CONTACT INFORMATION
Mining Records Curator
Arizona Geological Survey
416 W. Congress St., Suite 100
Tucson, Arizona 85701
520-770-3500
http://www.azgs.az.gov
inquiries@azgs.az.gov

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James Doyle Sell Mining Collection

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→ JD Sell

~~Z to F.T.G.~~

F.T.G.

~~Blue River (mid Tert) AMAX~~ OK

X ~~Bighorn Mtn (Cloud King)~~ OK

X Whetstone Mtn South – I've never been there. MS thesis by Vern DeRuyter in U. of Ariz library would give all necessary poop.

Articles Blue & please

?

Thanks JDS

Form Revised 3/8/75 by J.H.C

ASARCO EXPLORATION RECORD

☐ FIELD EXAMINATION ☐ LITERATURE SEARCH ☐ ASARCO FILE ☐ _____

PCD#

Section I General Indexing

① Name(s) of Property or Area Owner					② Country	③ State or Province	
					④ Co. or Map Sheet	⑤ File or Gore No.	
⑥ Latitude	⑦ Longitude	⑧ Mer.	Tws.	Rng.	Sec.	⑨ Examined by	⑩ Date
						⑪ Office	⑫ Field Days

Section II Sources of Information

⑬ References Author	Date	Title	Publications	Vol. No.

Section III Appraisal

⑭ Recommendations
- ☐ Action Now
- ☐ Too Low Grade
- ☐ Too Small
- ☐ Ownership Problem
- ☐ Access Problem
- ☐

⑮
- ☐ Past Producer
- ☐ Producer
- ☐ Mineral Deposit
- ☐ Prospect
- ☐
- ☐
- ☐ Geologic Concept
- ☐ Geochem Anomaly
- ☐ Geophy. Anomaly
- ☐

⑯ Production

Commodity	Tons	Grade

⑰ Reserves ☐ Measured ☐ Estimated

Commodity	Tons	Grade

⑱ Num. Drill Holes _____
Approx. Total Footage _____

⑲ Excavations

⑳ Spectro. Analysis Attached

㉑ Assays Attached

㉒ Geochem Results Attached

Section IV Geologic Data

㉓ Commodity or Contained Metals

㉔ Ore Minerals - Major _____ _____ _____ Minor _____ _____

㉕ Host Rocks - Major _____ _____ _____ Minor _____ _____

㉖ Age of Host Rocks _____ _____ _____ _____ _____

㉗ Nature of Exposures

㉘ Alteration

㉙ Total Extent

㉚ Structure

㉛ Ore Occurrence (Size)

㉜ Age of Mineralization

㉝ Conclusions and Recommendations Depth to Mineralization

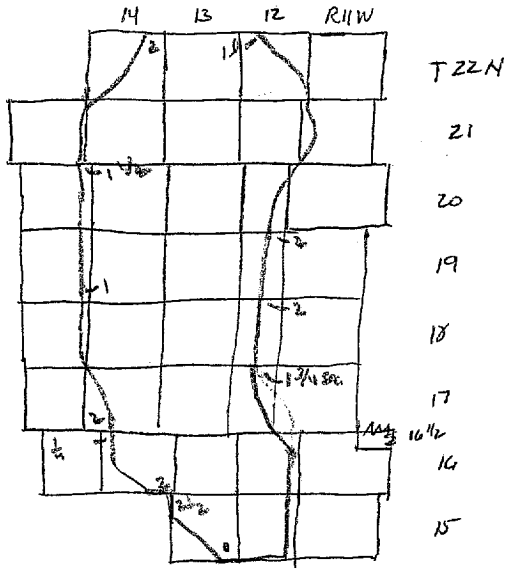
(For additional space use extra sheets)

See Cogan Butte Files for
Production Records. Ac-16A. 2.3

See Kings Red Hills report (Summary)
April 2, 74
for add'l info — map # 25-99a

Water-Resources Appraisal of the Big Sandy Area, Mohave County, Arizona, by C.S. Davidson, 1973. Arizona Water Commission Bulletin 6. (WRR series). Water Resources Report.

Plate 1.



Nos. = sections

1" = 2 miles

5280
12
10560
5280
1: 63360

USGS open file

Geol & gp ~~ewest~~ of an Apollo 9 photo around near Point of Pens, Ariz.
19 p. 8 pl 4 table

U of A open file

~~H Drewes, 1972, Prel. geol map of Happy Valley Quad, Ariz. 1:48,000 9 p. 1 sheet.~~

~~U of A open file.~~

Larry Barrett

Igneous Intrusions and Associated Mineralization in the Saddle Mtn Mining District, Pinal County, Arizona.

MS Thesis Univ of Utah SLC

HA-215 Otto Moorbrunner (1972) Analysis of the G-Weights by Electrical-Analog Model, Aora Valley. (1:125,000).
32° – 32° 45' & 111° – 111° 30'

OF- ~~Preliminary Geologic map of the Happy Valley quad. by Harold Graves (1972). Open-File Report.~~

OF- a) Fig 1 Reem Geol Map, Point of Pines Region (1972) 1:62,500.
Open-File Report CS Bromfield, GP Eaton, WL Peterson & JC Rotta
Geological & Geophysical investigation of an aeromag Photo Anomaly near Point of Pines, Ariz. USGS Open File Report.

b) Fig 2 West quad 1:24,000

c) Fig 3 East quad 1:24,000

~~Ch WSP 1897-H (G. Clemons & Bentley)~~

~~ASU Thesis (Master's Sci 1972) The Geology of the Volcanic Sequence in the Horseshoe Dam Area, Ariz. CSP. GB Malone.~~

Tap Plom. Cgl

Tam Mt Davis Aggl.

Tag

Tab

younger metamorphism

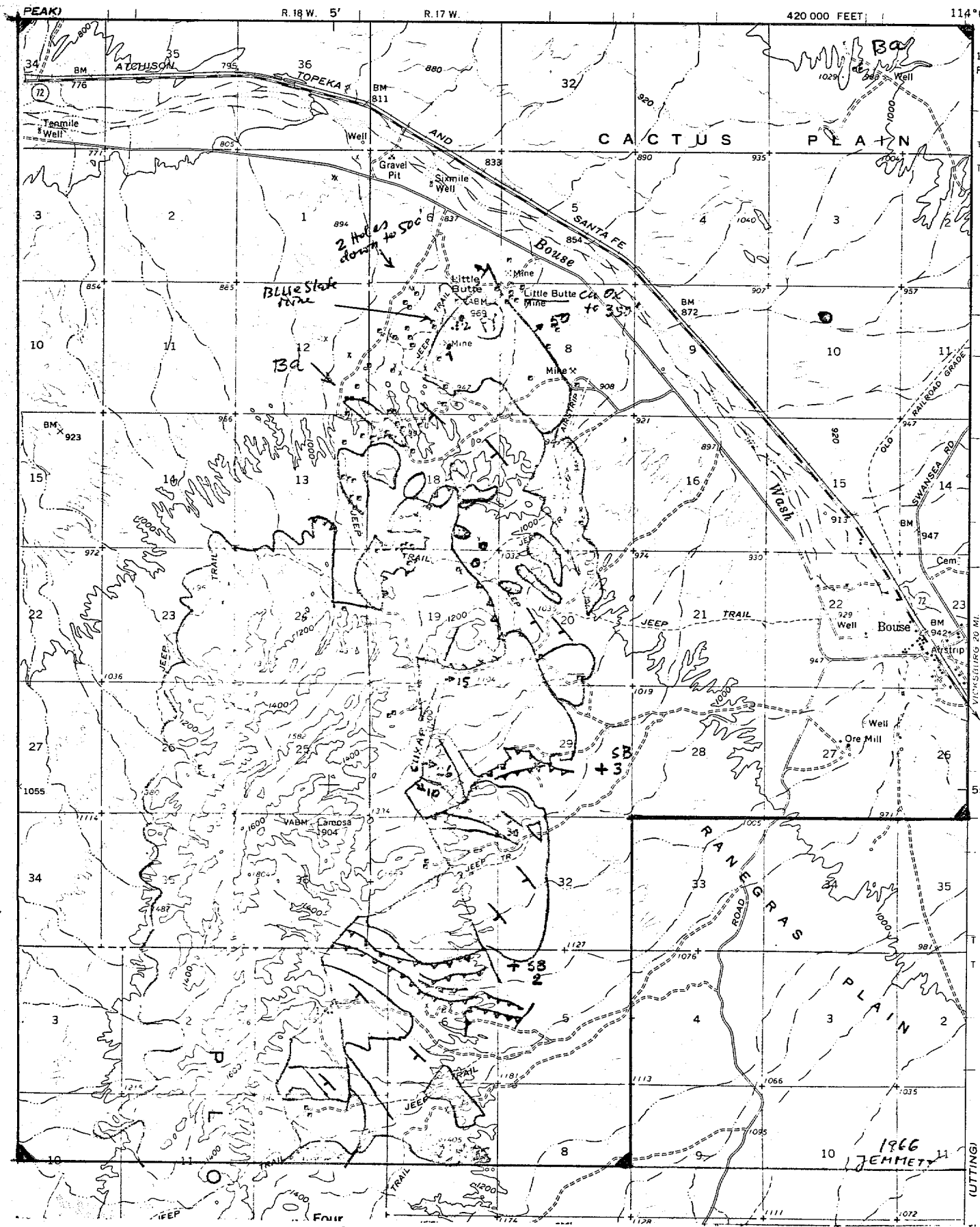
older "

To = Jim

From = Al

March 15, 73

BOUSE QUADRANGLE
ARIZONA–YUMA CO.
15 MINUTE SERIES (TOPOGRAPHIC)



"Geology of the northern PLOMOSA MT. Range" Ph.D. Thesis 1966

T-191

OUTLINE OF GEOL. MAP BY JEMMETT 1966.

~~II~~

Check the following theses

-85	✓ Chaffee, Maurice A, MS 1964	Cerro Colorado	(around Silver Hill - Many ⊕ mica)
-112	✓ Conrad, Robert D, MS 1964	Pre-Dev. uncert.	Gila Co.
-26	✓ Durand, Harvey S. MS 1947	Solomon Lake,	Was "not flown" at base of ~~mt.~~ walled terr. die varied under coppe
1961-10	Holua, Gerald J; MS 1961	Bendt.	(1961-10)
1961-171	Hammer, W.F., MS 1961	Ck pages!	(154)
-106	Hoffman, Victor J. MS 1963	Harquahala Tortolita Mts.	
-8	✓ Kortelmon, Wayne E. PhD 1944	Harshaw Dist.	
-209	✓ Mackie, David G, PhD 1964	Explorations programs	(comprehensive)
-48	✓ Schmidt, Richard A MS 1947	Mineral Mtn	
1961-199	Shute, Adrian F PhD 1961	Yuma Proj.	
-326	Tekmayian, Garabed A, MS 1964	Troy-Mesa & Roosevelt	X4
-19	Wilson, Elmer D, MS 1922	Morenci Dist.	

For Regional Project 2001 log see Shutt, E.A. thesis

Little DE

JDS

AGS Members and Friends:

Revision File
Arizona Highway Geologic Map

The map committee wishes to announce to all members and interested persons that P. O. Box 5795 is open to receive all comments, additions, corrections, etc., regarding the recently published AGS Geologic Map.

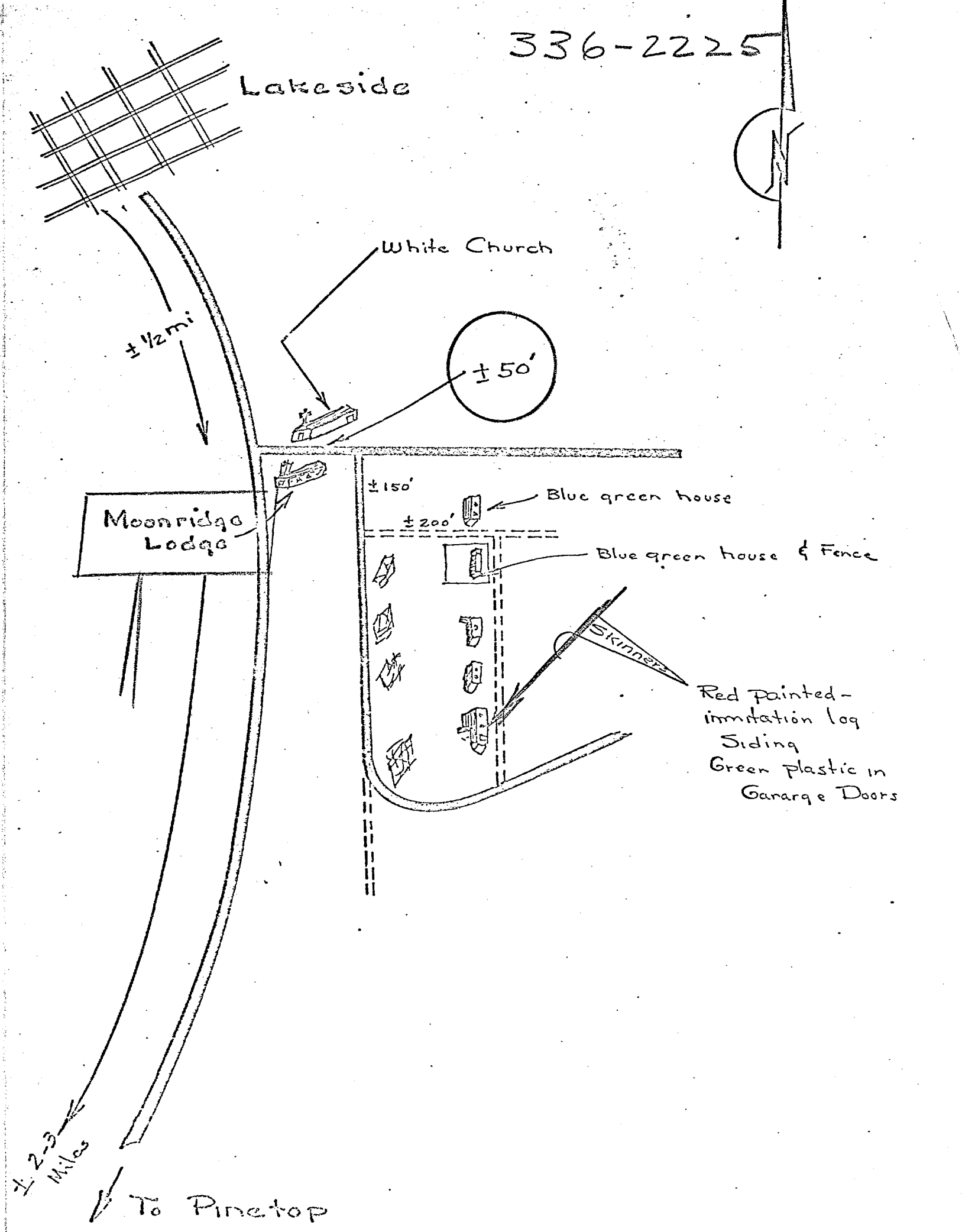
It is requested that the area concerned be specified with reference to the present map. Please verify by name, publication, etc., the source for the material listed. Using separate submittal papers for each area will facilitate handling and filing.

We also encourage notes from individuals and groups as to the availability of unreleased material which, at the time of the map revision, might be made available for incorporation into the revised edition.

Remit all correspondence for improving the map to:

Arizona Highway Geologic Map
Attention: Mr. James D. Sell
P. O. Box 5795
Tucson, Arizona 85703

336-2225


Lakeside
White Church
±½mi
±50'
±150'
±200'
Blue green house
Moonridge Lodge
Blue green house & Fence
Skinner
Red Painted - imitation log Siding
Green plastic in Garage Doors
±2-3 Miles
To Pinetop

is Formation. The original
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Paleozoic. There are, how-
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the deformed rocks in that
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Maria Mountains.

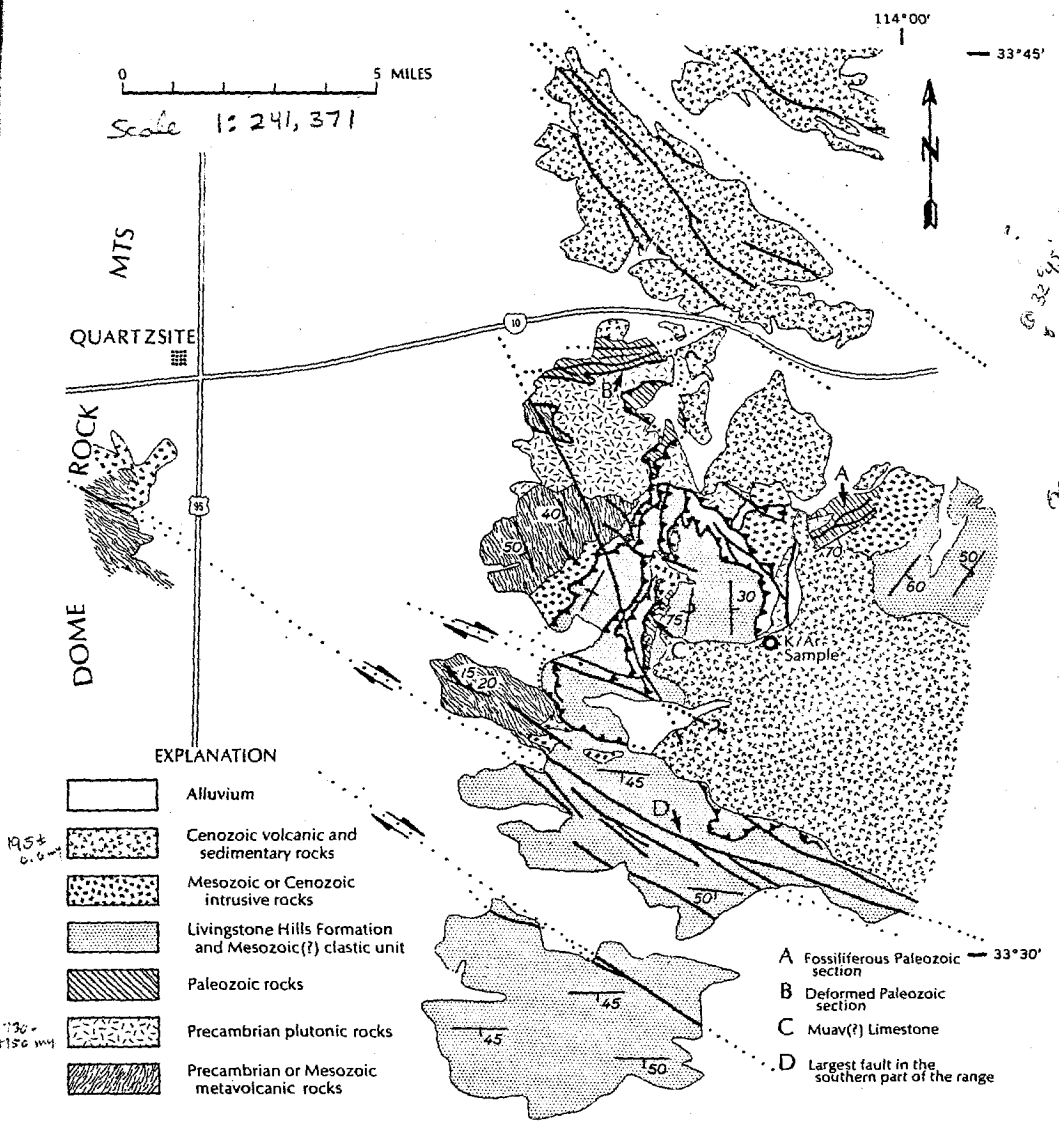

Figure 3. Generalized geologic map of the Plomosa Mountains.

The identical style and degree of deformation found 40 mi apart in both ranges indicates a widespread regional tectonic event. Furthermore, the fact that the upper plate rocks in the Plomosa Mountains are undeformed and have not been subjected to this regional event suggests that a large amount of telescoping has taken place between the thrust sheets. The fossiliferous and deformed sections in the Plomosa Mountains were once separated by a considerably greater distance than they are now. Because the thrust faults dip eastward under the fossiliferous Paleozoic section, the juxtaposition of the deformed and undeformed rocks must mean that the upper plate has moved westward relative to the lower plate.

In addition to difference in style of deformation between the Paleozoic sections of the upper and lower plates, an additional rock unit is found in the deformed section that is not present in the fossiliferous section (*see* Fig. 4). This too suggests that the two plates once were separated by a considerably greater

Hills Formation. The original
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west. Although these structures
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Maria Mountains.

