusses the properties of the determinants. It begins with a definition of the determinants and then discusses the properties of the determinants. The eighth part of the chapter discusses the properties of the eigenvalues and eigenvectors. It begins with a definition of the eigenvalues and eigenvectors and then discusses the properties of the eigenvalues and eigenvectors.

The ninth part of the chapter discusses the properties of the orthogonal matrices. It begins with a definition of the orthogonal matrices and then discusses the properties of the orthogonal matrices. The tenth part of the chapter discusses the properties of the symmetric matrices. It begins with a definition of the symmetric matrices and then discusses the properties of the symmetric matrices.

The eleventh part of the chapter discusses the properties of the Hermitian matrices. It begins with a definition of the Hermitian matrices and then discusses the properties of the Hermitian matrices. The twelfth part of the chapter discusses the properties of the normal matrices. It begins with a definition of the normal matrices and then discusses the properties of the normal matrices.

range. The nature of the bedrock beneath the alluvium is unknown, but since the exposed bedrock nearly is classified 2B, there is reason to believe the same exists beneath the alluvium.

WSA AZ 020-010

M5-4D. This classification area of high favorability with a high confidence level includes the mines and prospects of the Union Pass district which was a past gold producer along northwest- to east-west-trending veins. The classification area includes the southernmost portion of the WSA which includes the Precambrian outcrops, past prospecting activity and unpatented mining claims.

M2-4D. This classification area of high favorability with a high confidence level includes the Portland mine area as described above during the discussion of the previous WSA.

M3-2B. This low favorability classification area with very low confidence level includes some of the remaining volcanic rocks within the WSA and is described previously during the discussion of the prior WSA.

M6-2A. This low favorability classification area with very low confidence level includes the outcrop area of the Quaternary basalt. There is not believed to be any mineralization or even possibility of mineralization within the basalt. However, the nature of the underlying older volcanic rocks is unknown and they could be mineralized but there is no visible evidence.

M7-2B. This low favorability classification area with low confidence includes approximately three square miles in what is mapped as alluvium, but this area was found to include lode claims. The mining claims could indicate bedrock exposures which do not show on the map. This area should be field checked.

M4-2A. This classification area of low favorability with a very low confidence level includes the alluvial cover along much of the western portion of the WSA. The nature of the bedrock beneath the alluvium is unknown, but since the adjacent bedrock is classified 2B, there is reason to believe the same exists beneath the alluvium.

M8-2B. This classification area consists of the southernmost portion of the alluvial cover. The classification is for low favorability with a low confidence level. The nature of the bedrock beneath the alluvium is unknown. The reason for its classification as 2B is that there are mining claims in this area and the trend of the mineralized structures from the Union Pass district extends into this area, as some of the mineralization at

Union Pass is along northwest trending veins.

b. Uranium and Thorium

WSAs AZ 020-009 and AZ 020-010

U1-2B. This land classification area covers most of the WSAs indicating low favorability for uranium and thorium concentration at a low confidence level. The area consists of Precambrian gneiss and schist and Miocene granitic and volcanic rocks. Uranium has some potential for concentration in vein type and contact metamorphic deposits in these rocks with the source of the uranium being the Miocene granitic and acidic volcanic rocks. Uranium and thorium could possibly occur as primary mineral concentrations in pegmatites, though there is not much evidence of pegmatites occurring within the WSAs. Uranium mineralization does occur in pegmatite near the southwest border of the GRA at the Secret Pass claim, Sec. 5(?), T 21 N, R 21 W. However, this pegmatite is associated with a Precambrian granite which barely outcrops at the southwestern tip of WSA AZ 020-010.

U2-2B. This land classification covers the western boundaries and parts of the eastern boundaries of the WSAs. Uranium and thorium have low favorability at a low confidence level for concentration in the Quaternary and Tertiary sediments covering this area. Uranium could occur as epigenetic sandstone type uranium deposits in permeable sands, especially where there is abundant organic material to cause reduction and precipitation of the uranium from ground water. The source of the uranium would be the Miocene granitic and rhyolitic rocks of the range. Thorium minerals weathered from pegmatites may occur as resistate mineral concentrations in alluvial materials adjacent to granitic outcrops.

c. Nonmetallic Minerals

WSA AZ 020-009

N1-2B. This classification area covers all the silicic volcanic rocks within the WSA. The classification is low favorability with a low confidence level. The units are undivided and consist of anything from flows to breccias to tuffs. There are known perlite occurrences in these geologic units and just outside the southern border of the GRA and in the northern portion of the GRA there are zeolite occurrences in these same units. The classification of 2B is for the potential for perlite and zeolite.