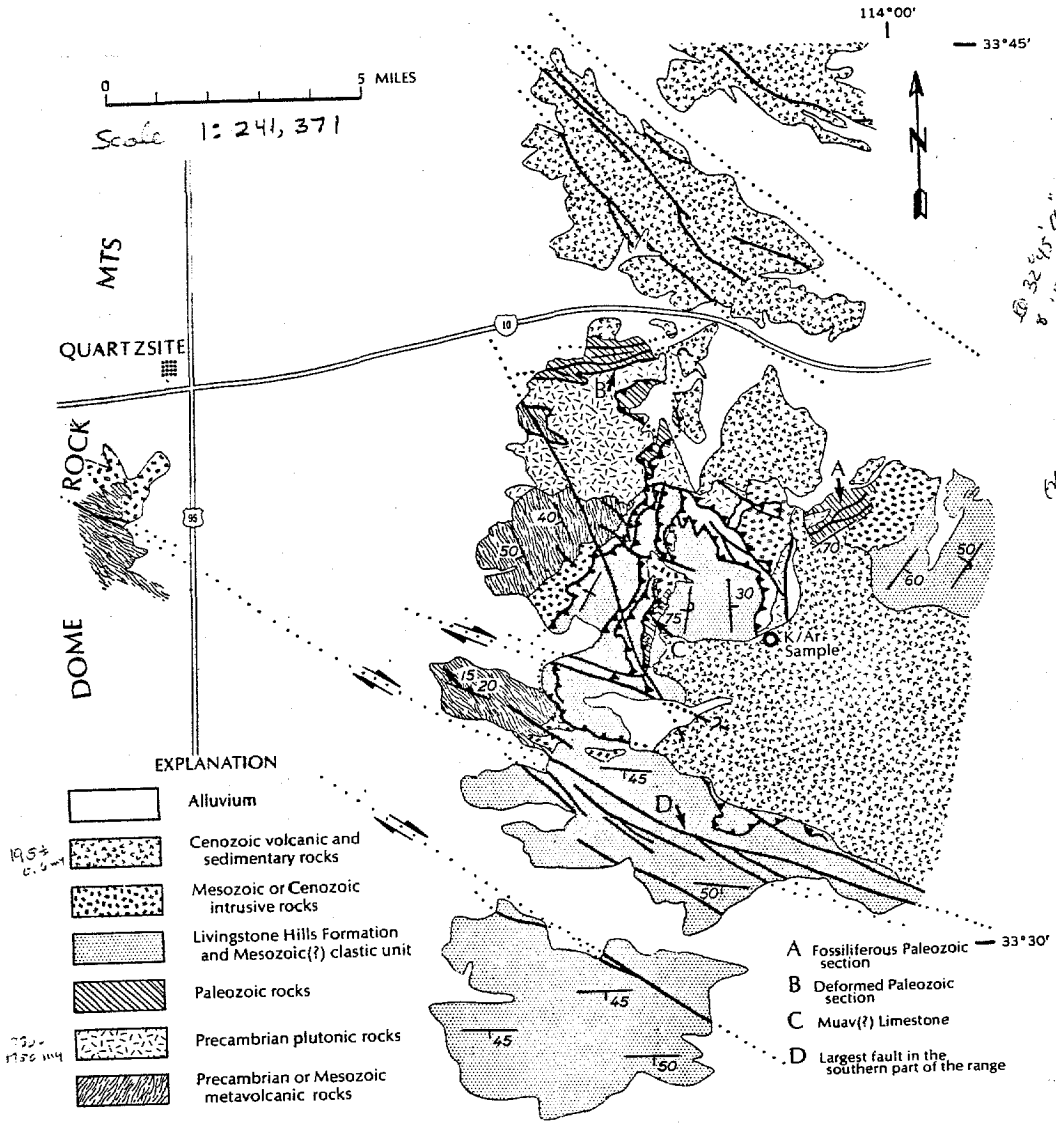

Figure 3. Generalized geologic map of the Plomosa Mountains.

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the SA Miller paper on S Palmer

the Laughton AIME Report

As of 11/8/71

SUPPLEMENT TO
BIBLIOGRAPHY OF GEOSCIENCES THESES AND DISSERTATIONS

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University of Arizona

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have have ? not

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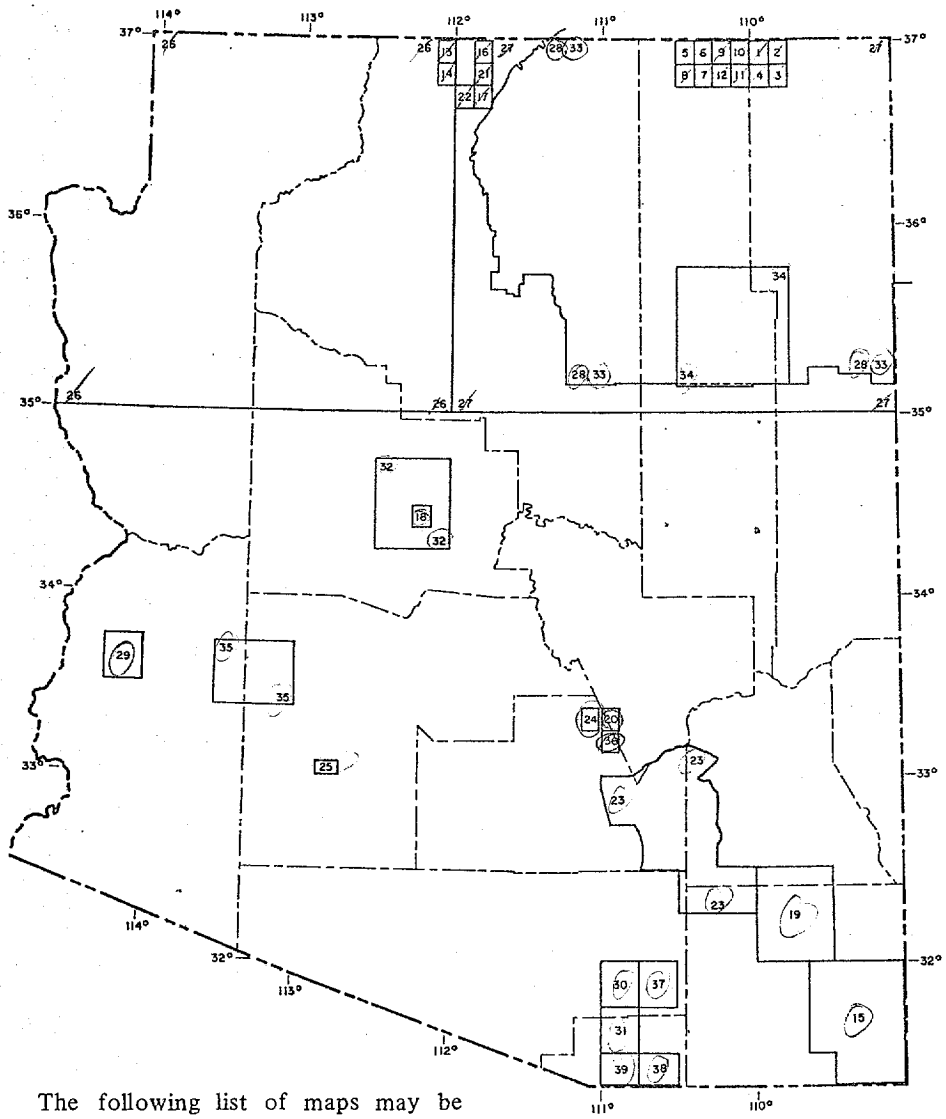
Field Notes Vol. 2 No. 1

3 items [illegible] inside

GEOLOGIC MAP INDEX OF ARIZONA



The following list of maps may be added to the geologic map index listed in Field Notes, Volume 1 No. 1, March, 1971. Back issues of Field Notes Nos. 1 and 2 may be acquired from the Arizona Bureau of Mines, University of Arizona, Tucson, Arizona 85721, to enable those who are interested to keep their map index up to date.

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35. 1971. Arizona State Land Department; Ground-Water Conditions in the Harquhala Plains, Maricopa and Yuma Counties, Arizona: Water Resources Report No. 45, maps plates 1 and 2.

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NOTE

Publications and maps issued by agencies other than the Arizona Bureau of Mines must be ordered directly from the issuing agency. Arizona Bureau of Mines publications and maps may be purchased at, or ordered from, the Arizona Bureau of Mines, University of Arizona, Tucson, Arizona 85721.

GAS STORAGE

The El Paso Natural Gas Company is considering a proposal to blast a huge cavity for storage of natural gas in a massive deep salt deposit beneath Red Lake, 20 miles northwest of Kingman. If five 200-kt detonations were employed at a depth of about 5600 feet underground, the cost could be about $20 million, versus $60 million for conventional surface storage. The blasts are not expected to cause unacceptable seismic damage to the few local water wells, nor will they disturb residences in Kingman.

Continued on page 8

19. 1962. Twenter, F.R., Geology and promising areas for ground-water development in the Hualapai Indian Reservation, Arizona: U.S. G.S. Water-Supply Paper 1576-A, p. 38, Plate 1, Geologic Map 1:125,000.

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22. 1964. Akers, J.P., Geology and ground-water in the central part of Apache County, Arizona: U.S.G.S. Water-Supply Paper 1771, p. 107, Plate 1, Geologic Map 1:125,000.

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26. 1962. Peterson, N.P., Geology and ore deposits of the Globe-Miami District, Arizona: U.S.G.S. Prof. Paper 342, p. 151, Plate 1, Geologic Map 1:24,000.

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29. 1964. Simons, F.S., Geology of the Klondyke Quadrangle, Graham and Pinal Counties, Arizona: U.S. G.S. Prof. Paper 461, p. 173, Plate 1, Geologic Map 1:62,500.

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Continued on page 8

MAP INDEX *(continued)*

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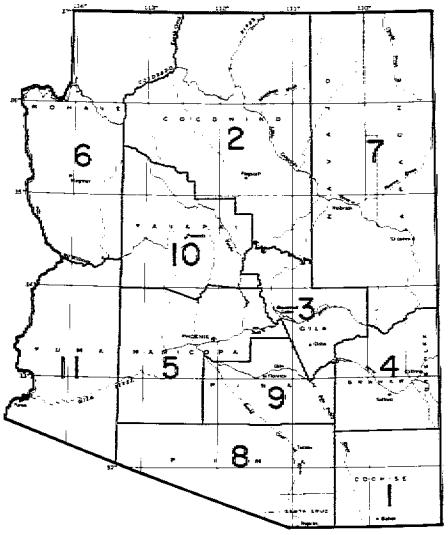
The Geologic Map of the State of Arizona is on a scale of 1:500,000 and is available (folded by mail) for $2.50 from the Arizona Bureau of Mines, University of Arizona, Tucson, Arizona and the United States Geological Survey, Denver Distribution Section, Denver Federal Center, Building 41, Denver, Colorado, 80225.

The Arizona Bureau of Mines County Geologic Map Series of Arizona on a scale of 1:375,000 is available for purchase from the Arizona Bureau of Mines, University of Arizona, Tucson, Arizona, 85721.

INDEX TO COUNTY GEOLOGIC MAPS OF ARIZONA



1. 1959. Cochise County.
2. 1960. Coconino County.
3. 1959. Gila County.
4. 1958. Graham-Greenlee Counties.
5. 1957. Maricopa County.
6. 1959. Mohave County.
7. 1960. Navajo-Apache Counties
8. 1960. Pima-Santa Cruz Counties.
9. 1959. Pinal County.
10. 1958. Yavapai County.
11. 1960. Yuma County.

PUBLICATIONS

This continuing section of the newsletter will list bibliographic material ranging from recent theses to popular paperback editions dealing with earth science. The inclusion of an item is a report of existence and not a recommendation of merit. Mrs. Jan Wilt, Assistant Geologist, is currently engaged in bibliographic compilation.

THESES

This listing of recent and imminent theses represents contributions from the geology-geosciences departments of the advanced degree granting institutions in Arizona for the year 1970-71, with the exception of Northern Arizona University. In the latter case because of the newness of the graduate program all completed theses are listed.

Arizona State University

BROWN, Ronald G. (1970-MS) Geochemical survey of the Oracle vicinity of Arizona: 50 p.

CLARY, Thomas A. (1970-MS) Geology of the Schultze Granite and related copper mineralization: 37 p.

McCURRY, Wilson G. (1971-MS) Mineralogy and paragenesis of the ores, Christmas Mine, Gila County, Arizona

MERRILL, Robert K. (1970-MS) The glacial geology of the Mount Baldy area, Apache County, Arizona: 118 p.

THROOP, Allen H. (1970-MS) The nature and origin of black chrysocolla at the Inspiration Mine, Arizona: 56 p.

Northern Arizona University

BENFER, J. Alan (1971-MS) The petrology of the eastern phase of the Toroweap Formation, Walnut Canyon, Coconino County, Arizona.

BILLINGSLEY, George H. (1970-MS) General geology of Tuckup Canyon, central Grand Canyon, Mohave County, Arizona

PETTENGILL, James G. (1970-MS) Structural analysis of Coconino Point, Coconino County, Arizona

SHOLTZ, Judith F. (1968-MS) Geology of the Woods Canyon drainage basin, Coconino County, Arizona

THOMPSON, John R. Jr. (1968-MS) Geology of Wet Beaver Creek Canyon, Yavapai County, Arizona.

University of Arizona

COLEMAN, Dennis D. (1970-MS) Investigation of a method for determining the rate of strontium diffusion in a potassium feldspar: 66 p.

KNIGHT, Louis H. Jr. (1970-PhD) Structure and mineralization of the Oro Blanco mining district, Santa Cruz County, Arizona: 172 p.

LAUGHON, Robert B. (1970-PhD) The crystal structure of a new hydrous calcium copper silicate mineral: 43 p.

LIVINGSTON, Donald E. (1970-PhD) Geochronology of Older Precambrian rocks in Gila County, Arizona: 224 p.

LODEWICK, Richard E. (1970-PhD) The petrology and stratigraphy of the Earp Formation, Pima and Cochise Counties, Arizona: 194 p.

MATIS, John P. (1970-MS) Hydrogeology of the Sells area, Papago Indian Reservation, Arizona: 59 p.

WEST, Robert E. (1970-MS) Analysis of gravity data from the Avra Valley area, Pima County, Arizona: 73 p.

ENVIRONMENTAL CORNER

Forrester heads up PD Environmental Division

Dr. James D. Forrester, former Dean of the College of Mines and Director of the Arizona Bureau of Mines, has become head of the Phelps Dodge Corporation's newly established Division of Environmental Engineering and Research. The division's main office is in Tucson in the Tucson Federal Savings Building.

Although the division is concerned with the total environment, one of its first projects will be intensified air quality monitoring programs and meteorological studies. Air sampling studies will be conducted in Phoenix and Tucson and the data collected will be made available to all interested agencies and individuals.

Atmospheric Analysis Laboratory

The Arizona Mining Association, composed of thirteen major mining companies, has granted the University of Arizona in excess of half a million dollars in support of an Atmospheric Analysis Laboratory. The initial project, to be supervised by the analytical division of the UA Chemistry Department, will last for three years. William J. Rundle, president of the Association, points out three basic questions: What is in the air? How did it get there? What are the processes now at work to cleanse the air? Answers to such questions have been hindered by the unavailability of precise techniques for both sampling and analysis. Also, little is known about the interaction of components of the atmosphere with sunlight and with each other.

Much research is needed if understanding is to be gained and this grant will make Arizona one of the first states to have a comprehensive air monitoring and analysis program.

Getting the Lead Out

Much has been said about getting the lead out of gasoline. The situation seems to be that lead needs to come out in order for new smog control devices on future cars to work effectively. In the meantime evidence suggests that burning low lead gas in conventional cars actually increases polluting emissions. This comes about because of compounds added in place of lead in order to maintain performance. According to Metals Week (Nov. 30, 1970) John L. Kimberley of the Lead Industries Association told the Arizona State Board of Health about the recent experiences of Tokyo, Japan involving the worst smog crisis in its history. It was attributed to reactive emissions that created a city-wide photo chemical smog when the spring rain clouds passed and let the sun hit the gaseous automobile emissions of nitrogen oxides and unburned hydrocarbons. This happened four weeks after low lead fuel went on sale which was a result of a government campaign for lead-free gasoline. According to Kimberley the government had been warned that if lead was removed petroleum companies would have to increase the level of hydrocarbons to produce normal performance.

Win or Lose

H. P. Doan, President of Dow Chemical Company, talking to a Manufacturing Chemists Association meeting in New York, made the following comments:

"I'm sure individual plants and even individual companies will be in trouble with tough environmental requirements placed on them, but shifts in demand, in values, in any number of ways, have always required major readjustments—and there has never been any guarantee that the race would be won by all. If we believe in competitive processes, we have to remember some people have to lose if others are going to win." He said he'd like to feel that industry is so committed to profits that it will see the profit opportunity in cleaning up the environment. Also, "the fact that we don't have all the technology needed simply means that there are new opportunities for invention. The profit-minded company will stop handwringing and start thinking."

Producers and Users are Polluters

In the preface to the Proceedings of the conference on "Mining and Ecology in the Arid Environment", W. C. Peters, Editor and Professor in the College of Mines, points out that the March 22 to 27, 1970 conference was unusual because it brought together (in a discussion sense) leaders in mining, ecology, and public administration. Dr. Peters says:

"Miners, having spearheaded the industrial revolution and having provided the raw materials for the nuclear age, will continue to be the providers. The providers as well as the users will be listed among the polluters. The users will not permit the miners to stop providing, but will certainly ask the miners to provide under conditions of the very least damage to the environment."

GEOTHERMAL ENERGY

A recent Department of the Interior news release entitled " 'Briefs' on Geothermal Energy from the U. S. Geological Survey" includes the following generalizations:

"The earth is a tremendous reservoir of heat, and its surface displays "hot spots" that generally occur near areas of "recent" volcanic activity. In the western United States, particularly along the Pacific Coast, widespread and intense volcanic activity has occurred during the past 10 million years; thus, the western States hold promise for geothermal power development. Over 5 percent of the world's resources of geothermal energy are in the United States, most of it stored in rocks in the upper 6 miles of the crust.

and . . .

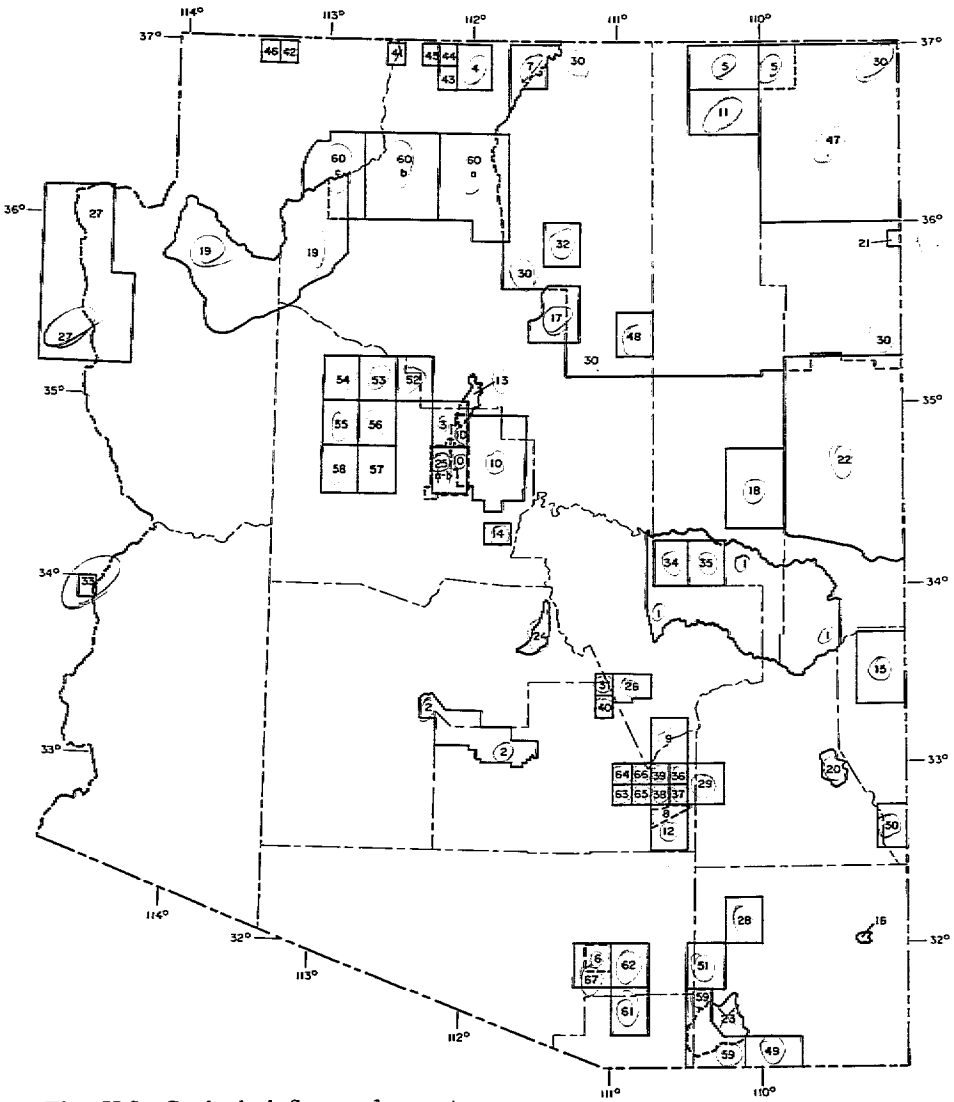
"Locating a promising geothermal system is often a difficult problem. A system is apparent only when it is defective—when it is "leaking" hot water or steam to the surface. These areas of hot springs and geysers are currently being explored, but experts have said that the state of our knowledge regarding geothermal resources is comparable to that regarding petroleum resources at the turn of the century. Current exploration, based on modern geologic, geochemical and geophysical methods, is likely to discover new fields. The recent discovery of a new field at Monte Amiata, Italy—where there were only meager surface manifestations of geothermal energy—was based on the use of such methods."

Some of the known Arizona "hot spots" are listed by L. B. Haigler of the U. S. Geological Survey in Arizona Bureau of Mines Bulletin No. 180, "Mineral and Water Resources of Arizona". The hottest surface water issues from Gillard Hot Springs, in Greenlee County, at a temperature of about 180 degrees F. Nine other springs are listed that have temperatures of about 100 degrees F. In addition, six wells are shown to have water temperatures above 100 degrees F, the hottest being 161 degrees in a Pinal County well.

The volcanic history of Arizona is complex because there have been many separate igneous episodes spread unequally through the State. The most recent, the eruption of Sunset Crater near Flagstaff, is believed to have occurred in 1064 A.D., less than one thousand years ago.

Although steam is not known to be reaching the surface anywhere in Arizona, a careful check of water temperatures in all types of wells should be encouraged. Only in this way will it be possible to learn the areas of abnormally high thermal gradients.

GEOLOGIC MAP INDEX OF ARIZONA



The U.S. Geological Survey has not issued a Geologic Map Index of Arizona since 1957. Joseph R. LaVoie of the Bureau staff has assembled a record of the various types of Arizona geologic maps published since the 1957 USGS index map and his record is presented here.

KEY TO MAP

1. 1968. Moore, R.T., Mineral deposits of the Fort Apache Indian Reservation, Arizona: Arizona Bureau of Mines Bulletin 177, Plate 2, Geologic Map 1:250,000.

2. 1969. Wilson, E.D., Mineral deposits of the Gila River Indian Reservation, Arizona: Arizona Bureau of Mines Bulletin 179, Plate 2, Geologic Map 1:250,000.

3. 1958. Lehner, R.E., Geology of the Clarkdale Quadrangle, Arizona: U.S.G.S. Bull. 1021-N, p. 511-592, Plate 45, Geologic Map 1:48,000.

4. 1960. Wells, J.D., Stratigraphy and structure of the House Rock Valley area, Coconino County, Arizona: U.S.G.S. Bull. 1081-D, p. 117-158, Plate 4, Geologic Map 1:62,500.

5. 1963. Witkind, I.J., and Thaden, R.E., Geology and uranium - vanadium deposits of the Monument Valley area, Apache and Navajo Counties, Arizona: U.S.G.S. Bull. 1103, p. 171, Plate 1, Geologic Map 1:62,500.

6. 1960. Cooper, J.R., Some geologic features of the Pima Mining District, Pima County, Arziona: U.S. G.S. Bull. 1112-C, p. 63-103, Plate 1, Geologic Map 1:62,500.

7. 1963. Phoenix, D.A., Geology of the Lees Ferry area, Coconino County, Arizona: U.S.G.S. Bull. 1137, p. 86, Plate 1, Geologic Map, two sheets North half and South half, 1:24,000.

8. 1963. Heindl, L.A., Cenozoic geology in the Mammoth area, Pinal County, Arizona: U.S.G.S. Bull. 1141-E, p. 41, Plate 1, Geologic Map 1:63,360.

9. 1964. Willden, R., Geology of the Christmas Quadrangle, Gila and Pinal Counties, Arizona: U.S.G.S. Bull. 1161-E, p. 64, Plate 1, Geologic Map 1:62,500.

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11. 1965. Beaumont, E.C., and Dixon, G.H., Geology of the Kayenta and Chilchinbito Quadrangles, Navajo County, Arizona: U.S.G.S. Bull. 1202-A, p. 28, Plate 1, Geologic Map 1:62,500.

12. 1967. Creasey, S.C., General geology of the Mammoth Quadrangle, Pinal County, Arizona: U.S.G.S. Bull. 1218, p. 94, Plate 1, Geologic Map 1:48,000.

13. 1966. Huff, L.C., Santos, E., and Raabe, R.G., Mineral resources of the Sycamore Canyon primitive area, Arizona: U.S.G.S. Bull. 1230-F, p. 19, Plate 1, Geologic Map 1:48,000.

14. 1967. Canney, F.C., Lehmbeck, W.L., and Williams, F.E., Mineral Resources of the Pine Mountain primitive area, Arizona: U.S.G.S. Bull. 1230-J, p. 45, Plate 1, Geologic Map 1:31,680.

15. 1969. Ratte, J.C., Landis, E.R., Gaskill, D.L., and Raabe, R.G., Mineral resources of the Blue Range primitive area, Greenlee County, Arizona, and Catron County, New Mexico: U.S.G.S. Bull. 1261-E, p. 91, Plate 1, Geologic Map 1:62,500.

16. 1962. Johnson, P.W., Availability of additional Water for Chiricahua National Monument, Cochise County, Arizona: U.S.G.S. Water-Supply Paper 1475-H, p. 209-216, Plate 17, Geologic Map 1 inch = ½ mile.

17. 1962. Cosner, O.J., Ground Water in the Wupatki and Sunset Crater National Monuments, Coconino County, Arizona: U.S.G.S. Water-Supply Paper 1475-J, p. 357-374, Plate 20, Geologic Map 1:63,360.

18. 1962. Johnson, P.W., Water in the Coconino Sandstone for the Snowflake-Hay Hollow area, Navajo County, Arizona: U.S.G.S. Water-Supply Paper 1539-S, p. 51-546, Plate 1, Geologic Map 1:125,000.

AMERICAN SMELTING AND REFINING COMPANY
Tucson Arizona

August 16, 1971

FILE MEMORANDUM

ASU THESES

Attached is a bibliography of Geology Theses from the Department of Geology, Arizona State University, Tempe, Arizona. Apparently, several others will be completed over the summer months.

James D. Sell/sg

James D. Sell

JDS:sg

cc: WLKurtz

June 1971

BIBLIOGRAPHY OF GEOLOGY THESES

Department of Geology
Arizona State University
Tempe, Arizona

1. Avedisian, Gary E.; MS 1966; GEOLOGY OF THE WESTERN HALF OF PHOENIX SOUTH MOUNTAIN PARK, ARIZONA; 52 pages.

2. Brown, Ronald G.; MS 1970; GEOCHEMICAL SURVEY OF THE ORACLE VICINITY OF ARIZONA; 50 pages.

3. Clary, Thomas A.; MS 1970; GEOLOGY OF THE SCHULTZE GRANITE AND RELATED COPPER MINERALIZATION; 37 pages.

4. Deal, Edmond G.; MS 1969; VOLCANIC GEOLOGY OF THE INTERIOR VALLEY, SAN FRANCISCO MOUNTAIN, ARIZONA; 82 pages.

5. Fodor, Ronald V.; MS 1969; PETROGRAPHY AND PETROLOGY OF THE VOLCANIC ROCKS IN THE GOLDFIELD MOUNTAINS, ARIZONA; 66 pages.

6. Lowery, Carol J.; MS 1964; SEDIMENTATION OF CENOZOIC DEPOSITS IN WESTERN SALT RIVER VALLEY, ARIZONA; 22 pages.

7. McCurry, Wilson G.; MS 1971; MINERALOGY AND PARAGENESIS OF THE ORES, CHRISTMAS MINE, GILA COUNTY, ARIZONA;

8. Merrill, Robert K.; MS 1970; THE GLACIAL GEOLOGY OF THE MOUNT BALDY AREA, APACHE COUNTRY, ARIZONA, 118 pages.

9. Pederson, Edward P.; MS 1969; SEDIMENTOLOGY AND STRATIGRAPHY OF BASIN-FILL SEDIMENTS OF THE PAYSON BASIN, GILA COUNTY, ARIZONA; 136 pages.

10. Stuckless, John S.; MS 1969; THE GEOLOGY OF THE VOLCANIC SEQUENCE ASSOCIATED WITH THE BLACK MESA CALDERA, ARIZONA; 79 pages.

11. Throop, Allen H.; MS 1970, THE NATURE AND ORIGIN OF BLACK CRYSOCOLLA AT THE INSPIRATION MINE, ARIZONA; 56 pages.

12. Tilford, Norman R.; MS 1966, ENGINEERING GEOLOGY--STEWART MOUNTAIN DAM SITE; 42 pages.

13. Updike, Randall G.; MS 1969, THE GLACIAL GEOLOGY OF THE SAN FRANCISCO PEAKS, ARIZONA; 154 pages.

AMERICAN SMELTING AND REFINING COMPANY
Tucson Arizona

August 24, 1971

TO: W. L. Kurtz

FROM: J. D. Sell

U of A, PhD. Dissertation
Ash-flow Sequence
Cochise County, Arizona

Dr. P. E. Damon has released a copy of the following dissertation from the University of Arizona to be placed in the Asarco Library.

"Geologic History of an Ash-flow Sequence and Its Source Area in the Basin and Rance Province of Southeastern Arizona", by Darwin K. Marjaniemi. PhD dissertation, U of A, 1969 (176 pages).

The paper is primarily a study of the volcanic sequence on the Chiricahua and northern Pedregosa Mountains, Cochise County, Arizona. The area is the site of a resurgent caldera with a central biotite hornblende porphyritic monzonite having an age date of 25 m.y.

The abstract is attached.

James D. Sell

JDS:sg
att.

ABSTRACT

The Tertiary history of the Chiricahua volcanic field of southeastern Arizona is essentially that of rhyolitic ash-flow deposition and concomitant block faulting in the period from 29 to 25 m.y., as determined by K-Ar analysis. The Rhyolite Canyon ash-flow sheet is the youngest of three sheets, each more than 1000 feet thick. Its distribution is limited mainly to the Chiricahua and northern Pedregosa Mountains with a lesser amount of deposits in the neighboring Swisshelm and Peloncillo Mountains. It is estimated that the original areal extent was of the order of 700 square miles and that the volume of deposits was around 100 cubic miles.

The source area of the Rhyolite Canyon sheet is identified as a 13-mile diameter caldera, named the Turkey Creek caldera. This is the first major caldera of the Valles type described in the Mexican Highland and Sonoran Desert sections of the Basin and Range. It is unique because of its denudation. Erosion to 5000-foot depth locally has exposed thick sections of moat deposits and a fine grained monzonite pluton associated with central doming. Rhyolite Canyon tuff in the caldera, some 3000 feet thick, is domed and intruded by the monzonite. More than 1500 feet of tuff breccia, tuffaceous

sediments, and rhyolite flows are exposed in the moat, along with 3000 feet of monzonite forming annular segments a couple miles wide abutting or overlying rocks forming the caldera wall. The moat monzonite is similar to that in the dome and was emplaced amidst the period of deposition in the caldera.

Petrographic and trace element analyses indicate a cogenetic relation between the Rhyolite Canyon sequence and the moat rhyolites. The K-Ar age of the Rhyolite Canyon tuff is very close to that of the monzonite.

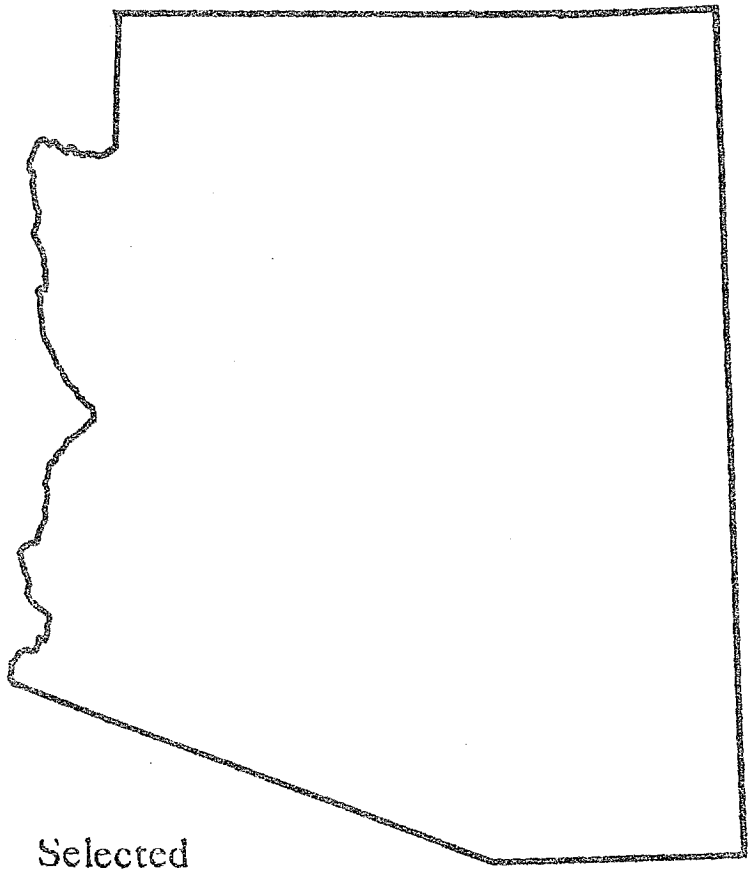
The ash-flow sheet immediately underlying the Rhyolite Canyon sheet is also very close in age as indicated by K-Ar analyses. Block faulting and tilting took place between the two sheets and also following the deposition of the Rhyolite Canyon sheet. There is evidence that the present basin-range structure was not established until after the Rhyolite Canyon sheet had been emplaced.

Map Collection
University of Arizona Library
University of Arizona

Special Series – Map Indexes 1 – 1971

UA Map News Monthly

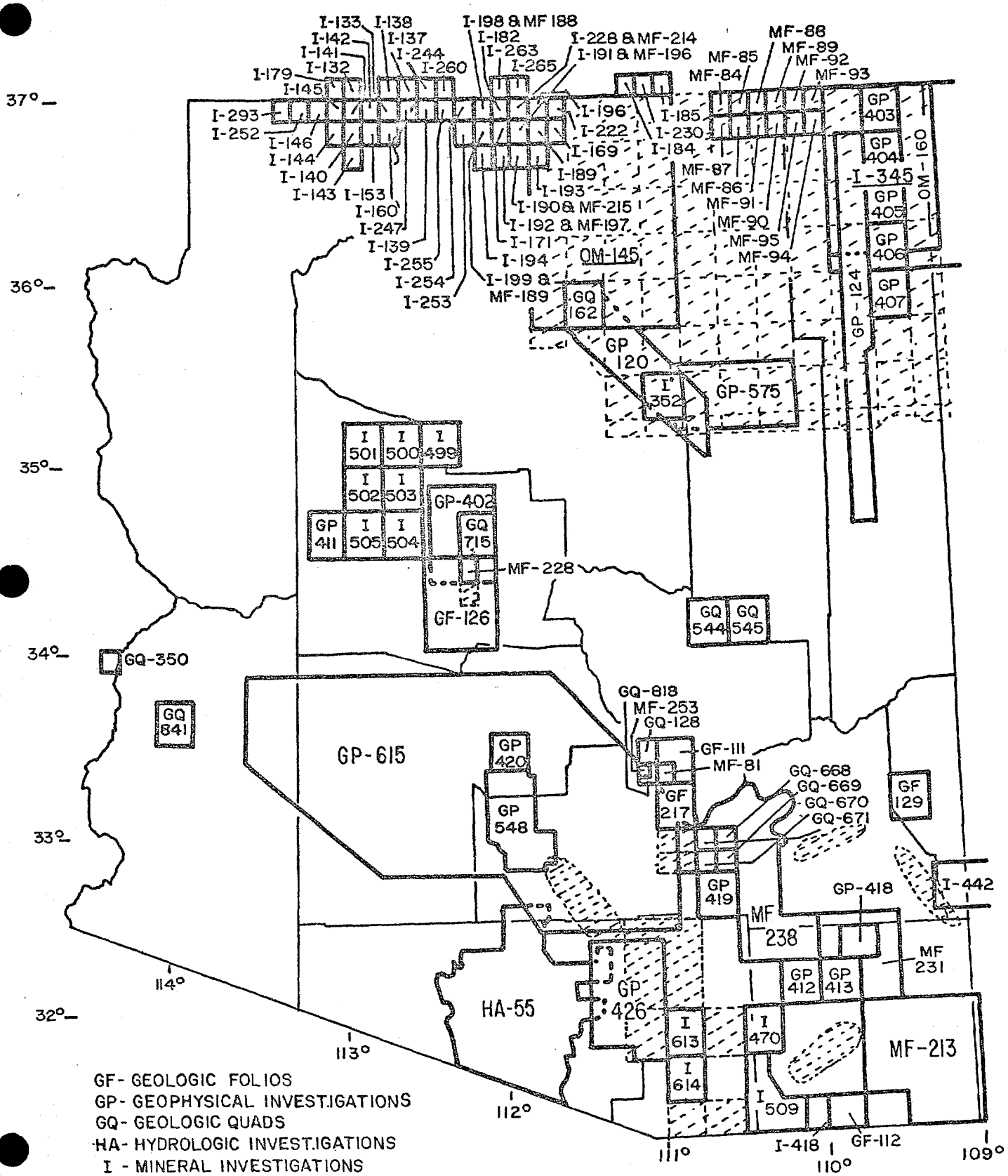
Special Summer Issue 1971



Selected

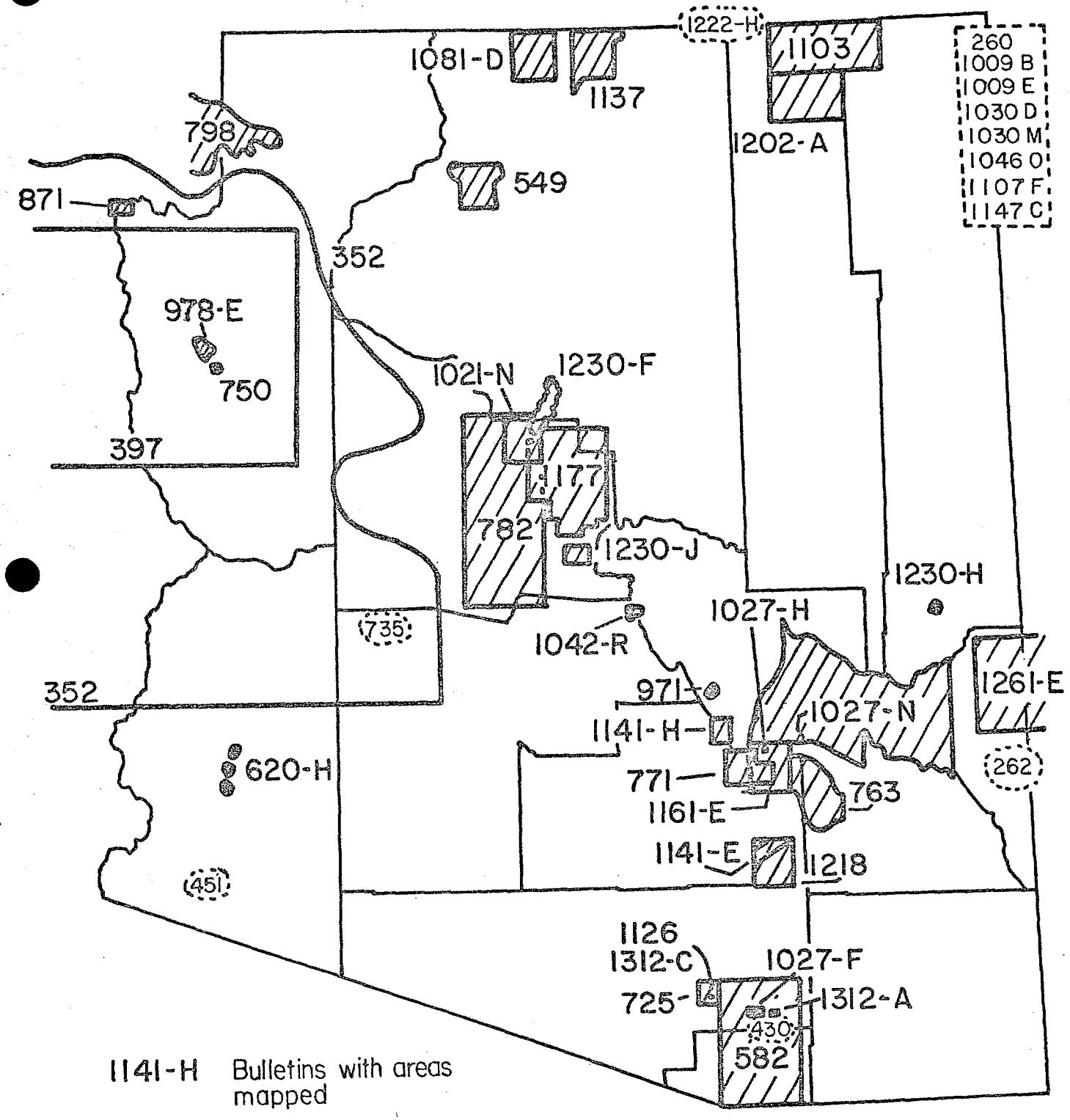
ARIZONA INDEX MAPS

Index 12- U.S.G.S. Geologic Sheets



GF- GEOLOGIC FOLIOS
GP- GEOPHYSICAL INVESTIGATIONS
GQ- GEOLOGIC QUADS
HA- HYDROLOGIC INVESTIGATIONS
I - MINERAL INVESTIGATIONS
MF- MINERAL FIELD STUDIES
OM- OIL & GAS INVESTIGATIONS
OPEN FILE REPORTS