N2-3C. This moderate favorability classification area with a moderate favorability classification covers an area in the vicinity of the known perlite occurrences. Nothing additional is known, however, about the quality or the size of these occurrences.

N3-2B. This classification area is one of low favorability and low confidence level and covers the Precambrian bedrock in the northeast portion of the WSA. No nonmetallic mineral deposits are known within the unit but the material could possibly be used for at least some construction applications.

N4-2B. This is the andesite outcrop and the same rationale as N3-2B can be applied for this classification.

N5-3C. This classification area is one of moderate favorability and moderate confidence level and includes the alluvium on both sides of the WSA. The material could be used for sand and gravel or other nearby construction applications.

WSA AZ 020-010

N2-3C. These are areas of known perlite occurrences in the northern part of the WSA and just outside the east border. The rationale for the classification has been previously discussed under the previous WSA.

N1-2B. This is the same as discussed under the previous WSA.

N6-2B. This classification area of low favorability with a low confidence level covers the Tertiary basalt and Precambrian rock in the southern WSA. No nonmetallic resources are known in this classification area but they could at least be used for nearby construction purposes.

N5-3C. This area includes the alluvium on the west side of the WSA. The discussion is the same as that mentioned under the previous WSA.

2. LEASABLE RESOURCES

a. Oil and Gas

WSAs AZ 020-009 and AZ 020-010

OG1-2A and OG2-2A. There has been little or no serious oil and gas exploration within the region, and no indications of oil or gas occurrences in Mohave County. The GRA is within the Overthrust Belt which has prolific production in Wyoming/Utah, Mexico and Canada. The

Federal leases are for rank wildcat acreage, and surficial stratigraphic units do not necessarily have a bearing on possible drilling objectives at depth, considering overthrust structural implications.

b. Geothermal

WSA AZ-020-009

G1-2B. This area is within the structural belt of Quaternary basalts and basin and range deep-seated faulting, though there are no young basalts within the WSA.

G2-3B. This classification incorporates volcanics of Cretaceous and Tertiary ages which have been host to widespread Quaternary volcanic activity in the form of basalts. The presence of these young flows suggests the presence of a heat source at depth. Multiple fissure vents are indicated.

G3-2B. This area is within the structural belt of Quaternary basalts and basin and range deep-seated faulting, though there are no young basalts within the WSA.

c. Sodium and Potassium

S1-1A. There are no known potassium or sodium resources within the GRA.

d. Other

There are no other leasable mineral resources known within the GRA.

3. SALEABLE RESOURCES

The saleable resources (sand and gravel) have been described above under nonmetallics and includes the classification area M4-2A.

V. RECOMMENDATIONS FOR ADDITIONAL WORK

The geology used in the classification of this GRA was the Mohave County Geologic Map (1959) which is very generalized. More detailed mapping of geology and structures of the area would greatly help in further delineating the classification areas.

Further contacting persons or mining companies who have worked in the area may lead to acquiring additional information which may also be of help.

Detailed geochemical sampling may identify potential mineralized areas. Geologic mapping and sampling would identify areas of perlite and zeolite potential.

This GRA was not field checked and at least one area should be, that in Secs. 1 through 3 of T 22 N, R 21 W, where claims cover a large area of alluvium.

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*X denotes one or more claims per section

Black Mountain North GRA AZ-05

Black Mountain North GRA AZ-05

EXPLANATION

- Uranium Occurrence
- ~ Land Classification Boundary
- WSA Boundary

THE
END

EXPLANATION

- Occurrence, commodity
- Land Classification Boundary
- WSA Boundary

EXPLANATION

- Thermal well
- Region of high chemical geothermometry
- Land Classification Boundary
- WSA Boundary