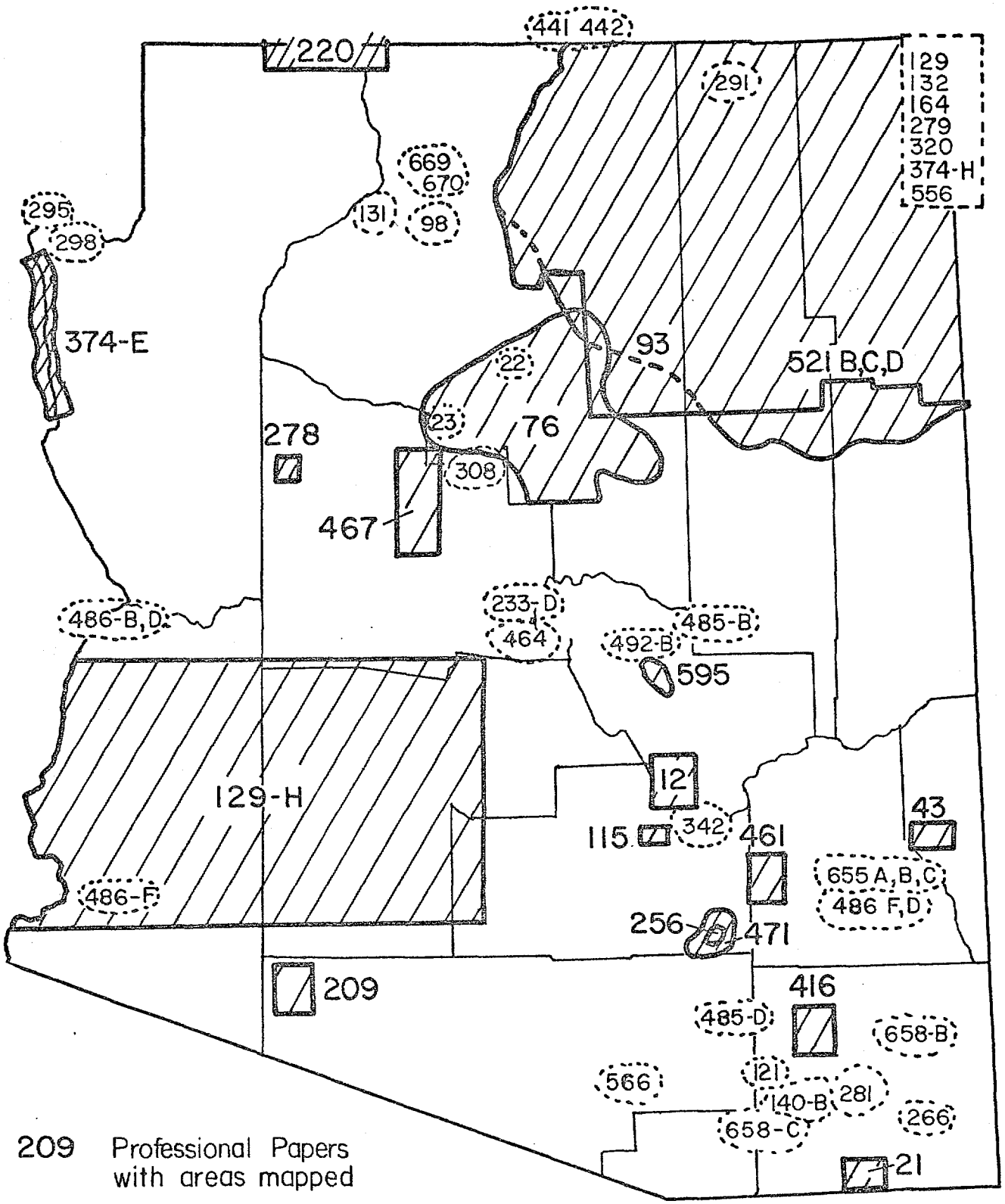
Index 13 - U.S.G.S. Bulletins



1141-H Bulletins with areas mapped

1009-B Approximate Area Mapped

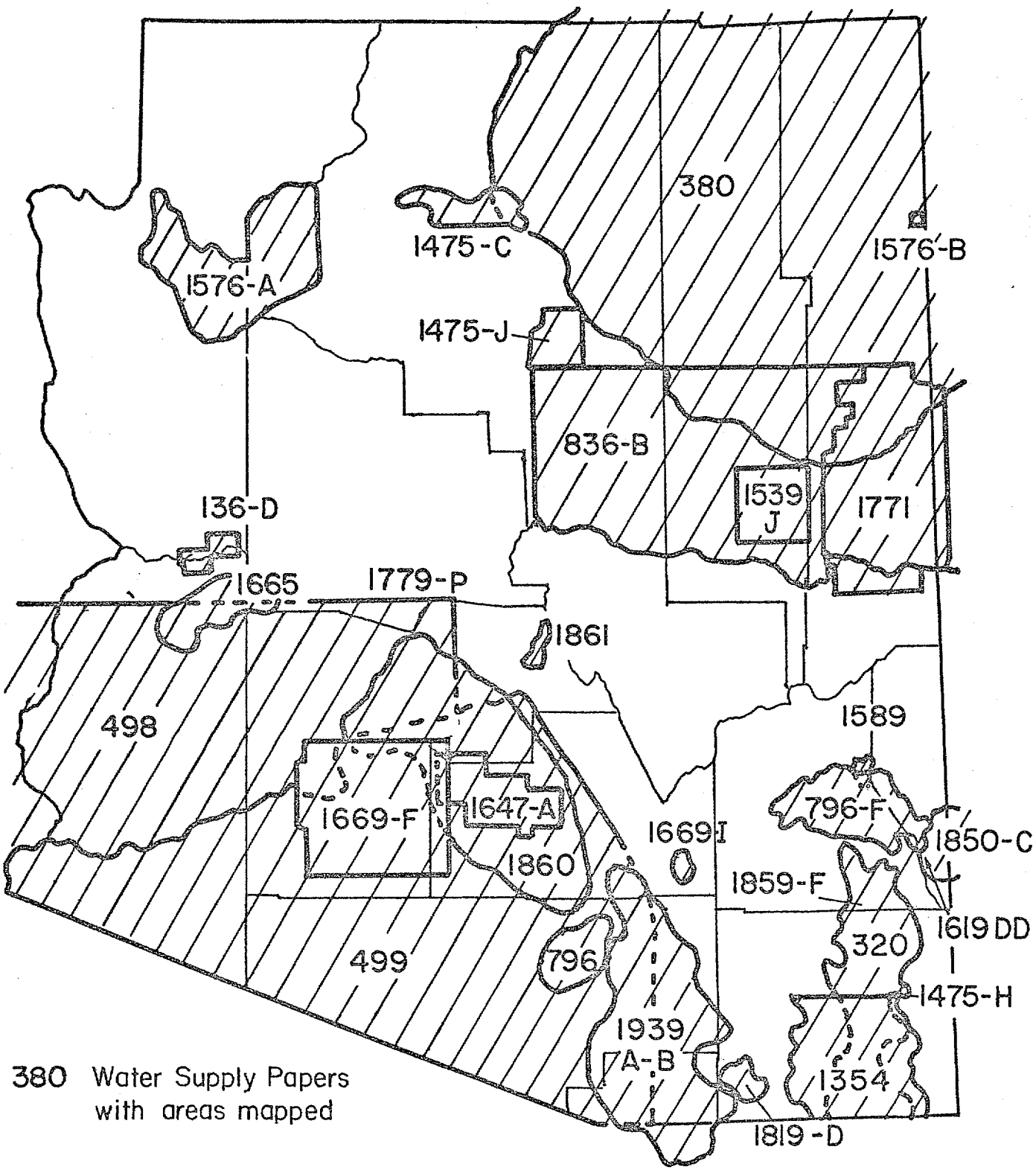
Index 14 - U.S.G.S. Professional Papers



209 Professional Papers with areas mapped

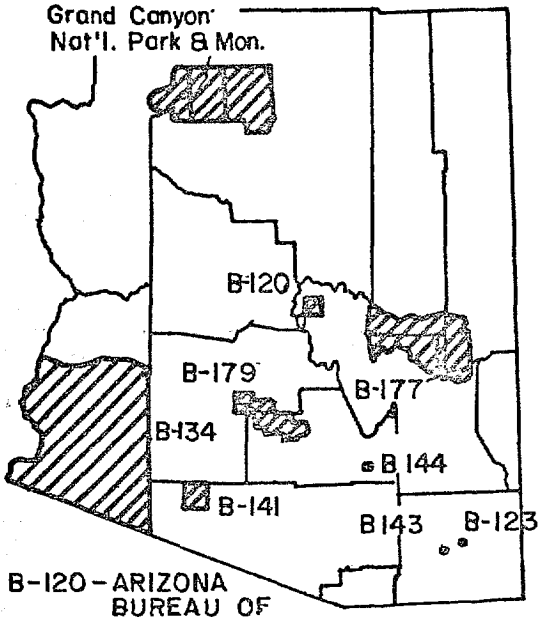
566 Approximate Area Mapped

Index 15 - U.S.G.S. Water Supply Papers



380 Water Supply Papers with areas mapped

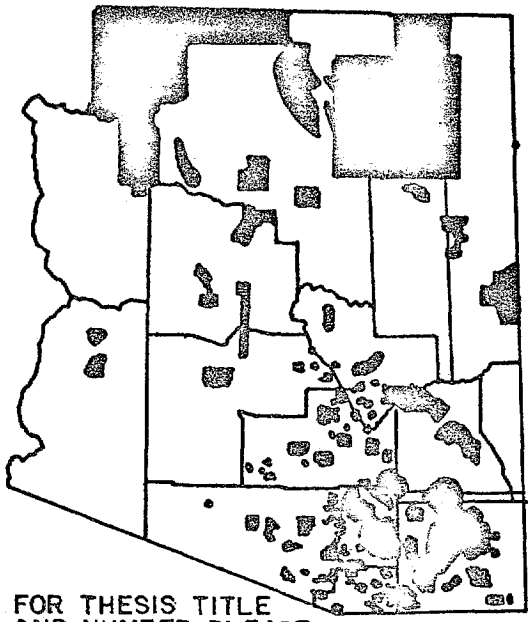
Index 16 - Other Geologic Maps



B-120 - ARIZONA BUREAU OF MINES BULLETIN

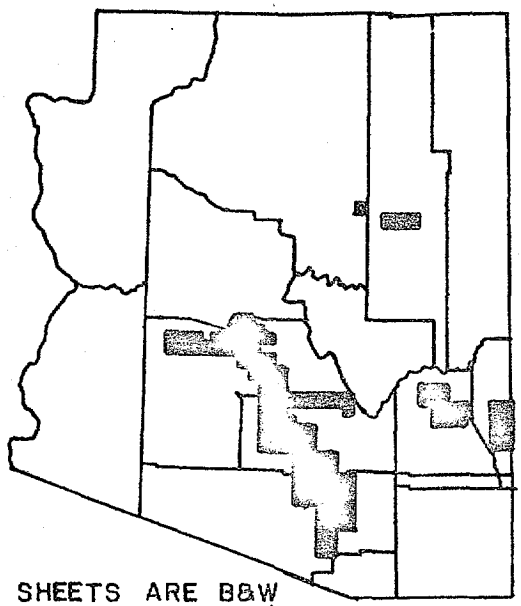
Grand - GRAND CANYON NATURAL HISTORY ASSOCIATION GEOLOGIC MAPS

Index 17 - Geologic Theses



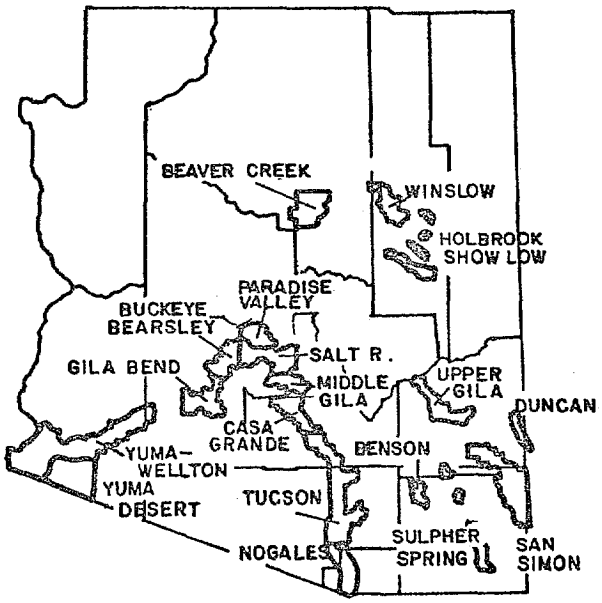
FOR THESIS TITLE AND NUMBER PLEASE REFER TO THE "INDEX TO THESIS MAPS COMPLETED IN ARIZONA" prepared by SIGMA GAMMA EPSILON Univ. of Ariz.

Index 18 - Flood Prone Areas



SHEETS ARE B&W AND ARE 7.5' or 15'

Index 19 - Soil Surveys



AMERICAN SMELTING AND REFINING COMPANY
Tucson Arizona

February 18, 1970

TO: W. E. Saegart

FROM: J. D. Sell

Attached is a list and map (File No. 2229) of geologic material used in up-dating the Index to Geologic Mapping in Arizona by Leona Boardman (1957).

A complete search for material has not been made but it is believed that the additions are essentially all of the "available" and useable maps. The Boardman map material has not been added to this Supplement except in areas of strong interest, sufficient detail, or non-availability of new material.

Only pertinent thesis material has been placed on this Supplement and all have not yet been checked at the University. Nearly complete thesis coverage is contained in a listing and map (in our library) recently published by the Sigma Gamma Epilson group at the University of Arizona.

Review by other staff geologists will probably bring further references, especially Company Reports, that need to be included in this basic compilation.

James D. Sell

James D. Sell

JDS:lab

cc: WLKurtz

AGS Arizona Geological Society Publications:

GUIDEBOOK II:

II-1. Waterman Mountains (McClymons, p.66). 1:24,370

II-2. Clifton (Wilson, p.98). 1:152,000

II-3. Empire Mountains (Galbraith, p.128). 1:54,000

II-4. Dragoon Quadrangle (Cooper, p.140). 1:169,170

II-5. San Xavier Reservation (Heindl, p. 152). 1:125,000

II-6. Waterman-Silver Bell Mountains (McClymonds, p.212). 1:101,380

II-7. Baboquivari, Roskruge, South Comobabi and Artesa Mountains (Galbraith, p.256) 1:215,400

GUIDEBOOK III:

III-1 Ray (Metz p.139). 1:24,000

III-2 Peña Blanca-Walker Canyon (Nelson, p.178). 1:44,350

III-3 Roskruge Mountains (Bikerman, p.186). 1:125,000

III-4 Del Bac Hills (Penincious, p.200). 1:47,500

III-5 Superior Quadrangle (Peterson, p.218). 1:79,200

III-6 Goldfield-Superstition Mountains (Sheridan, p.228). 1:120,000

III-7 Santa Rita-Empire Mountains (Drewes, p.317). 1:125,000

DIGEST 4:

4-1 Geology of West Saguaro National Monument, (McColly,R.A., p.87, (1961) See T-125. 1:42,200

DIGEST 7:

7-1 Structure of East Hualpai Indian Reservation, Koons, D. p.97 (1964). 1:465,000

DIGEST 8:

8-1 Geology of Sierrita Mountains, Lootins, D.J., p.33 (1966) See T-174. 1:45,300

8-2 Geology of Cerro Colorado, Smith, R., p.131 (1966) See T-86 1:24,000

8-3 Geology of Cabeza Prieta Game Range, Simmons, H.L., (1966) No Map.

B United States Geologic Surveys Bulletin

582 Mineral deposits of Santa Rita and Patagonia Mountains (Schrader, 1915) 1:125,000

743 Geology of Oatman Gold District (Ransome, 1923) 1:48,000

782(1) Ore Deposits of Jerome and Bradshaw Mountains (Lindgren 1926) 1:125,000

782(2) Ore Deposits of Jerome and Bradshaw Mountains (Lindgren 1926) 1:125,000

1021-N Geology of Clarkdale Quadrangle (Lehner, 1958) 1:48,000

1027-F Copper Deposits of Helvetia District (Creasey, 1955) 1"=200 ft., etc.

1027-H Geology of the Christmas Copper Mine (Peterson, 1956) 1"=300 ft., etc.

1027-N Mineral Resources of San Carlos Indian Reservation (Bromfield, 1956) 1:250,000

1112-C Geology of Pima Mining District (Cooper, 1960) 1:31,680

1121-H Paleozoic and Cenozoic rocks Alpine-Nutriose Area (Wrucke, 1961) 1:198,000

1141-H Geology of Pinal Ranch Quadrangle (Peterson, 1963) 1:24,000

1161-E Geology of Christmas Quadrangle (Willden, 1964) 1:62,500

1177 Geology of Verde Valley Region (Twentier, 1963) 1:62,500

1194-G Mesozoic Formation in Vekol Mountains (Heindl, 1965) 1:125,000

1194-H Mesozoic Formation in Comobabi and Roskruge Mountains (Heindl, 1965) 1:540,000

B USGS Bulletin (Cont'd)

1194-I Mesozoic(?) Rocks in Baboquivari Mountains (Heindl, 1965) 1:125,000

1194-M Low Mesozoic Extrusive Rocks (Hayes, 1965) 1:443,500(?)

1218 General Geology of Mammoth Quadrangle (Creasey,1967) 1:48,000

1230-F Geology of Sycamore Canyon Area (Huff, 1966) 1:48,000

1230-J Mineral Resources of Pine Mountain Area (Canney, 1967) 1:31,680

1261-E Blue Range, Arizona and New Mexico (Ratte, 1969) 1:62,500

CR: Company Reports, w/maps

1. Aa-16A.3.0 Reconnaissance Geology of the Casa Grande Mountains,(Luning, R.H. 12/21/64) 1:62,500, No map number.

2. Aa-16A.3.20A Geological Reconnaissance of the Haley Hills and Palo Verde Mountain (Luning,R.H. 12/18/64) 1:62,500, no map number.

3. Aa-16A.2.0 Blackwater and Poston Butte (Blucher, A.G. 6/7/60) 1:62,500 (Map No. 1457)

4. Aa-16A.3.20A Table Top Region (Sell, J.D. 9/8/64) 1:62,500 (Map No. 1632)

5. Aa-0.0.16 Globe-Superior Region (Blucher, A.G. 12/15/58) 1:62,500 (Maps 1407 - 1408)

6. Aa-13.19D.0 Sand Tank Region (Sell, J.D. 7/26/65) 1:62,500 (Map 1761)

7. Aa-16.0.0 Sierrita Mountains (Blucher, A.G., 11/14/60) 1:62,500 (Maps 1474-1475)

8. Aa-13A-3.2. Gold Bug District (Beck, D.B. 6/24/66) 1:2,000 (Maps 1874-1875)

9. Aa-16.1.0 Ajo District (Kinnison, J.E. 8/25/61)
A) 1:125,000 (Map 1493)
B) 1:62,500 (Map 1494)

10. Aa-16.1.3J Copper Mountain and Ajo Valley (Kinnison,J.E. 7/26/66) 1:62,500 (Map 1883)

CR Company Reports (Cont'd)

11. Aa-16.19.0 Silver Bell District. Map 1166 - 1:62,500 Geology
Map 1230 - 1:62,500 Alteration
Map 1757 - 1:6,000

12. Aa-16.16.3C Cholla Flat-Twin Buttes (Kinnison, J.E. 4/12/61) 1:31,250 (Map 1525. Also see Map 1298 (1:62,500)

13. Aa-19.19.0 Southern Santa Rita Mountains (Alteration) (Blucher, G.A. 8/27/58) 1:31,250 (Map 1400)

14. Aa-19.18.0A Geology of Harshaw District (Reinhart, J. W. 2/18/52) 1:24,000 (Map 2106) 1:60,000 (Map 995)

15. Aa-16A.16.16 Exploration, Potential Picacho District (Red Rock Quadrangle) (Briscoe, J.A. 9/20/67) 1:62,500 (Map 1980)

16. Aa-16.1.0B South Amole District (Kinnison, J.E. 5/18/60) 1:62,500 (Map 1459) Also see Map 1298 (1:62,500)

17. Aa-7A.12.0 Safford (Lone Star District) (Richard, K. E. 5/27/59)
Aa-7A.19.12 Report, 1:62,500 (Map 896). Also see
Aa-7A.0.0 Blue Crystal Claims 1:11,700

18. Aa-16A.3.19B Sacaton Reconnaissance (Blucher, G. A. 7/7/61) 1:31,250 (Map 1490)

19. ? Reconnaissance South and West of Ray (Bogue, R.G. 4/49) 1:62,500 (Map 776)

20. Aa-16A.3.19C Sacaton-Santa Cruz (Kinnison, J.E. 5/14/68) Map - no number

21. Sacaton Reconnaissance (Beck, D.B. - unpublished)

22. Aa-16A.3.3D Chuichu Area (Kinnison, J.E. 7/13/61) 1:250,000 (Map 1507)

23. Aa-16.0.16 Noipa Kam Area (Sell, J.D. 8/21/69) 1:24,000 (Map 2198)

24. Aa-19.16.0 Southwestern Patagonia (Blucher, A.G. 12/2/57)
1:125,000 (Map 1388) 1:125,000 (Map 995, Index to mapping)
1:48,000 (Map 1386)
1:125,000 (Map 1401) 1:21,700 (Map 968)
(KM) Kerr McGee:Geology of Patagonia Mountains 1:24,000 (Map T-6-84)

25. Aa-16A.6.16A Price Prospect (Saegart, W.E. 4/20/61) 1:31,250 (Map 1483)

CR Company Reports (Cont'd)

26. Aa-25.20.3 Copper Basin (Tiger District) (Boltz, K. L. 10/24/66) Plate 2, 1:54,000

27. Aa-13.23C.7 White Tank Mountains (Jansen, L.J. 4/21/69) 1:12,000 (Map 2165)

28. Aa Ray San Manuel Zone (Blucher work sheet) 1:62,500 (Maps 1495-1496)

29. Aa-3.20A.0 Willcox Project (Teviston District)(Stauffer M.R. 1/10/66) 1:62,500 (Map 1841)

30. Aa-7A.7B.7 Southern Pinaleno Mountains (Beck, D.B. 9/12/64) 1:62,500 (Map 1634-1635)

31. Aa-3.20B.19A Stockton Hill (Devere, B.J. 11/15/65) 1:24,000 (Map 1432)

32. Aa-13A.7C.7 Greenwood Peak (Saegart, W. E. 4/12/66) 1:31,250 Sketch Map (Wojcik, J.R. 9/29/66) 1:9,600 (Map 1882)

33. Aa-13A.2.22 Virgin River Area (Watson, B.M. 8/10/67) 1:12,000 (Map 1955)

34. Aa-13.7.16 Painted Rock (Kinnison, J.E. 3/19/69) 1:125,000 (two maps without number)

35. Aa-16.0.16 Papago Central Project (Karvinen, R.D. 6/19/69)
A. Copperosity 1:12,000 (Map 2158-B)
B. North Santa Rosa 1:12,000 (Map 2156)
C. South Slate Mountains 1:12,000 (Map 2168)

36. Aa.16.17.0 Quijotoa District (Courtright, J.H. 5/26/50) 1:125,000 (Map 887) Map 916 for mines visited and reported on.

37. Aa.16.19.20A Sheridan District (Blucher, A.G. 7/10/57) 1:31,250 (no map number)

38. Aa.16A.3.19C Santa Cruz Summary (Wojcik, J.R. 2/3/66) 1:24,000 (Map 1885)

39. Aa.16A.3.19E Santa Rosa Project (Wojcik, J.R. 11/16/67) 1:62,500 (No map number)

40. Aa-3.3.0 Paradise Prospect (Devere, B.J. 2/24/67) 1:24,000 (Map 1934)

41. Aa.3.0.0 Fort Bowie Prospect (Devere, B.J. 10/7/66) 1:12,000 (Map 1902)

CR Company Reports (Cont'd)

42. Aa-3.23A.0 Whetstone Prospect (Von Fay, S. 1/10/67)
1:9,600 (Map 1913-1918)

43. Aa.25.2.0A Big Bug Creek Prospect (Beck, D.B. 11/10/66)
1:31,680 (Map 1922)

44. Aa-25.2E.6 Francis Young Prospect (Kinnison, J.E. 9/23/65)
1:125,000 (No map number)

45. Aa-25.3.0B Copper Basin District (Yavapai County) Various reports.

46. Aa-25.20.17 Pine Flat Prospect (Beck, D.B. 11/8/66)
1:9600 (No map number)

47. SO-6-7 Frontera Prospect (Sell, J.D. 6/25/68)
1:13,400 (Map 2089)

48. Aa-3.19.0 Swisshelm District (McLean, H.J. 4/12/50)
1:12,000 (Map 889-890)
Also: Rasor, C.A. 3/11/48; 1:6,000 (Map 730)
Also: Knochel, C.P. 4/24/46; 1:3,600,(Map 14-165)

49. Aa-3.20B.0 Turquoise District (Payne, A.L. 3/11/52)
1:12,000 (No map number)
Aa-3.20B.0 Also: Reinhart,J.W. 2/27/50; 1:12,000 (Map 859)
Aa-3.20B.0 Also: Richard, K.E. 8/11/52; 1:4,800 (Map 1038)
and District Map 1:24,000 (Map 1039)
Aa-3.20B.19 Also: Shannon Mine (Field, T.F. 11/13/19,
Surface Map (No Number) 1:1,200 (9/55)
Aa-3.20B.20 Also: Tejon Mine (Pollock, J. P., 3/20/47)
1:2,400 (Map 693)

50. Aa-13.0.0 Copper Prospect, Wickenburg District (Cummings, R. B. 2/23/68). Index Map to drill holes.
NOTE: Same folder contains PD's Red-Man Geologic maps of two areas. 1:4,800 (1966-67)

51. Aa-16.0.16 Reconnaissance in the Papago Indian Reservation (Kurtz, W. L. 9/1/66)
A. 1:62,500 (Map 2151)
B. 1:62,500 (Map 2152)

52. Aa-7A.0.0 Markham Wash Intrusive (Hoskins, W. G. 1/4/66)
1:18,000 (No map number)

53. Aa-7A.1.0 Aravaipa District (Reinhart, J. W. 10/1/52)
3 volume set, numerous maps of district geology at 1:12,000. Geologic outline map 1:60,000 (Map 1048)

F United States Geologic Surveys Folio

111 Globe Quadrangle (Ransome, 1904) 1:62,500

112 Bisbee Quadrangle (Ransome, 1904) 1:62,500

126 Bradshaw Mountains Quadrangle (Jagger, 1905) 1:62,500

129 Clifton Quadrangle (Lindgren, 1905) 1:62,500

217 Ray Quadrangle (Ransome, 1923) 1:62,500

I USGS Miscellaneous Geologic Investigation Series:

352 Geology of Leupp Quadrangle (Irwin, 1962) 1:62,500

418 Geologic Map of Southern Part Mule Mountains (Hayes, 1964) 1:48,000

442 Geologic Map of Duncan-Canador Peak Quadrangle (Morrison, 1965) 1:48,000

470 Geologic Map of Benson Quadrangle (Creasey, 1967) 1:48,000

499 Reconnaissance Geology of the Ash Fork Quadrangle (Krieger, 1967) 1:62,500

500 Reconnaissance Geology of Picacho Butte Quadrangle (Krieger, 1967) 1:62,500

501 Reconnaissance Geology of Turkey Canyon Quadrangle (Krieger, 1967) 1:62,500

502 Reconnaissance Geology of Camp Wood Quadrangle (Krieger, 1967) 1:62,500

503 Reconnaissance Geology of Simmons Quadrangle (Krieger, 1967) 1:62,500

504 Reconnaissance Geology of Iron Springs Quadrangle (Krieger, 1967) 1:62,500

505 Reconnaissance Geology of Sheridan Mountain Quadrangle (Krieger, 1967) 1:62,500

509 Geologic Map of Huachuca-Mustang Mountain (Hayes, 1968) 1:48,000
Also: USGS WSP 1819-D

M USGS Mineral Investigation Field Studies Maps

81 Preliminary Geology of Pinal Ranch Quadrangle (Peterson, 1961) 1:24,000

213 Reconnaissance Geologic Map of SE Cochise County (Cooper, 1959) 1:125,000

228 Preliminary Geologic Map NW1/4 Mayer Quadrangle,(Anderson, 1959) 1:24,000

231 Reconnaissance Map of Wilcox, Fisher Hills, Cochise and Dos Cabezas Quadrangles (Cooper, 1960) 1:62,500

238 Reconnaissance Geology of San Pedro-Aravaipa Valleys (Creasey, 1961) 1:125,000

253 Preliminary Geologic Map West Superior (7 1/2) Quadrangle (Peterson, 1962) 1:12,000

OF USGS Open File Reports

1. Preliminary Geologic Map SW 1/4 Mayer Quadrangle (Anderson 1967) 1:24,000

2. Preliminary Geologic Map NE 1/4 Mount Union Quadrangle (Anderson, 1962) 1:24,000

3. Geologic Map SE 1/4 Mount Union Quadrangle (Blacet, 1964) 1:24,000

4. Preliminary Geologic Map of Crozier Peak Quadrangle (Krieger, 1969) 1:24,000

5. Preliminary Geologic Map of Winkelman Quadrangle (Krieger, (1969) 1:24,000

6. Preliminary Geologic Map of Black Mountain Quadrangle (Krieger, 1969) 1:24,000

7. Preliminary Geologic Map of Putnam Wash Quadrangle (Krieger, 1969) 1:24,000

8. Preliminary Geologic Map of Mount Wrightson Quadrangle (Drewes, 1966) 1:48,000

9. Preliminary Geologic Map of Sahuarita Quadrangle (Drewes, 1968) 1:48,000

10. Geologic Map of Tucson Quadrangle (Moore, 1949) 1:62,500

OF USGS Open File Reports (Cont'd)

11. Geologic Map of Quartzite Quadrangle (Miller, 1968) 1:48,000

12. Mineral Deposits of the Gila River Indian Reservation (Wilson, 1963) 1:125,000

13. Geology of Gila Bend Basin (Babcook, 1948) 1:145,700

14. Geology of Verde River Valley (McDonald, 1946) 1:125,000

15. Geology of Deer Valley (Bluhm, 1949) 1:79,200

16. Geology of Ranegras Plain (Metzger, 1954) 1:190,000

P USGS Professional Paper

12 Geology of Globe Copper District (Ransome, 1903) 1:62,500

21 Geology and Ore Deposits of Bisbee Quadrangle (Ransome, 1904) 1:62,500

43 Copper Deposits of Clifton-Morenci (lindgren, 1905) 1:62,500

76 San Franciscan Volcanic Field (Robinson, 1913) 1:96,000

115 Copper Deposits of Ray-Miami (Ransome, 1919) 1:125,000

209 Ajo Mining District (Gilluly, 1946) 1:62,500
See also U. of A. Bulletin 141

278 Geology and Ore Deposits of Bagdad (Anderson, 1955) 1:20,000

281 General Geology of Central Cochise County (Gilluly, 1956) 1:62,500

308 Geology and Ore Deposits of Jerome Area (Anderson, 1958) 1:24,000

342 Geology and Ore Deposits of Globe-Miami (Peterson, 1962) 1:24,000

374-E Reconnaissance Geology of Lake Mead-Davis Dam (Longwell, 1963) 1;125,000

416 Geology and Ore Deposits of Dragoon Quadrangle (Cooper, 1964) 1:31,680

461 Geology of Klondyke Quadrangle (Simons, 1964) 1:62,500

P USGS Professional Paper (Cont'd)

467 Geology of Prescott-Paulden Quadrangle (Krieger, 1965) 1:48,000

471 Geology of San Manuel Area (Creasey, 1965) 1:24,000

521-A Regional Hydrogeology of Navajo-Hopi Indian Reservation (Cooley, 1969) 1:125,000

PCV Porphyry Copper Volume (University of Arizona)

1. Ajo (Dixon, p.125) 5" = 6 miles
2. San Manuel (Thomas, p. 135) 1" = 850 feet
3. Miami (Olmstead, p. 149) 1:24,000
4. Silver Bell (Richard, p. 159) 1" = 2750 feet
5. Ray (metz, p. 176) 1" = 1700 feet
6. Bisbee (Bryant, p. 195) 1" = 2750 feet
7. Morenci (Moolick, p. 230) 1" = 2500 feet
8. Safford (Robinson, p. 254) 1" = 4800 feet
9. Esperanza (Lynch, p. 270) 1" = 1050 feet

Q USGS Geologic Quadrangle Maps

41. Geology of Globe Quadrangle (Peterson, 1954) 1:24,00

128 Geology of Haunted Canyon Quadrangle (Peterson, 1960) 1:24,000

162 Geology of Cameron Quadrangle (Akers, 1962) 1:62,500

350 Geologic Map of Big Maria Mountain, NE Quadrangle (Hamilton, 1964) 1:24,000

544 Geology of Chediski Quadrangle (Finnell, 1966) 1:62,500

545 Geology of Cibeque Quadrangle (Finnell, 1966) 1:62,500

668 Geology of Brandenburg Quadrangle (Krieger, 1968) 1: 24,000

669 Geology of Holy Joe Peak Quadrangle (Krieger, 1968) 1:24,000

Q USGS Geologic Quadrangle Maps (Cont'd)

670 Geology of Lookout Mountain Quadrangle (Krieger, 1968) 1:24,000

671 Geology of Saddle Mountain Quadr-ngle (Krieger, 1968) 1:24,000

715 Geologic Map of Mingus Mountain Quadrangle (Anderson 1967) 1:62,500

T Thesis Map from SGE Supplement

University of Arizona

11 Geology of Quijotoa Mountains (Gebhardt, R.C., M.S. 1931, No. 10) ?

31 Geology of Northern Slate Mountains (Hogue, W.G., M.S., 1940, No. 44) 1:6,000

39 Geology of Potts Canyon (Wardwell, H.R., M.S., 1941, No. 64) 1:7,200

44 Geology of North Canelo Hills (Feth, J.H., PhD, 1947, No. 13) 1:31,680

82 Structure of Oracle Granite (Banner's E.F., PhD, 1957, No. 57) ?

84 Geologic Reconnaissance of Cienega Valley (Brennan, D., PhD, 1957, No. 53) 1: 31,680. (Company Map No. 1402)

86 Geology of Cerro Colorado,(Jones, R.D. M.S. 1957)

88 Geology of West Cobabi District (MacKallor, J.A., M.S. 1957, No. 55) 1:126,720

89 Structure of South Waterman Mountain (McClymonds, N. E., M.S. 1957, No. 34) 1:6,000

99 Geology of South Amole District (Kinnison, J. E., M.S. 1958) No. 29) Company files. 1:62,500

100 Geology of Northwest Mohave County (Moore, R. T., M.S. 1958, No. 22) 1:125,000

102 Geology of South Comobabi Mountains (Bryner, L., PhD, 1958, No. 98) 1:31,680

119 Geology of North Tumacacori Foothills,(Cunningham, J.E. PhD, 1964)

T Thesis Map from SGE Supplement (Cont'd)

University of Arizona (Cont'd)

122 Geology of Jackrabbit Area (Hammer, D. F. M.S. 1961, No. 171) 1:3,600

125 Geology of the Saguaro National Monument Area (McColly R. A., M.S. 1961)

131 Geology of Owl Head District (Barter, C.F., M.S., 1962, No. ?) Company files 1:62,500

151 Geology of Tres Alamos Dam Site (Montgomery, G.L., M.S. 1963, No. ?) ?

152 Peña Blanca-Walker Canyon (Nelson, F. J., M.S. 1963, No. ?) ?

168 Structure of East Silver Bell (Watson, B.N., PhD, 1964, No. 192) 1:8,000

170 Geology of West Granite Wash Mountain (Ciancanelli, E.V., M.S. 1965, No. 92) 1:4,800

174 Structure of East Sierrita Mountains (Looten, D.J., PhD 1965, No. 246) 1:12,000

177 Metamorphism in Rincon Mountains (Miles, C.H., PhD, 1965, No. 358) 1:6,000

184 Geology of Roskruge Range (Bikerman, M., PhD, 1966) (Damon 1965 AEC files) 1:112,000

191 Geology of North Plomosa Mountains (Jemett, J.P. PhD 1966, No. 67) 1:12,000

197 Structure of Tucson Basin (Pashley, E.F., PhD, 1966, No. 261) Scale ?

198 Structure of Fraquite Peak, (Reed, R.K., M.S. 1966)

201 Geology of Mineral Mountain Quadrangle (Schmidt, E.A., M.S. 1966, No. 48) ?

203 Geology of Las Guijas District,(Shiekh, A.M., M.S. 1966)

207-A Geology of El Tiro Hills, West of Silver Bell (Clarke, C.W., M.S. 1966) No. 43) Company files. 1:12,000

207 Geology of Picacho Peak (Briscoe, J.A., M.S. 1967, No. 69) 1:10,560

209 Geology of East Camelo Hills, (Cetinay, H.T. M.S. 1967)

T Thesis Map from SGE Supplement (Cont'd)

University of Arizona (Cont'd)

210 Geology of Sahuaro Lake (Durand, H.S., M.S. 1967 No. 26) 1:10,560

216 Geology of Esperanza Mine and Vicinity,(Lynch, D.W. M.S. 1967, No. ?) 1:6,000

218 Geology of SE Canelo Hills, (Denney, P.P., M.S. 1968)

220 Geochemical Investigation of the Del Bac Hills Volcanics, (Percious, J. K., M.S. 1968)

222 Structure of East Catalina Forerange (Peterson, R.C. PhD 1968, No. ?) 1:62,500

230 Geochronology of Older Precambrian (Livingston, D.E. PhD 1969, No. ?) 1:31,700

2?? Geologic History of Ash-flow sequence in SE. Arizona (Marjaniemi, D., PhD 1969, No. ?) ?

OTHERS

0-5 Geology of Vekol Mountains (Carpenter, R.H., PhD, 1947) Stanford

0-10 Structure of South Plomosa Mountains (Miller, F.K. Phd 1966) Stanford

0-11 Structural Study of Virgin and Beaverdam Mountains (Moore, R.T., PhD, 1966) Stanford

0-14 Geology of Springville-Saint Johns Area (Sirrine, G.V., PhD, 1958) University of Texas

W USGS Water Supply Paper

1475-C Geology along South Rim of Grand Canyon (Metzger, 1961) 1:125,000

1475-J Geology of Waputki - Sunset Crater Area (Cosner, 1962) 1:63,360

1539-S Geology of Snowflake-Hay Hollow Area (Johnson, 1962 1:125,000

W USGS Water Supply Paper (Cont'd)

1561 Water Resources in Sycamore Creek (Thomsen, 1968) 1:125,000

1576-A Geology of Hualapai Indian Reservation (Twenter, 1962) 1:250,000

1589 Geology of Lower Bonita Creek (Heindl, 1961) 1:48,000

1619-H Geology of Headwaters of Gila River Drainage (Feth, 1963) 1:500,000. 109° - 112'30'W and 33°30' N (very rought map)

1665 Geology of McMullen Valley (Kam, 1964) 1:126,720

1771 Geology of Central Apache County (Akers, 1964) 1:125,000

1819-D Water Resources of Fort Huachuca Reservation (Brown, 1966) 1:62,500

1858 Use of Water in Cottonwood Wash (Bowie, 1968) 1:12,000

WRR Water Resources Report; Arizona State Land Department

3. Geology of Harquahala Plains Area (Metzger, 1957) 1:125,000

4 Geology of Palomas Plain-Dendora Valley Area (Armstrong, 1958) 1:125,000

8 Geology of McMullen Valley (Kam, 1961) See WSP 1665 1:250,000

23 Geohydrology of Dateland - Hyder Area (Weist, 1965) 1:187,000

35 Groundwater in Paradise Valley (Ortega, 1968) 1:158,400

MISCELLANEOUS PUBLICATIONS

AAPG AAPG Bulletin

32-1 Geology of Northern Canelo Hills (Feth, 1948) 1:36,000

AIME Transactions

Vol. 235 General Geology of Courtland-Gleeson Area, (McRae,O.M. 1966) p. 133-138, with discussion by Jones on p.446-450.
NOTE: AIME Preprint 651320 is same article, McRae,O.M. 10/7/65). Figure 2, 1:36,000.

ABM Arizona Bureau of Mines Bulletin

123 Geology of Courtland-Gleeson District (Wilson, E.D. 1927) Plate I, 1:24,400 (See Also AIME Transaction 235 and K. E. Richard's Turquoise Map. No. 1039.

131 Geology of Oatman-Katherine District (Larsen, C. 1931) Plate 2 1:100,000

134 Geology of Southern Yuma County (Wilson, E.D. 1933) Plate 9 1:14,400

143 Geology and Ore Deposits of Tombstone (Butler, B.S. 1938) Plate III, 1:23,900 (District) Plate IV, 1:6,000 (Central Area)

177 Mineral Deposits-Fort Apache Indian Reservation (Moore, R.T. 1968) Plate 2, 1:250,000

179 Mineral Deposits - Gila River Indian Reservation (Wilson, E.D. 1969) Plate 2, 1:250,000

EG Economic Geology Bulletin

56-5 Breccia Pipes in Copper Basin (Johnson, W.P. and Lowell, J.D., 1961, p. 916-940) 1:70,400

GSA Geological Society of America Bulletins

47-9 Geology of Boulder Reservoir Floor (Longwell, 1936) 1:110,000

50-5 Geology of the Tucson Mountains (Brown, 1939) 1:62,500

50-7 Precambrian in Central Arizona (Wilson, 1939) Plate 10, 1:80,000; Plate 11, 1:62,500

56-2 Geology of Uinkaret Plateau (Koons, 1945) 1:108,612

68-10 Geology of Cochise Head-Vanar Quadrangle (Sabin, 1957 1:62,500

GSA Geological Society of America Bulletins (Cont'd)

69-12(1) Geology of East 1/2 Diamond Butte Quadrangle (Gastil, 1958) 1:31,680

GCN Grand Canyon Natural History Society

1 Geologic Map of Bright Angel Quadrangle (Maxson,1966) 1:48,000

2 Geologic Map of East Section Grand Canyon (Maxson, 1967) 1:62,500

NBM Nevada Bureau of Mines Bulletin

69 Relation of Metal Mining District W.U.S. (Jerome, 1967)

NMGB-New Mexico Geological Society Guidebook

4 Southwestern New Mexico (Fourth Field Conference) Maps 3-4 and 3-5 1:126,720

13 Mogollon Rim (Thirteenth Field Conference) Various maps of Globe-Miami-Superior Area.

PLATEAU - Museum of Northern Arizona - Flagstaff

20-4 Geology of Eastern Hualpai Reservation (Koons, D., 1948) 1:674,000

24-4 Geology of Aubrey Valley (Blissenbach, E., 1952) 1:316,800

33-4 Riverview Mine (Chenoweth, W.L., 1961) 1:169,000

1971 SEG list
Map Index

1/

Thesis

Thesis may not be on map. Numbers refer to SEG list and map index sheets. See ASARCO Library Index and Map Sheets for entire thesis listing

TU- Thesis, University of Arizona.

11. Geology of Quijotoa Mountains, Pima County, RC Gebhardt, MS 1931 (No.), 1:

62. Geology of Ruin Basin area, Gila County, W. Bejnar, PhD 1952 (No.), 1:

79. Geological Reconnaissance of the Cenozoic Walnut Grove Basin, Yavapai County, L. Plafker, MS 1956 (No.), 1:

84. Geological Reconnaissance of Ciénega Valley, Cochise County, W. Brennan, Jr., PhD 1957 (No.), 1:

86. Geology of Cerro Colorado District, R.W. Jones, MS 1957 (No.) 1:

88. Geology of Cobabi Mining District, Pima County, JA MacKallor, MS 1957 (No.), 1:

100. Geology of NW Mohave County, RT Moore, MS 1958 (No.) 1:

102. Geology of South Comobabi Mtns and Ko Vaya Hills, Pima County, L. Bryner, PhD 1959 (No.) 1:

119. Geology of North Tumacacori Foothills, Santa Cruz County, JE Cunningham, PhD 1964, (No.) 1:

122. Geology of Jackrabbit area, Pinal County, DF Hammer, MS 1961 (No.) 1:

Thesis, University of Arizona (Continued)

2/

TU-131. Geology of Owl Head Mining District, Pinal County, CF Barter, MS 1962 (No.) 1:

152. Geology of Pena Blanca-Walker Canyon Area, Santa Cruz County, FJ Nelson, MS 1963 (No.) 1:

168. Structure of Eastern Portion Silver Bell Mountains, Pima County, BN Watson, PhD 1964 (No.) 1:

171. Geology of Fresnal Canyon, Baboquivari Mtn, Pima County, CL Fair, PhD 1965 (No.) 1:

184. Geological and Geochemical Studies, Roskruge Range, Pima County, M. Biberman, PhD 1966, (No.) 1:

191. Geology of Northern Plomosa Mtn, Yuma County, JP Jennett, PhD 1966 (No.) 1:

196. Geology of Picketpost Mtn., Pinal County, E. Nelson, MS 1966 (No.) 1:

201. Geology of Mineral Mountain Quadrangle, Pinal County, E. Schmidt, MS 1966 (No.) 1:

207. Geology of Picacho Peak Area, Pinal County, JA Briscoe, MS 1967 (No.) 1:

210. Geology of Saharo Lake Area, Maricopa County, HS Wenrand, MS 1967 (No.) 1:

220 Geochemical Investigations, Del Bac Hills, Pima County, JK. Percious, MS 1968 (No.) 1:

226. Petrology and Geochemistry of Dos Cabezas Mountains, Cochise County, RC Erickson, PhD 1969 (No.) 1:

3/

Thesis, University of Arizona (Continued)

TU-230 Geochronology of Older Precambrian Rocks, Gila County, DE Livingston, PhD 1969 (No.)
1:

237. Structure and Mineralization, Oro Blanco Mining District, Santa Cruz County, LH Knight, PhD 1970 (No.) 1:

239. Hydrogeology of Sells Area, Pima County, JP Matis, MS 1970 (No.) 1:

246. Petrographic Study of Quartz Diorite Stock (Silver King Area), Pinal County, DC Peabett, Jr, MS 1970 (No.) 1:

268. Geochemical Study of Mid-Tertiary Volcanism in Part of Pima-Pinal County, RL Eastwood, PhD 1970, (No.) 1:

275. Structural Investigation of Northern Tortilla Mountains, Pinal County, EA Schmidt, PhD 1971, (No.) 1:

4/ Thesis – Arizona State University, Tempe, (AS-)

TA-1. Geology of Western Half of Saddle Mountain Park, Maricopa County, JE. Avedisian, MS 1965 (No.) 1:

-4 Petrology of Volcanic Rocks in Goldfield Mountains, Maricopa County, RV Fodor, MS 1968 (No.) 1:

-6. Geology of Black Mesa Caldera (Superstition Mtns), Pinal and Maricopa Counties, DS Stuchless, MS 1969 (No.) 1:

-9. Geology of Schultz Granite (Miami Area), Gila County, TA Cherry, MS 1970 (No.) 1:

5/

Thesis - Out of State Universities.