LEVEL OF CONFIDENCE SCHEME

- A. THE AVAILABLE DATA ARE EITHER INSUFFICIENT AND/OR CANNOT BE CONSIDERED AS DIRECT EVIDENCE TO SUPPORT OR REFUTE THE POSSIBLE EXISTENCE OF MINERAL RESOURCES WITHIN THE RESPECTIVE AREA.
- B. THE AVAILABLE DATA PROVIDE INDIRECT EVIDENCE TO SUPPORT OR REFUTE THE POSSIBLE EXISTENCE OF MINERAL RESOURCES.
- C. THE AVAILABLE DATA PROVIDE DIRECT EVIDENCE, BUT ARE QUANTITATIVELY MINIMAL TO SUPPORT TO REFUTE THE POSSIBLE EXISTENCE OF MINERAL RESOURCES.
- D. THE AVAILABLE DATA PROVIDE ABUNDANT DIRECT AND INDIRECT EVIDENCE TO SUPPORT OR REFUTE THE POSSIBLE EXISTENCE OF MINERAL RESOURCES.

CLASSIFICATION SCHEME

1. THE GEOLOGIC ENVIRONMENT AND THE INFERRED GEOLOGIC PROCESSES DO NOT INDICATE FAVORABILITY FOR ACCUMULATION OF MINERAL RESOURCES.
2. THE GEOLOGIC ENVIRONMENT AND THE INFERRED GEOLOGIC PROCESSES INDICATE LOW FAVORABILITY FOR ACCUMULATION OF MINERAL RESOURCES.
3. THE GEOLOGIC ENVIRONMENT, THE INFERRED GEOLOGIC PROCESSES, AND THE REPORTED MINERAL OCCURRENCES INDICATE MODERATE FAVORABILITY FOR ACCUMULATION OF MINERAL RESOURCES.
4. THE GEOLOGIC ENVIRONMENT, THE INFERRED GEOLOGIC PROCESSES, THE REPORTED MINERAL OCCURRENCES, AND THE KNOWN MINES OR DEPOSITS INDICATE HIGH FAVORABILITY FOR ACCUMULATION OF MINERAL RESOURCES.

MAJOR STRATIGRAPHIC AND TIME DIVISIONS IN USE BY THE
U.S. GEOLOGICAL SURVEY

Erathem or Era	System or Period		Series or Epoch	Estimated ages of time boundaries in millions of years
Cenozoic	Quaternary		Holocene	
			Pleistocene	2-3 ¹
	Tertiary	Pliocene	12 ¹	
		Miocene	26 ²	
		Oligocene	37-38	
		Eocene	53-54	
		Paleocene	65	
Mesozoic	Cretaceous [*]		Upper (Late) Lower (Early)	136
	Jurassic	Upper (Late) Middle (Middle) Lower (Early)	190-195	
		Triassic	Upper (Late) Middle (Middle) Lower (Early)	225
	Permian [*]		Upper (Late) Lower (Early)	280
	Paleozoic	Carboniferous Systems	Pennsylvanian [*]	Upper (Late) Middle (Middle) Lower (Early)
Mississippian [*]			Upper (Late) Lower (Early)	345
Devonian			Upper (Late) Middle (Middle) Lower (Early)	395
Silurian [*]		Upper (Late) Middle (Middle) Lower (Early)	430-440	
Ordovician [*]		Upper (Late) Middle (Middle) Lower (Early)	500	
Cambrian [*]		Upper (Late) Middle (Middle) Lower (Early)	570	
Precambrian [*]			Informal subdivisions such as upper, middle, and lower, or upper and lower, or younger and older may be used locally.	3,600 + [*]

¹ Holm, Arthur, 1965, Principles of physical geology, 2d ed., New York, Ronald Press, p. 360-361, for the Pleistocene and Pliocene, and Obradovich, J. D., 1965, Age of marine Pleistocene of California: Am. Assoc. Petroleum Geologists, v. 49, no. 7, p. 1987, for the Pleistocene of southern California.

² Geological Society of London, 1964, The Phanerozoic time-scale; a symposium: Geol. Soc. London, Quart. Jour., v. 120, suppl., p. 260-262, for the Miocene through the Cambrian.

³ Stern, T. W., written commun., 1968, for the Precambrian.

⁴ Includes provincial series accepted for use in U.S. Geological Survey reports.

Terms designating time are in parentheses. Informal time terms early, middle, and late may be used for the eras, and for periods where there is no formal subdivision into Early, Middle, and Late, and for epochs. Informal rock terms lower, middle, and upper may be used where there is no formal subdivision of a system or of a series.