TO-17. Geology of Vekol Mountains, Pinal County, RH Carpenter, PhD 1947, Stanford, 1:

-22 Geology of West-Central Portion of Promontory Butte Quad, Gila County, RE Ostrander, MS 1950, State Univ. of Iowa, 1:

-23 Geology of East-Central Part of Promontory Butte Quad, Gila County, LC Satterthwaite, MS 1951, State Univ. of Iowa, 1:

-30 Geology of Eastern Half of Diamond Butte Quad, Gila County, G. Gastil, PhD 1953, Univ. of Calif. Berkeley, 1: (See GSA-)

-34. Geology of Copper Basin Mining District, Yavapai County, WP Johnston, PhD 1955, Univ. of Utah, 1: (See Econ. Geol.-

-36. Geology of parts of Cochise Head-Vaca Quads, Cochise County, FF Sabins, Jr. PhD 1955, Yale Univ., 1: (See GSA-

-40 Geology of Pedregosa Mountains, Cochise County, RC Epis, PhD 1956, Univ. of California, Berkeley, 1:

-42. Geologic Reconnaissance of Black Canyon Schist Belt, Bradshaw Mtns., Yavapai & Maricopa Counties, SE Jerome, PhD. 1956, Univ. of Utah, 1:

-51 Geology Central Palomillo Mountain, Hidalgo County, New Mexico and Cochise County, Arizona, E. Gillerman, PhD 1957, Texas, 1:

6/

Thesis — Out-of-State Universities (Continued)

-53. Stratigraphy of Southern Swisshelm Mountains, Cochise County, T H Rogers, MA 1957, Univ of Calif., Berkley, 1:

-70. General Geology of the Hump Area between Ray and Superior, Pinal County, J.A. Portugal, MS 1961, Univ. of Cincinnati. 1:

-72. Geology of Eastern Portion of Patagonia Mountains Santa Cruz County, R C Baker, PhD 1962, Univ. of Michigan, 1:

-91. Structure of Southern Half of Plomosa Mtns, Yuma County, F K Miller, PhD 1964, Stanford, 1:

-95. Geology of Tascuela Area, Sierita Mtns., Pima County, J A Thoms, PhD 1966, Univ of Michigan, 1:

-89 Geology of Cienega Mining District, Yuma County, E. Zambrand, MA 1965, Univ. of Missouri, 1:

ASARCO

Southwestern Exploration Division

February 26, 1976

STAFF MEMORANDUM

Aeromagnetic Map Index

Attached is a list of all aeromagnetic maps of company origin. You will note that an asterisk has been placed in front of those which are available in the Tucson Drafting Room.

Our Salt Lake City office advises that all of the aeromagnetic maps have been forwarded by them to this office. I have not been able to locate any of the maps on the list which do not have an asterisk and would appreciate each of you checking your files and map cabinets as soon as possible in an effort to locate the missing maps. If you will bring any that you have to me, they will be added to our list, duplicates will be made for our master file in the Drafting Room, and the maps will be returned to you.

The aeromagnetic map index is filed under Aa-0.0.1F, the geologic map index under Aa-0.0.7F, and the gravity index under Aa-0.0.7G, all in the Arizona General Files.

Louis Bormolini

L. A. Bormolini

Att.

AEROMAGNETIC INDEX

* - Available in Drafting Room;
All other Company reports available from Salt Lake City Office.

CR - Company Reports

1. Kino Peak
2. Mt. Ajo
3. Valley of the Ajo
4. Ajo
5. Sikort Chuapo Mts.
*6. Cimarron Peak
*7. Gu Achi
8. Hat Mountain
*9. Estrella
*10. Kaka
*11. Vekol Valley
*12. Lake Shore
*13. Santa Rosa
*14. Quijotoa Mts.
*15. Comobabi
*16. Silver Bell - Avra Valley
*17. Vaca Hills
*18. Silver Reef
19.
20. Eloy
*21. Red Rock
22. Valley Farms
*23. Sacaton - Casa Grande
*24. Sacaton
25. Apache Jct.
*26. Florence
27. Pickett Post
*28. Superior
*29. Teapot Mt., Grayback, Ninety-Six Hills, N.E. & S.E.
30. Sonora - El Capitan Mt.
*31. Winkleman
32. South Winkleman
*33. Tortilla Mt.
34. Cocoraque Butte
35. Avra - Jaynes
36. Palo Alto Ranch
*37. Oracle
38. Cammeran Wash
39. Christmas
40. Holy Joe Peak
41. Sahuarita
42. Mt. Wrightson
43. Nogales
44. Lochiel
*45. Rincon Valley
46 Empire Mts.

CR - Company Reports - Continued

*47. Klondyke
*48. Galiuro Mts.
49. Benson
*50. Jackson Mt.
51. St. David
*52. Tombstone
*53. Hereford
*54. Ft. Thomas
55. Pearce
56. Gleeson
57. Bisbee
*58. Bryce Mt.
*59. Safford
*60. Clifton
*61. Guthrie
*62. Big Lue Mts.
*63. York Valley
*64. White Tank Mts.
*65. Twin Buttes Block-1
*66. Brown Mtn. Block-3
*67. Silver Bell Mts. Block-2
*68. Southern Arizona Residual Magnetic Map (WGF after Sumner)
*69. Southern Arizona Residual Magnetic Map (SLC after Sumner)
*70. Silver Bell District
*71. Superior Area
*72. Magnetic Modeling of Safford Area
*73. Silver Bell Peak Quadrangle
*74. Sacaton Area
*75. Vaca Hills District
*76. Vaca Hills #2
*77. Center Portions of Safford & Guthrie Quads.

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
FEDERAL CENTER, DENVER, COLORADO 80225

IN REPLY REFER TO:
Geologic Division
Base and Ferrous
Metals Branch

June 18, 1969

Mr. James D. Sell
Exploration Department
American Smelting and Refining Company
P.O. Box 5795
Tucson, Arizona 85703

Dear Jim:

The published geologic map coverage in Arizona shown in figure 8 of "Mineral and Water Resources of Arizona" was compiled by Willard McIntosh in Washington. No formal map index with accompanying list of publications is available. However, McIntosh has provided the sources of data in the form of work sheets, a copy of which is enclosed.

You will note that he has set up 3 colored index maps keyed to an accompanying thumb-nail list of the published sources of data. I hope this information will be adequate for your purpose.

The new Geologic Map of Arizona has just been published. Copies at $2.50 each are obtainable, or soon will be, from the Arizona Bureau of Mines office in Tucson.

With best regards to Marnee and yourself.

Sincerely yours,

John

John R. Cooper, Geologist
Branch of Base and Ferrous Metals

AMERICAN SMELTING AND REFINING COMPANY
EXPLORATION DEPARTMENT
SOUTHWESTERN UNITED STATES DIVISION
P. O. BOX 5795, TUCSON, ARIZONA 85703

1150 NORTH 7TH AVENUE
TELEPHONE 602-792-3010

June 27, 1969

Mr. John R. Cooper, Geologist
Branch of Base and Ferrous Metals
Room 1213, Bldg. 25
Denver Federal Center
Denver, Colorado 80225

Dear John:

Your packet of map information arrived and is certainly a help in our compiling program. After reading your note on the new Arizona map being available I called down to the U of A and they had a few for over-the-counter sale. I haven't had much time for detailed examination, but spot checks were very gratifying. My congratulations to you and the others on this great improvement.

It does appear that "the ice is about to go out of the Santa Cruz" very shortly now. Otherwise, work and events are going along. Marnee is now taking some summer school work at the University.

My extended thanks for the material and your interest in the project.

Best regards to all,

Jim

JDS:ir

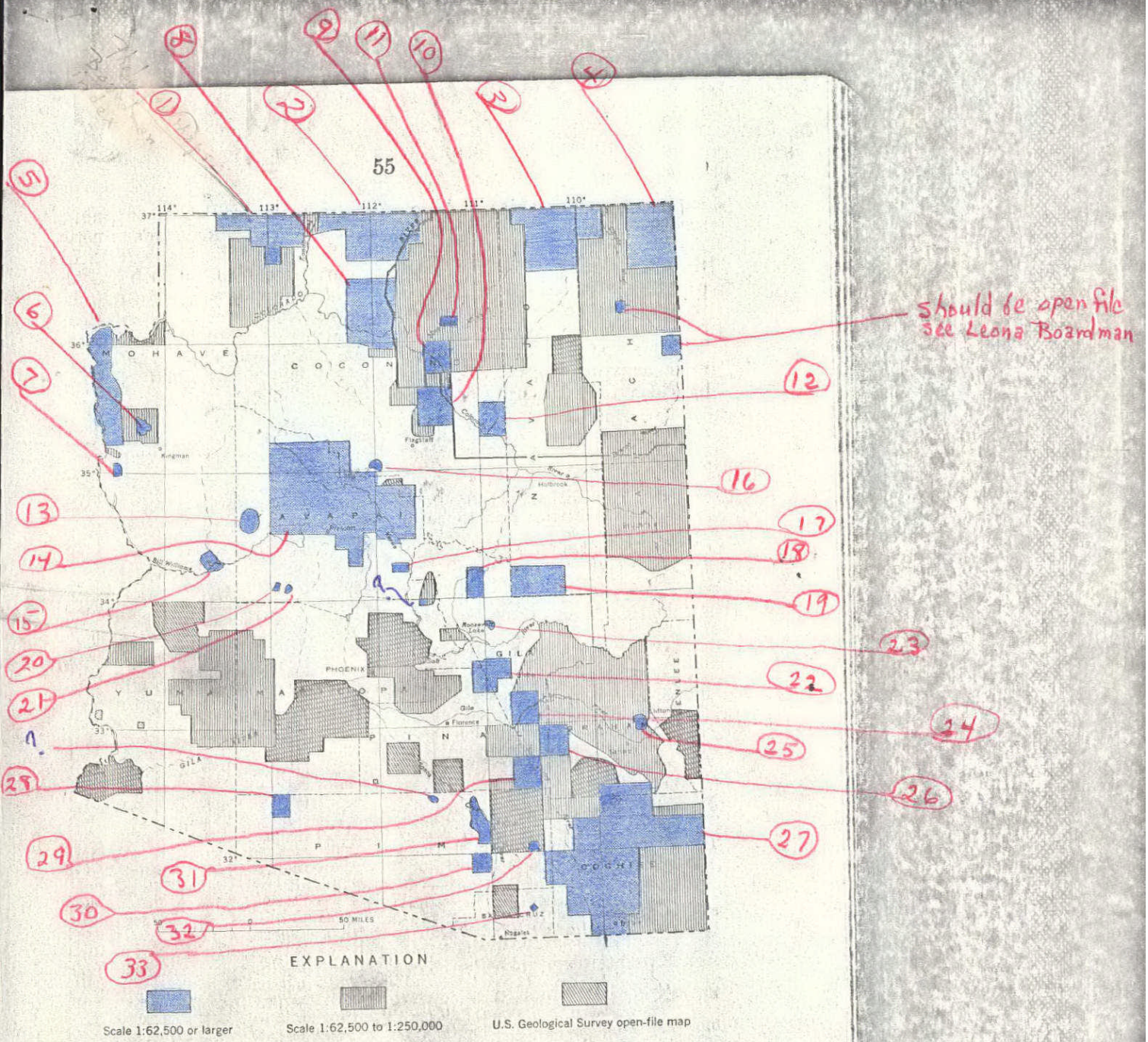


FIGURE 8.—Published geologic map coverage in Arizona, January 1968.

GEOPHYSICAL AND GEOCHEMICAL STUDIES

Geophysics and geochemistry are, respectively, the studies of the physical and chemical properties of the earth. A great many techniques have been developed, and are continually being improved, to measure the electric, magnetic, gravity, seismic, and chemical properties of the Earth. Geophysical and geochemical surveys, when properly interpreted, can be of extreme practical importance in determining subsurface structure and the locations of buried ore bodies, aquifers, potential oil-bearing formations, and other rock units. Many geophysical and geochemical surveys are conducted by or for private

Geologic map coverage in Arizona

Scale 1:62,500 or larger

1. Photo geologic maps from Leona Boardman index map of Ariz. 1

2. Photo geologic maps from Leona Boardman index map, also I-293 and I-252.

3. Photo-geol. maps from Leona Boardman index map; USGS Bull. 1103 (pl. 1); USGS Bull. 1202-A (pl. 1).

4. USGS OM.160

5. USGS WSP 1669-I !? P-374-E. Water Supply of Sunset Valley of San Pedro River, Mammoth. !!

6. 1949, Thomas, B. E., Ore deposits of the Wallapai district: Econ. Geol. v. 44, no. 8, fig. 2, USGS Bull. 978-E.

7. USGS Bull. 743

8. Maxson, J. H., 1967, Preliminary geol. map Grand Canyon and vicinity, Arizona: Grand Canyon Nat. History Assoc.

9. GQ-162

10. USGS WSP 1475-J

11. 1948, Brown, S. C., and Halpenny, L. C., Water Supply inv. at Tuba City Navajo Res: USGS Prelim. rept.

12. USGS I-352 (Kingman Quad.

13. Nev. Bur. Mines, Bull 69. PP278

14. USGS: I-502; I-503; I-504, I-505, Prof. Paper 308, 467, Bull. 1177; MF-228; I-501; I-500; I-499 SW 1/4 Mayer quad=open file/NE Mt. Union=open file.

15. USGS Bull. 936-R; USGS Bull 871.

16. USGS Bull. 1230-F

17. USGS Bull. 1230-J.

18. East 1/2 Diamond Butte-Gaskill, pl. 2

19. GQ-544; GQ-545

20. 1948 Babcock and Brown, Water Supply Data ck: Ariz. State Land Dept.

21. 1947, Halfpenny L. Cushman, Cactus Flat open file.

22. USGS Prof. Paper 342; USGS Bull. 1141-H.

23. USGS Bull. 1046-P

24. USGS Bull. 1161-E

25. USGS WSP 1589

26. USGS open file.

27. USGS I-418; MF 231; GSA Bull., v. 58; N. Mex. Bur. Mines Bull. 57; Prof. Paper 416; MF-213, PP-416; PP-281.

28. Arizona Bur. Mines Bull. 141.

29 USGS Bull 1218

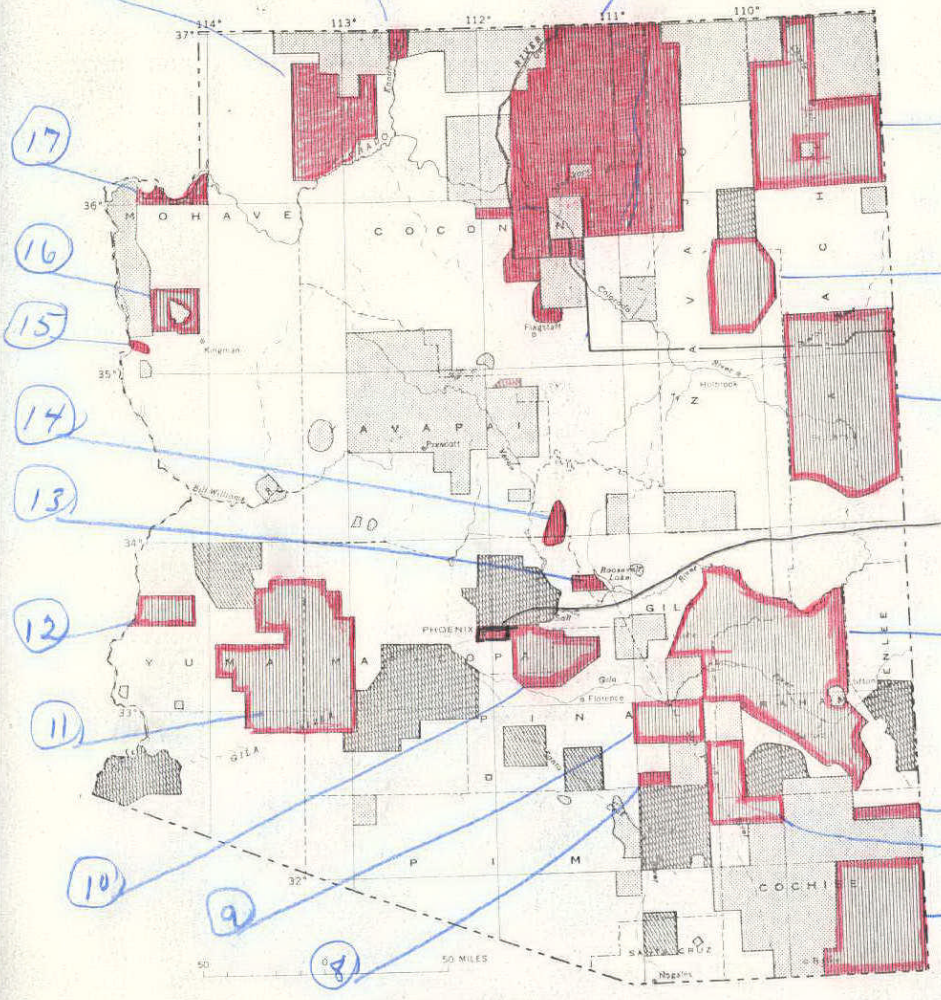
30. USGS Bull. 1112-C

31 GSA Bull., v. 50, no. 5.

32 Pan Am Geologist, v. 75, no. 4

33. AAPG Bull., v. 32, no. 1

om 145 extend too far east



should be omitted – is pre 1920

EXPLANATION

Scale 1:62,500 or larger

Scale 1:62,500 to 1:250,000

U.S. Geological Survey open-file map

FIGURE 8.—Published geologic map coverage in Arizona, January 1968.

GEOPHYSICAL AND GEOCHEMICAL STUDIES

Geophysics and geochemistry are, respectively, the studies of the physical and chemical properties of the earth. A great many techniques have been developed, and are continually being improved, to measure the electric, magnetic, gravity, seismic, and chemical properties of the Earth. Geophysical and geochemical surveys, when properly interpreted, can be of extreme practical importance in determining subsurface structure and the locations of buried ore bodies, aquifers, potential oil-bearing formations, and other rock units. Many geophysical and geochemical surveys are conducted by or for private

Scale 1:62,500 to 1:250,000

1. USGS I-345
2. Boardman 103a
3. USGS WSP-1771
4. Boardman 203, 123, 90.
5. Boardman 200 b, c, d.
6. USGS MF-213 and WSP-1354.
7. USGS MF-238
8. Boardman 185
9. USGS MF-238
10. Boardman 183
11. Ariz. Water Res. Rept. 4 and 3.
12. Boardman 77b
13. Boardman 92c
14. Boardman 92s
15. Boardman 72b
16. Boardman 193
17 Boardman 81
18 Boardman 120
19. Boardman 174
20. Boardman 197, 119, 194. OM-145 (OM-145 extends too far east).

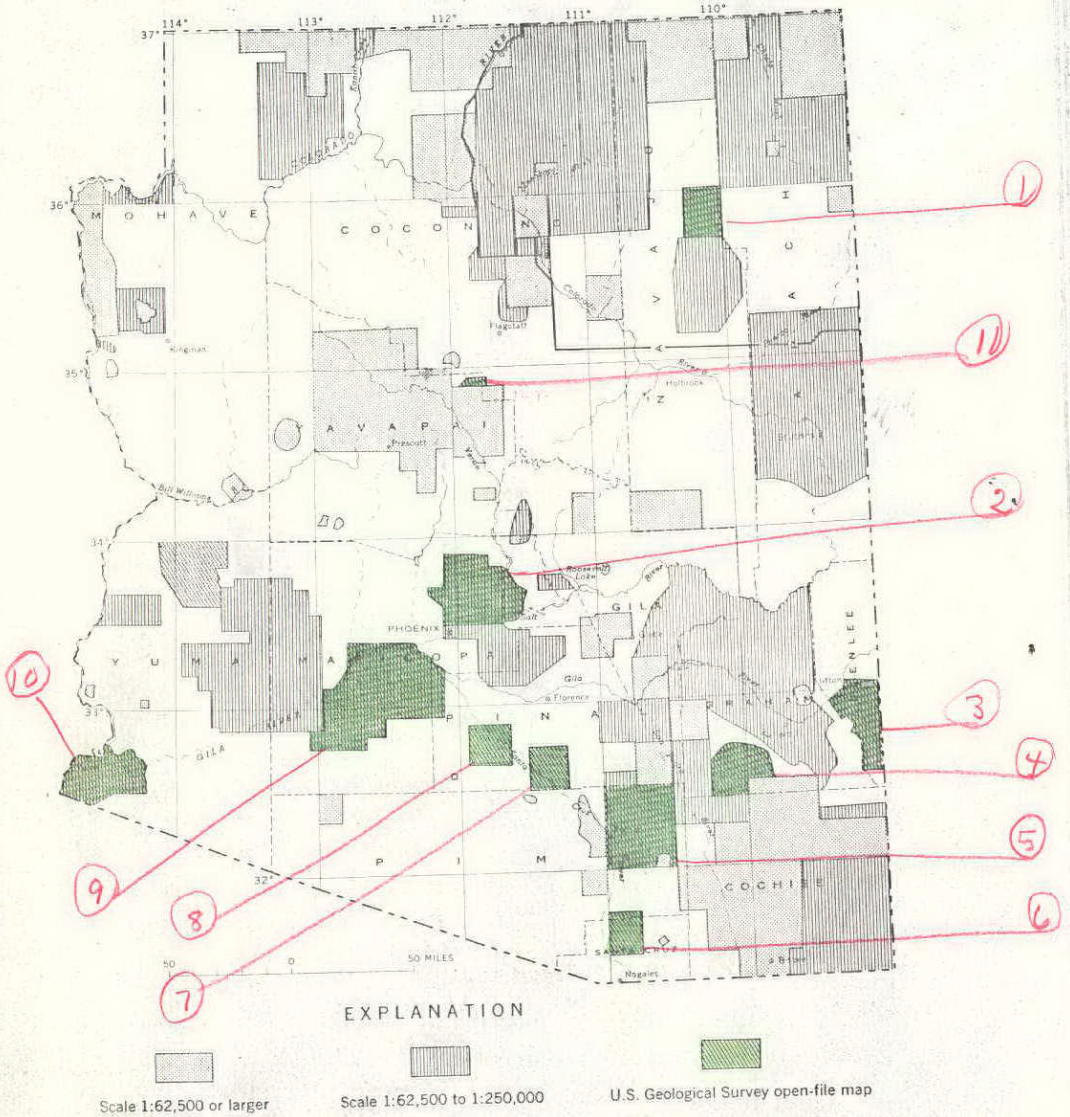


FIGURE 8.—Published geologic map coverage in Arizona, January 1968.

GEOPHYSICAL AND GEOCHEMICAL STUDIES

Geophysics and geochemistry are, respectively, the studies of the physical and chemical properties of the earth. A great many techniques have been developed, and are continually being improved, to measure the electric, magnetic, gravity, seismic, and chemical properties of the Earth. Geophysical and geochemical surveys, when properly interpreted, can be of extreme practical importance in determining subsurface structure and the locations of buried ore bodies, aquifers, potential oil-bearing formations, and other rock units. Many geophysical and geochemical surveys are conducted by or for private

USGS open-file maps

1. Boardman index # 180
2. Boardman index # 156, 131, and 121
3. Boardman index # 124
4. Boardman index # 134
5. Boardman index # 152
6. Drewes, Harold, 1966, Wrightson quad.
7. Boardman index # 166
8. Boardman index # 201
9. Boardman index # 143 and ~~105~~ 195
10. Boardman index # 248
11. Boardman 207

Ariz. Misc.
A-0.0.0.

September 23, 1969

Mr. Douglas M. Kinney
Geologic Map Editor
United States Geological Survey
Washington, D. C. 20242

Geologic Map of Arizona
Stable base, black-line negative

Dear Sir:

In pursuance of our telephone conversation of September 22, 1969, I submit an order for one negative copy of the 1969 Geologic Map of Arizona.

The map requested would be a one-piece sheet of clear stable material as a negative at the same scale as the published map (1:500,000). The base features of culture, subdivision lines, roads, etc., would be a light screened grey background with the geological boundaries, structure, etc., as bold black lines. The map negative would contain the legend, index, borders, etc., as does the published map.

Upon completion of the map, it would be submitted to this office rolled in a tube suitable for its safe transmission.

It is understood that the project price would be between two hundred and two hundred and fifty dollars. The billing to be for American Smelting and Refining Company, Tucson, Arizona 85703.

I thank you for your kind assistance with the completion of this project.

Sincerely,

ORIGINAL SIGNED BY
JAMES D. SELL

James D. Sell

JDS/kvs

cc: JHCourtright
WESaegart

Ariz. Misc.
A-0.0.0.

September 23, 1969

Mr. Douglas M. Kinney
Geologic Map Editor
United States Geological Survey
Washington, D. C. 20242

Geologic Map of Arizona
Stable base, black-line negative

Dear Sir:

Thank you for your recent aid and explanation for securing a negative copy of the Geologic Map of Arizona on a stable base with the geologic features shown as sharp black lines.

In checking with the local blueprint companies, I find that they can process negative maps up to 54 inches in width for making mylar, sepia, or ozalid prints.

Another point has been brought up. Can a stable base negative be secured with only the geologic features shown? How many pieces of copy are generally needed for compositing a geologic map? Would leaving off the culture base lower the cost significantly? Also, are all published maps by the USGS available in negative form on stable base material?

If any questions arise on our order in the accompanying letter, please contact either myself or Mr. J. Harold Courtright, Chief Geologist of the Southwestern Exploration Department, ASARCO.

Sincerely,

FOR ASARCO BY
JAMES D. SELL

James D. Sell

JDS/kvs

cc: JHCourtright
WESaegart

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WASHINGTON, D.C. 20242

September 30, 1969

Mr. James D. Sell
American Smelting and Refining Company
Southwestern Exploration Department
P. O. Box 5795
Tucson, Arizona 85703

Dear Mr. Sell:

In reply to your letters of September 23:

I have taken the letter ordering the combination of the blackline geology and base of the Geologic Map of Arizona to our Map Reproduction Branch, who will prepare the negative in their Silver Spring Laboratory. If the cost exceeds the dollar limits set in your letter, I will contact you again. My oral estimate of the time requirement for preparation of the negative is only an educated guess.

In answer to your second letter, it is good that you know that mylar, sepia, and other photographic process prints can be made locally. My concern was not that ozalid prints made on a revolving drum machine could be made but that cronaflex prints requiring a vacuum frame or sun frame up to 72 inches in length was available in Tucson.

Reproducible negatives or positives showing only geologic features can be supplied by our Map Reproduction Branch at cost. For most geologic maps two pieces of copy must be combined photographically to show the black geology. One piece of copy has all the line work and the second copy has all the type. Because the base for the Geologic Map of Arizona consists of 4 pieces of copy, each piece responsible for a printing plate showing a separate color, the omission of the base would make the cost considerably less, probably less than $100.00.

Reproducible line work and geologic symbol copy for all maps in the GQ, I, and other map series are retained by the Geological Survey and can be reproduced at established standard rates based on size of negative and number of pieces of original copy that must be combined. Line copy and symbols for some older maps included in Professional Papers and Bulletins are available on printing plates which must be taken from storage, cleaned, inked, and photographed. Other older maps were printed on contract outside the Geological Survey and for them no reproducible copy is available. Whether reproducible materials for the maps accompanying Gilluly's Central Cochise County, Arizona, report are available can only be determined by research by our Map Reproduction Branch. Any requests for reproducible copy of our printed geologic maps and their bases should be directed to the Chief, Publications Division, U.S. Geological Survey, Washington, D. C. 20242.

Your letters have been shown to Don Peterson, who sends his regards.

Sincerely yours,

Douglas M. Kinney

Douglas M. Kinney

AMERICAN SMELTING AND REFINING COMPANY
SOUTHWESTERN EXPLORATION DIVISION
P. O. BOX 5747, TUCSON, ARIZONA 85703

1150 NORTH 7TH AVENUE
TELEPHONE 602-792-3010

November 1, 1973

Mrs. Donald Skinner
Rt. 1, Box 38
Lakeside, Arizona 85929

Dear Mrs. Skinner:

After discussing the Arizona Map Compilation Project with Mr. Sell, I have decided to terminate your work as of 1 January 74. Prior to this date you should be able to complete the Phoenix sheet and bring the Prescott sheet to near completion.

Your work on this project has been excellent and I regret that we do not have any other long-term drafting jobs for you. From time to time we may have occasion to use your services on a contract basis.

By copy of this letter, I am informing Mr. Coumides, Chief Accountant, that your long association with ASARCO will end 1 January 74, and am asking him to communicate with you concerning retirement benefits, etc.

Very truly yours,

W. L. Kurtz
Manager of Exploration

WLK:lb

cc: ADCoumides
JDSell
VKellogg

ASARCO

Southwestern Exploration Division

October 29, 1976

TO: F. T. Graybeal

FROM: J. D. Sell

Southwest Structural Study
Arizona-New Mexico

The Arizona Geological Society publication committee has plans to publish a study of the structures and intrusions in Arizona. This study is a compilation by J. W. Allan and M. M. Swan, formerly with Kennecott Exploration, and will be completed and the text written by them. Publication date is Fall 1977.

Attached is an outline of their "Final Report-Southwest Structural Study" which will be the basis of the text. Also attached is a print of their preliminary map at a scale of 1:500,000 covering from the Colorado River to the Rio Grande River and south of the Colorado Plateau (in three parts).

Also attached is a copy of Swan's thesis.

Present plan is to redraft the 1:500,000 map and expand the coverage to include the Colorado Plateau in Arizona, then reduce the map to the scale and outline of the AGS Highway Geologic Map (1:1,000,000). The map will probably be in three colors to separate structures and intrusions based on age brackets: 1) Precambrian, 2) Laramide, 3) Post Mid-Tertiary (Basin and Range). For examples see the last five sheets of the Outline attachment.

Within their text they will detail the major mining districts and areas which best exemplify their concepts as indicated in the Outline. See Swan's thesis for the type of black and white 8-1/2 x 11 maps to be used.

This study, at present, represents some 13 man-years of devotion while self employed and funded and working with PD, KCC, and KEI, and perhaps others.

They have some 40 maps of 1° x 1° size blown up to 1:125,000 scale with all the structures-intrusives shown. These were used for the 1:500,000 compilation. It is hoped that the 1° x 1° sheets will be available for open-file at the Arizona Bureau of Mines.

As the above information is preliminary, it is requested that the maps not be disseminated nor discussed outside the office.

Jim

J. D. Sell

JDS:lb

Atts.

ASARCO

Southwestern Exploration Division

March 15, 1983

To: R. L. Brown

From: J. H. Courtright

EXPLORATION RECORDS

The following tabulation shows the state of Record Sheet reporting as of March 1st of this year.

	Number of ERS's Received		
Division Office	Thru January 1980	Thru February 1982	Thru February 1983
Vancouver	69	10	194
Toronto	--	--	--
Spokane	41	47	--
Denver	--	30	19
Knoxville	20	12	32
Tucson	33	71	35
Latin America	--	3	59
Perth	77	33	19

J. H. Courtright

J. H. Courtright

JHC/cg

cc: REGale
RSGray
JCBalla
DHHarper
WLKurtz
JDSell
DMSmith
HCWilliamson

FILE

JDS

ASARCO

Please Note and clarify your expression of item 27.
T. Dalla Vista
AE. Giesecke
FR. Kourty
HG Kreis
J.D. Sell

Southwestern Exploration Division

August 15, 1985

J.D. Sell, Manager
SW Exploration Div

Exploration Record Sheets

Among the Record Sheets produced here in the past few months there are several (11 sheets) wherein information on the extent of outcrop (item 27) is not provided. For example, on the Red Cloud Canyon sheet "Rocks of the P€ Chuckwalla Complex, etc." is entered under item 27 (Nature of Exposures), on the Osborne Wash sheet, "Adit and Cliff" appears under 27 and on the Lime Canyon sheet, "Surface Outcrops" is entered under 27.

Observing and recording the extent of outcrop is an elementary but essential feature of efficient prospecting. Unless the possible continuation, or recurrence of mineralization beneath cover, is taken into account, the evaluation of the potential of a prospect can be inadequate, or worse.

Since some geologists persist in misinterpreting item 27, the title should no doubt be expanded to read: "Nature of Exposures, Extent of Outcrop."

J. H. Courtright

J. H. Courtright

JHC:mek

cc: R.L. Brown
W.L. Kurtz
P.G. Vikre
D.M. Smith
J.C. Balla
D.D. Harper
R.S. Gray
H.C. Williamson

ASARCO

Southwestern Exploration Division

JHC
JDS

August 15, 1985

J.D. Sell, Manager
SW Exploration Div.

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J. H. Courtright

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cc: R.L. Brown
W.L. Kurtz
P.G. Vikre
D.M. Smith
J.C. Balla
D.D. Harper
R.S. Gray
H.C. Williamson

Blind note to R.L. Brown:

The Record Sheets referred to are not up to the generally high quality of those produced by the SWED in the past; however, it should be noted that two of the three geologists involved were on loan ---- one from the NW Div. and one from the Eastern Div.

JHC

JDS

ASARCO

Southwestern Exploration Division

August 15, 1985

J.D. Sell, Manager
SW Exploration Div.

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J. H. Courtright

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JHC:mek

cc: R.L. Brown
W.L. Kurtz
P.G. Vikre
D.M. Smith
J.C. Balla
D.D. Harper
R.S. Gray
H.C. Williamson

JDS

ASARCO

Southwestern Exploration Division

April 8, 1986

Mr. D. M. Smith, Manager
Rocky Mountain Exploration Division

Exploration Records

Dear Douglas:

I have reviewed the 14 "Asarco Exploration Records" sent here during the past month. The new format which you have implemented contains all items of the standard ERS and is more flexible, being turned out on a word processer machine. It is, however, somewhat less easy to read than the pre-printed form. Along with attached highway location map, assay results and sample location map, these records comprize brief, but quite adequate reports for most prospects.

In only one case, the San Tex mine in New Mexico, is follow-up recommended. There, one surface sample ran 2.5 ppm Au. Since the best of 12 other samples in the vicinity was .03 ppm, I suggest that first a check assay be run on the 2.5 ppm sample.

In regard to the Wind River Gold prospect, your 20 samples all ran less than .009 ppm Au in an area where 40 USGS samples ranged from less than .01 ppm to 2.0 ppm and averaged .222 ppm (per Cu yd). You have stated (under Conclusions ...) that the USGS values were derived from panned concentrates. If so, your sample results would not be surprising; however, on the next to the last page of attachments (pg. 9) with my letter of 8-07-85 it is stated under the heading "Sampling" that "the samples were small (1-2 lbs.) and preference was commonly given to conglomerate matrix and sandstone .... Round stones were included in samples of the conglomerate, but commonly were not in proportion to their abundance." Some upgrading no doubt occurred in the conglomerate samples, but not in the sandstone. I am attaching

the following pages (10 and 11) where it is pointed out that "to obtain reliable evaluation data .... very large samples should be taken because most 15 g (portions assayed) will not contain even one gold particle."

On the same page under a separate heading, panned concentrates are discussed at some length and a table on page 11 compares the average in-place content of gold (ppb), first, computed from panned concentrates, second, indicated by analytical data. Of note are those from the Wind River Formation where the first gave 24 ppb and the second 222 ppb. I suggest you contact the authors of GS circular 541 and determine, if possible, the precise location of their samples, or at least that of localities 40, 41, and 42. Additional sampling may be justified.

Some time ago I obtained Open File Report #75-328, 1975, which gives sample descriptions, locations and analytical detail of the program reported in USGS circular 541. The Wind River sample data were not included as they had unfortunately been destroyed in a warehouse fire.

J. H. Courtright

J. H. Courtright

JHC/gb

Attachments

cc: RLBrown - with attachs.
WLKurtz - " "

sampling error is large. The average mass of gold particles recovered by washing in a gold pan is about 8 micrograms; the average grade found so far at most localities is between 50 and 100 ppb. To obtain reliable evaluation data at this level of particle size and concentration, very large samples (several hundred pounds) should be taken because most 15-g samples will not contain even one gold particle. Although the particles are very small (more than 1,000 are required to make 1 cent's worth of gold), they are not evenly distributed, and wide deviations in analytical results are therefore inevitable.

It is important to note that one or a few samples with relatively high gold content can change significantly the average grade at a locality and that these high values cannot be excluded because such scatter in analyses is typical of economic deposits. For example, in a study of gold ore from the Witwatersrand in South Africa, the U.S. Bureau of Mines found that one-half of the gold was in fewer than 10 percent of 495 samples; and in ore from the Homestake mine in South Dakota, one-half of the gold was in 3 percent of 219 samples (George S. Koch, Jr., written commun., 1966).

A final word of caution concerns gold analyses in all tables. The figures presented do not necessarily provide a basis for quantitative comparisons of gold values between one area and another because different sampling patterns rather than sampling problems or actual differences in gold content may account for some of the variations.

PANNED CONCENTRATES—THEIR PROBLEMS AND CONTRIBUTIONS

In an attempt to solve the difficult problem of determining reliably the gold content of rocks containing very small amounts of gold, extensive experiments were made to preconcentrate large samples and then to analyze the concentrates.

As a test of the effectiveness of a simple concentration method in obtaining representative 15-g samples for analysis, 754 field samples, for which bulk analyses were available, were concentrated by hand panning with a gold pan, and the concentrates were analyzed. This procedure should facilitate determination of the gold content of several hundred grams of sample but, like the bulk sample analyses, is subject to error that may be very large. The panned concentrates were analyzed for gold using a sodium bromate-hydrobromic acid-atomic absorption procedure that is quite satisfactory for small samples with high gold content. Panning was done by J. G. Frisken, W. H. Raymond, F. S. Fisher, and J. C. Antweiler, and analyses were made under the direction of J. C. Negri by Elizabeth Martinez, S. McDanal, H. King, B. Hansen, A. Toevs, A. Meier, T. A. Roemer, C. Cole, and R. Miller.

Averages of the gold content in concentrates from each locality are given in table 9. The field samples and the concentrates obtained from them were weighed, and the percentage of gold recovered in the concentrates, shown in the last column of table 9, was obtained by computation from the gold content of the bulk samples. A few analyses were made of the material that floats and remains in suspension when the sample is first wet with water, and some analyses were made of the material washed out of the pan during the panning process.

The tests made so far on concentration of samples by panning lead to several conclusions. First, some samples have gold particles that cannot be recovered by panning because they float on the surface of the water; this is shown by the high gold content of some of the very fine size fractions. Second, some gold particles cannot be recovered because they are washed out during panning, either because they are very small or because they are attached to lighter grains that are washed out; analyses of a few of the "tails" fractions show about the same gold content as the bulk samples. Third, some panned concentrates yield more gold than is indicated by the bulk sample analysis. During some panning, this gold is visible, but commonly it is not; the invisible gold may be attached to or tied up in the structure of heavy minerals such as magnetite.

The gold that is recovered but not seen is finely divided and uniformly distributed so that analyses of replicate splits are in reasonable agreement. Visible gold particles, however, are few in number and so erratic in distribution that replicate analyses may give widely varying results.

Recovery of gold by panning is influenced not only by the uncertainties just discussed but also by the skill of the panner. In one test, a weighed amount of gold, in particles somewhat larger than the average flake observed in the natural samples, was added to 500 g of typical sample material, and the sample was then panned by two people. Recovery by one operator was about 40 percent and by the other about 24 percent. In view of the fact that problems of panning all result in loss of gold, it is not surprising that average recoveries from concentrates shown in table 9 are low.

Despite the low recoveries obtained by panning, we believe the effort is justified; gold missed in analysis of bulk samples is discovered in concentrates of some samples, and a crude knowledge is obtained of the particle size at various localities. For example, at localities 1 and 2, at the northwest end of the Teton Range, analyses of bulk samples indicated average gold contents of 64.8 and 145.4 ppb (11 and 23 cents per cu yd), respectively, but only 2.3 percent of the gold was recovered by panning at locality 1 and only 2.0 percent at locality 2. Practically no accessory heavy minerals were recovered at either locality. The very small particle size of gold suggests the possibility that gold precipitated after deposition of the conglomerate. If the gold is indeed not detrital at this place, then it may not be in many other areas of conglomerate in northwestern Wyoming.

Table 9.—Comparison of gold content in panned concentrates with that in unconcentrated samples

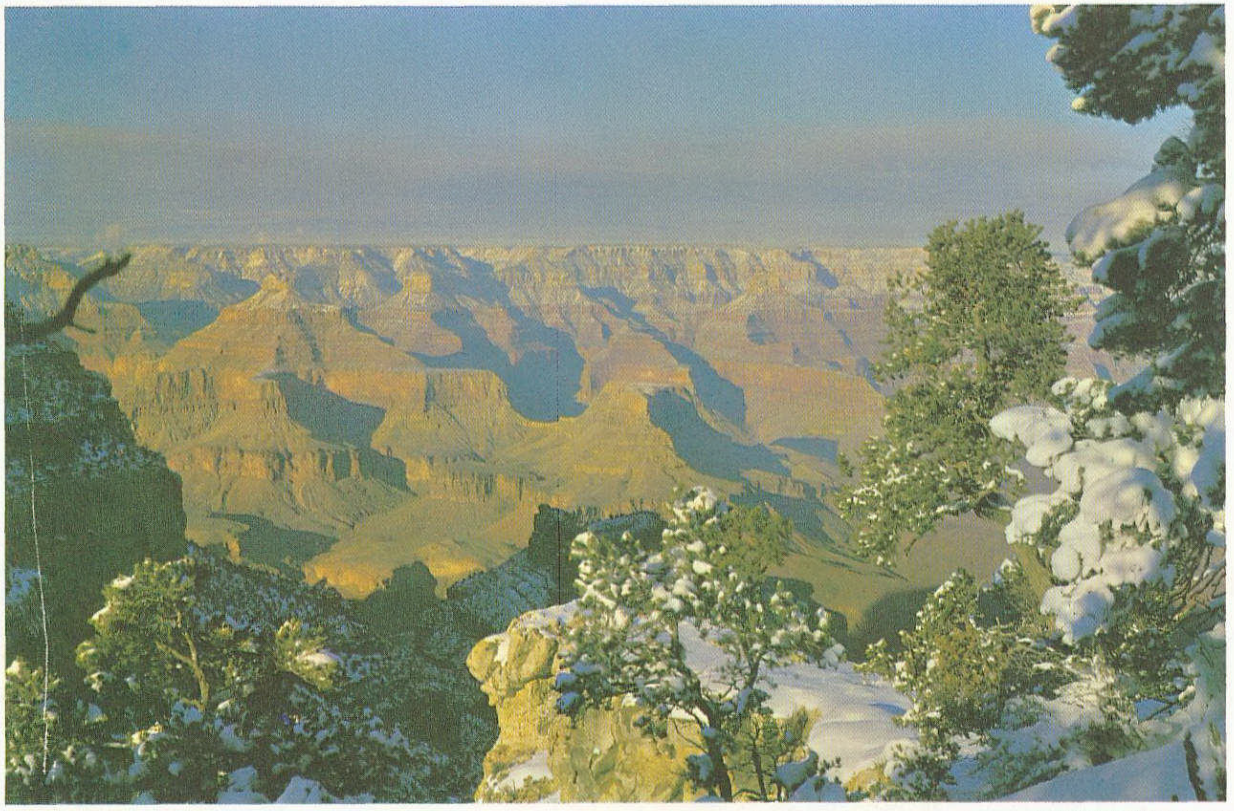
Locality No.	No. of samples panned	Au (ppb) recovered in concentrate by panning: Range <100 to-	No. of samples having >1,000 ppb	Average Au	Average in-place content of Au (ppb): Computed from Au recovered by panning	Indicated by analytical data (No. of samples in parentheses)		Percent of indicated Au recovered by panning
Harebell Formation (Upper Cretaceous)								
9	24	14,400	2	690	2.8	31.3	(23)	8.9
10	25	38,000	10	4,930	19.4	43.3	(39)	44.8
11	36	17,900	9	1,200	5.0	99.7	(59)	5.0
12	7	400	0	165	.5	70.0	(10)	.7
31	6	1,000	1	225	1.0	83.2	(14)	1.2
	1/ 98	2/ 38,000	1/ 22	3/ 1,890	3/ 7.6	3/ 65.2	1/ (145)	3/ 11.5
Pinyon Conglomerate (Paleocene)								
2	8	3,500	3	994	2.9	145.4	(13)	2.0
5	75	30,900	15	2,160	10.8	75.4	(74)	14.3
6	17	40,000	7	3,620	15.9	203.0	(37)	7.8
7	20	55,000	8	5,210	14.1	52.9	(31)	26.7
17	7	250	0	65	.6	33.7	(33)	.2
18	46	16,700	13	1,730	9.8	50.4	(84)	19.4
31	11	6,000	2	750	1.9	73.2	(31)	2.6
32	44	50,800	10	2,660	11.5	112.7	(103)	10.2
33	25	28,500	9	2,770	15.6	116.3	(26)	13.4
34	35	55,100	11	3,880	21.8	151.0	(39)	14.4
4/35	16	38,500	8	4,610	23.9	30.2	(45)	79.1
35S	39	32,000	22	3,670	34.4	85.0	(30)	40.5
36	19	4,700	1	295	1.5	138.0	(20)	1.1
37	18	1,000	3	228	1.2	50.8	(24)	2.4
38	12	11,000	2	1,680	12.1	27.6	(31)	43.8
39	17	8,400	4	1,240	19.3	87.1	(31)	22.2
	1/ 409	2/ 55,100	1/ 118	3/ 2,480	3/ 14.1	3/ 86.0	1/ (652)	3/ 16.4
Fort Union Formation (Paleocene)								
52	14	4,000	5	710	3.8	35.4	(14)	10.7
Lowest(?) Eocene conglomerate, Bighorn Basin								
53	26	24,000	9	2,500	10.4	94.4	(26)	11.0
Wind River Formation (lower Eocene)								
40	16	3,000	3	3,000	3.4	220.0	(23)	1.5
41	2	4,500	1	2,250	50.0	227.0	(3)	22.0
42	11	40,400	6	6,260	54.1	223.2	(14)	24.2
	1/ 29	2/ 40,400	1/ 10	3/ 2,720	3/ 24.2	3/ 221.8	1/ (40)	3/ 10.9
Pass Peak Formation (middle(?) Eocene) of Eardley and others (1944)								
50	20	11,200	6	1,770	25.8	46.6	(25)	55.4
Quartzite boulder conglomerate in Miocene(?) pyroclastic sequence								
1	18	10,000	3	840	1.5	64.8	(21)	2.3
Quaternary deposits derived chiefly from the Harebell Formation, Pinyon Conglomerate, Wind River Formation, and Pass Peak Formation of Eardley and others (1944)								
3	3	5,000	2	2,370	18.3	228.0	(5)	8.0
4	5	21,000	3	7,700	101.0	615.8	(6)	16.4
7	5	2,520	3	9,000	13.6	64.6	(15)	21.1
8	14	23,500	8	4,360	58.7	71.0	(5)	82.7
15	14	2,800	1	200	1.9	104.6	(14)	1.8
16	15	10,900	4	1,250	6.5	65.0	(16)	10.0
5/20	35	12,000	7	1,000	5.2	44.0	(49)	11.8
20	15	18,100	8	3,600	21.6	107.0	(20)	20.2
24	7	6,800	3	2,140	11.7	88.8	(12)	13.2
45	6	7,500	2	1,750	6.6	188.7	(8)	3.5
46	7	<100	0	<100	<1.0	57.1	(7)	0
49	1	4,900	1	4,900	25.0	25.0	(1)	100.0
	1/ 127	2/ 23,500	1/ 42	3/ 2,050	3/ 17.5	3/ 98.3	1/ (158)	3/ 17.8
Pre-Harebell rocks (or alluvium derived therefrom)								
43	2	1,750	1	850	6.0	35.0	(2)	17.1
44	3	1,700	1	800	.7	132.5	(4)	.5
47	2	1,100	1	550	1.5	50.0	(2)	3.0
48	2	300	0	150	.5	<10	(2)	----
51	4	6,900	1	1,800	4.9	41.2	(4)	11.9
	1/ 13	2/ 6,900	1/ 4	3/ 980	3/ 2.4	3/ 21.3	1/ (14)	3/ 11.2

1/ Total. 2/ Highest value. 3/ Overall average. 4/ Scarp. 5/ River bottom.

Arizona Geological Society
P. O. Box 4489, University Station
Tucson, Arizona 85717

ARIZONA

HIGHWAY GEOLOGIC MAP



Ray Manley Photograph

PUBLISHED BY ARIZONA GEOLOGICAL SOCIETY

To: _____

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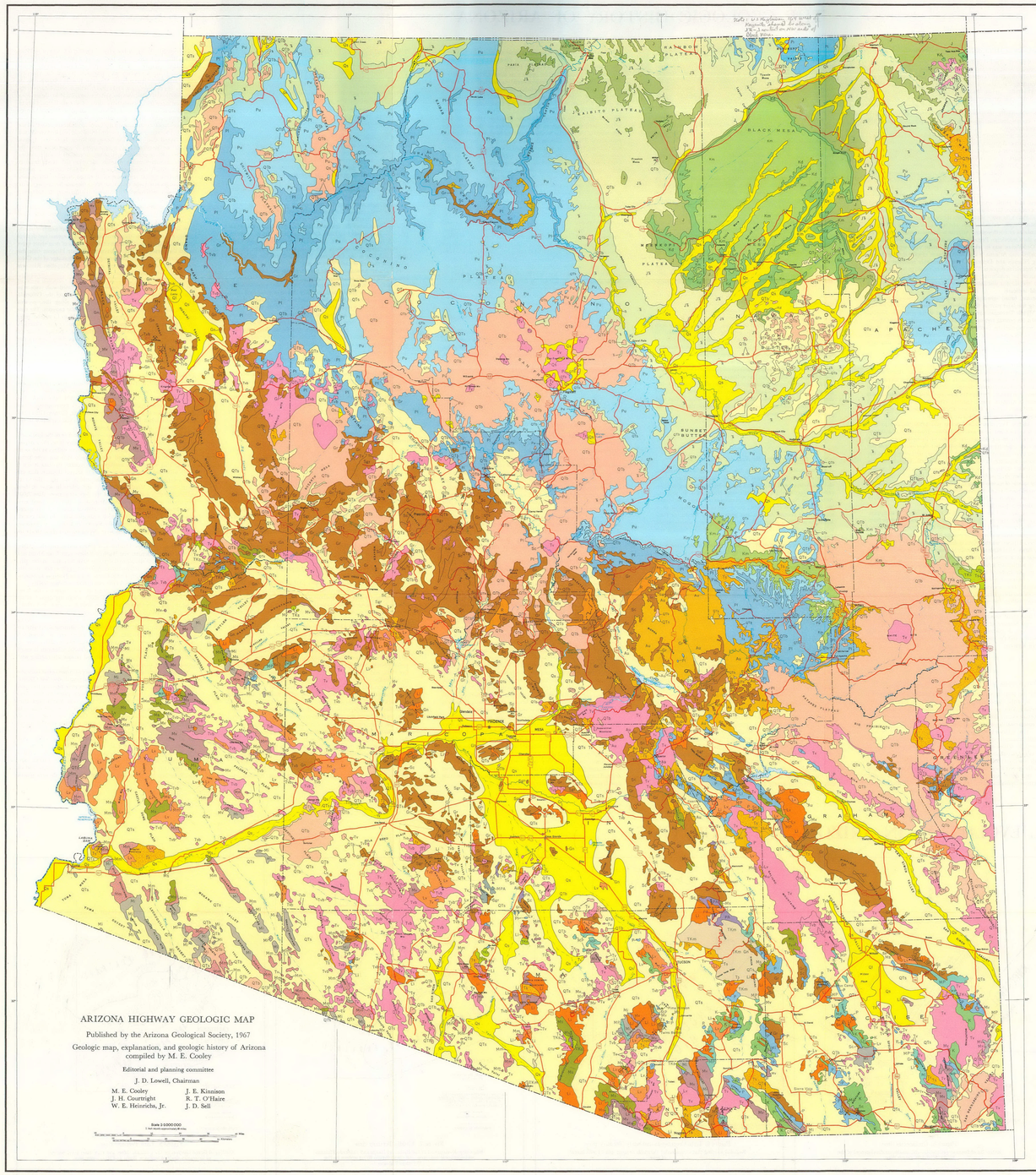

EXPLANATION

PERIOD	EPOCH	(MILLIONS OF YEARS BEFORE PRESENT)
QUATERNARY	RECENT	0.01 M. Y.
	PLEISTOCENE	2-3 M. Y.
TERTIARY (CENOZOIC ERA)	LATE: PLIOCENE	12 M. Y.
	MIDDLE: MIOCENE	25 M. Y.
	MIDDLE: OLIGOCENE	40 M. Y.
	EARLY: EOCENE AND PALEOCENE	70 M. Y.
CRETACEOUS (MESOZOIC ERA)		135 M. Y.
JURASSIC (MESOZOIC ERA)		180 M. Y.
TRIASSIC (MESOZOIC ERA)		225 M. Y.
PENNSYLVANIAN AND PERMIAN (PALEOZOIC ERA)		600 M. Y.
CAMBRIAN TO MISSISSIPPIAN (PALEOZOIC ERA)		
PRECAMBRIAN ERA: YOUNGER		
PRECAMBRIAN ERA: OLDER		3,000+ M. Y.

SEDIMENTARY ROCKS

Qa, Ql — Unconsolidated flood-plain alluvium (Qa), including lake and beach deposits at Willcox Playa and Red Lake

QTs — Weakly to moderately consolidated alluvium of early Quaternary and late Tertiary age, including Gila Group (Gila Conglomerate) in parts of central and southern Arizona, Hidahochi Formation in northeastern Arizona, Verde Formation near Jerome, Muddy Creek Formation and Hualpai Limestone near Lake Mead. Includes terrace deposits, alluvial fans, and deposits overlying pediments of late Quaternary age. Unconformities are present in the alluvial sequence

Unconformity

Ts — Rocks of middle Tertiary (roughly late Eocene to early Miocene) time, including the Helmet Fanglomerate, Pantano Formation, Whitetail Conglomerate, and Locomotive Fanglomerate in southern Arizona and the Chuska Sandstone and sedimentary units of the Dell Formation in northeastern Arizona

Major unconformity

Laramide orogeny

TKs — Rocks of Late Cretaceous to early Tertiary age, including the Claflin Ranch Formation, Cloudburst Formation, and other unnamed rocks in southern Arizona; pale-red conglomerate and sandstone near Springerville; and many unnamed rocks in western Arizona

Major unconformity

Km — Mesaverde Group, in descending order, the Yale Point Sandstone, Wepo Formation, and Toreva Formation in Black Mesa; Gallup Sandstone along the Arizona-New Mexico State line; and undivided rocks near the Mogollon Rim

Kd — Mancos Shale and Dakota Sandstone

Unconformity

K — Rocks of Late and Early Cretaceous age in southern Arizona, including the Sonoita Group; Patagonia Group; Bisbee Group, in descending order, the Cintura Formation, Mural Limestone, Morita Formation, and Glance Conglomerate; Recreation Red Beds; and Amole Arkose. Probably includes some rocks of pre-Cretaceous Mesozoic age and Late Cretaceous-early Tertiary age

Mz — Conglomerate, shale, and sandstone of probable Mesozoic age in southern and western Arizona

J — Rocks, in descending order, the Morrison Formation, Cow Springs Sandstone, and San Rafael Group, in descending order, the Summerville Formation, Entrada Sandstone, and Carmel Formation

JTr — Glen Canyon Group, in descending order, the Navajo Sandstone, Kayenta Formation, Moenave Formation, and Wingate Sandstone

Tr — Chinle and Moenkopi Formations. An unconformity is present between these formations

Major unconformity

Pu — Sedimentary Permian rocks, in descending order, the Kaibab Limestone, Toroweap Formation, and Coconino Sandstone in the Grand Canyon-Mogollon Rim region; and the De Chelly Sandstone in the Defiance Plateau

Pl — Sedimentary rocks of Permian to Cambrian age in the Colorado Plateaus and Mogollon Highlands, in descending order, the Hermit Shale and Cutler Formation of Permian age; Supai Formation of Permian and Pennsylvanian age; Naco Formation and part of Callville Limestone equivalent of Pennsylvanian age; Redwall Limestone of Mississippian age; Martin Formation and Temple Butte Limestone of Devonian age; and Muav Limestone, Bright Angel Shale, and Tapeats Sandstone of Cambrian age. Includes the Troy Quartzite which is of late Precambrian age. An unconformity is present between the Pennsylvanian and Mississippian rocks, Mississippian and Devonian rocks, and Devonian and Cambrian rocks

MPA — Mesozoic and Paleozoic rocks and Apache Group undivided

MP — Mesozoic and Paleozoic rocks undivided

P — Sedimentary rocks of Permian to Cambrian age in southern Arizona, in descending order, the Naco Group that in descending order includes the Rainvalley Formation, Concha Limestone, Scherrer Formation, Epitaph Dolomite, and Colina Limestone of Permian age; Earp Formation of Permian and Pennsylvanian age; Horquilla Formation of Pennsylvanian age; Escabrosa Limestone of Mississippian age; Martin Limestone and Morenci Shale of Devonian age; Longfellow Limestone of Ordovician and Cambrian age; and Abrigo Limestone, Bolsa Quartzite, and Coronado Quartzite of Cambrian age. Includes the Troy Quartzite of late Precambrian age

PA — Paleozoic rocks, Troy Quartzite, and Apache Group undivided

Major unconformity

Aw — Rocks of younger Precambrian age including the Grand Canyon Series in the Grand Canyon and the Apache Group, in descending order, the Mescal Limestone, Dripping Springs Quartzite (including as the basal unit the Barnes Conglomerate Member), Pioneer Shale, and Scanlan Conglomerate in central and southern Arizona. Includes Troy Quartzite and large intrusive masses of diabase exposed principally in east-central Arizona

Major unconformity

R — Sedimentary and volcanic rocks undivided of older Precambrian age. Includes the Mazatzal Quartzite and Red Rock Rhyolite

IGNEOUS ROCKS

VOLCANIC ROCKS

QTb — Basalt flows, cinder cones, dikes, and necks. Includes some rhyolite and andesite flows and tuffs

Tv, TVb — Tv, andesite, rhyolite, latite, and dacite flows, welded tuff, and tuffs; includes some flows of Quaternary age near Flagstaff. TVb, dark andesite, basaltic andesite, and basalt

Lv — Chiefly rhyolite, andesite, and latite flows, welded tuffs, and tuffs. Includes the Silver Bell Andesite, Cat Mountain Rhyolite, and Bronco and Concentrator Volcanics

Mv — Rhyolite to andesite of Mesozoic and Mesozoic(?) age in southern and western Arizona. Includes the Kofa and Gold Road

INTRUSIVE ROCKS

Li — Intrusive igneous rocks consisting mainly of granite and monzonite, usually porphyritic

Mi — Intrusive igneous rocks of Mesozoic and Mesozoic(?) age in southern and western Arizona

Gr — Chiefly granite

METAMORPHIC ROCKS

TKm — Mainly schist and gneiss, including the Catalina Gneiss

Mm — Metamorphic rocks consisting of gneiss and schist of Mesozoic and Mesozoic(?) age

Sgr, Sc, Gn — Schist (Sc), including the Yavapai, Pinal, and Vishnu Schists, gneiss (Gn), and schist and granite undivided (Sgr)

STRUCTURAL EVENTS

Continued uplift of the Colorado Plateaus, which was accompanied by uplift of much of southeastern and northern Arizona and subsidence in the Gulf of California embayment and in the Phoenix basin of central Arizona; some small-scale normal faulting, but large-scale normal faulting took place to the west of Arizona in the Gulf of California embayment

Continued uplift of the Colorado Plateaus as large-scale normal faulting and tilting was prevalent in the Basin and Range province; recurrent fault movements accompanied by subsidence in the valleys and uplift in the mountains accentuating and developing the mountain ranges and valleys of the Basin and Range province; beginning of subsidence and development of Gulf of California embayment

General structural quiescence in northeastern Arizona and structural unrest in southern and western Arizona that included local folding, large-scale normal faulting and thrust faulting; thrust faulting was not as intense as it was during the Laramide orogeny; beginning of uplift of northeastern and central Arizona, the formation of mountain chains and valleys in southern and western Arizona, and the development of the Colorado Plateaus (in northeastern Arizona) and Basin and Range physiographic provinces (in the rest of the State)

Major structural activity of the Laramide orogeny, including uplift, large-scale thrust and normal faulting, igneous intrusion, and volcanism; regional folding and uplift destroyed the Rocky Mountain and Sonoran geosynclines and formed the basins and monoclines of the Colorado Plateaus

General subsidence in northern and eastern Arizona with the maximum extension of the Late Cretaceous Rocky Mountain geosyncline; continued structural and igneous activity in much of western and southern Arizona

Subsidence of the eastern part of the Mogollon Highlands with the northwestward extension of the Sonoran geosyncline into southeastern Arizona during Early Cretaceous time; generally, upwarping in northern Arizona; continued structural and igneous activity throughout much of southern Arizona

Slight upwarping and downwarping accompanied by the maximum southward extension of the Jurassic seas into northeastern Arizona; continued structural and igneous activity in southern Arizona

Regional structural unrest; the area occupied by the Cordilleran geosyncline was elevated and remained high throughout most of remaining Mesozoic time; considerable faulting, volcanism, igneous intrusion, and some metamorphism in southern Arizona; gentle upwarping and downwarping in northern Arizona

Regional upwarping and subsidence in northern Arizona; more intense structural activity accompanied by the rise of the Mogollon Highlands and some volcanism in southern Arizona; Uncompahgre Highlands continued to be prominent in southwestern Colorado

Broad, intermittent warping movements accompanied by the rise of the Uncompahgre Highlands in southwestern Colorado

General structural quiescence; gentle downwarping tended to be centered in the northwestern and southeastern Arizona areas of the Cordilleran and Sonoran geosynclines, respectively, and intermittent upwarping and downwarping in the other parts of the State

Widespread upwarping accompanied by large-scale normal faulting, intrusion of diabase, and the formation of the Sonoran and Cordilleran geosynclines; this structural activity often is referred to as the Grand Canyon Disturbance

General downwarping

Major structural and igneous activity including the Mazatzal Revolution

ECONOMIC PRODUCTS

Aggregate—gravel, sand, and cinders; volcanic ash, bentonite, and clay; limestone, gypsum, and salt (halite); uranium from diatremes in Hopi Buttes and in Grand Canyon; alluvial deposits of sand and gravel are the chief source of ground water in southern and western Arizona

Gold, mercury, and some manganese; sandstone and conglomerate yield some ground water in Chuska Mountains and near Phoenix, Tucson, and Gila Bend

Copper with some lead and zinc at Morenci, Globe, Miami, Ray, San Manuel, Silverbell, Pima, Ajo, Esperanza, Mission, Christmas, Superior, Hagdad, and Kingman

Coal and some uranium in Mesaverde Group; coal in Dakota Sandstone; copper in intrusive rocks at Bisbee; uranium and vanadium mined from Chinle Formation in Monument Valley and near Cameron and from Morrison Formation in the Carrizo Mountains, most mines now abandoned; limestone used for cement from Mural Limestone; Navajo Sandstone is one of the main water-yielding units of northeastern Arizona

Oil and gas from Pennsylvanian, Mississippian, and Devonian rocks in northeastern Arizona; potash in Supai Formation; helium from Coconino Sandstone; limestone used for cement principally from Mississippian rocks; flagstone from Coconino Sandstone; Coconino Sandstone and De Chelly Sandstone are chief water-yielding units tapped by wells in northeastern Arizona; large springs issue from the Muav and Redwall Limestones in Grand Canyon

Gold mines, largely abandoned, in all mountainous regions; Iron King mine near Prescott produces copper, gold, and zinc; abandoned mines at Jerome produced copper; asbestos from Mescal Limestone; deeply weathered granite and fractured rocks yield small amounts of water to wells, especially along faults

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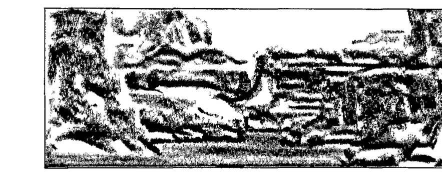
ARIZONA HIGHWAY GEOLOGIC MAP

GRAND CANYON

The Grand Canyon is at the same time one of the most awesome scenic features on the face of the earth and a textbook of earth history Here the Colorado River has cut a mile-deep slice into the earth's crust, not only illustrating the erosive power of running water but also exposing rocks that were formed nearly two billion years ago, when our planet was young A great amount of geologic time, Older Precambrian, Younger Precambrian, and Paleozoic, is recorded in the walls of the canyon, and in places rocks of the Mesozoic are found near the canyon as erosional remnants



MARBLE CANYON

Marble Canyon, formed by the Colorado River, is rimmed by the Permian Kaibab Limestone and carved into red sandstone, shale, and limestone of Paleozoic age, upstream from the Grand Canyon When traveling downstream, the canyon is a prelude to the Grand Canyon West of the canyon, the East Kaibab monocline, a great earth flexure, carries the Kaibab Limestone and other sedimentary formations abruptly up 3,000 feet to the level of the Coconino and Kaibab Plateaus On the east, the Colorado River enters Marble Canyon at Lees Ferry, east of Navajo Bridge on Highway 89, where a great line of cliffs composed of Mesozoic rocks makes another flexure that drops the Kaibab Limestone deep below the landscape.

MONUMENT VALLEY

The towering spires and buttes of Monument Valley are erosional remnants of red Permian sandstone and shale, the highest of them capped by a resistant layer of Triassic Shinarump Member of the Chinle Formation The sheer cliff near the top of each pinnacle is formed by Permian De Chelly Sandstone, once a great blanket of windblown sand that covered much of the Four Corners region The monuments are widely familiar as an impressive backdrop to scenes in dozens of western movies purportedly representing locales from Laramie to Lordsburg.

PAINTED DESERT

The brilliant hues of the Triassic Chinle Formation are to be seen in numerous localities in northeastern Arizona, but the term Painted Desert is particularly applied to exposures along Highway 89 at the base of Echo Cliffs and in the Little Colorado River valley traversed by Highway 66. The colors, mostly red, brown, pink, and purple, present an endless variety of changing shades and patterns under differing atmospheric conditions but usually show to best advantage in the late afternoon sun

SUNSET CRATER

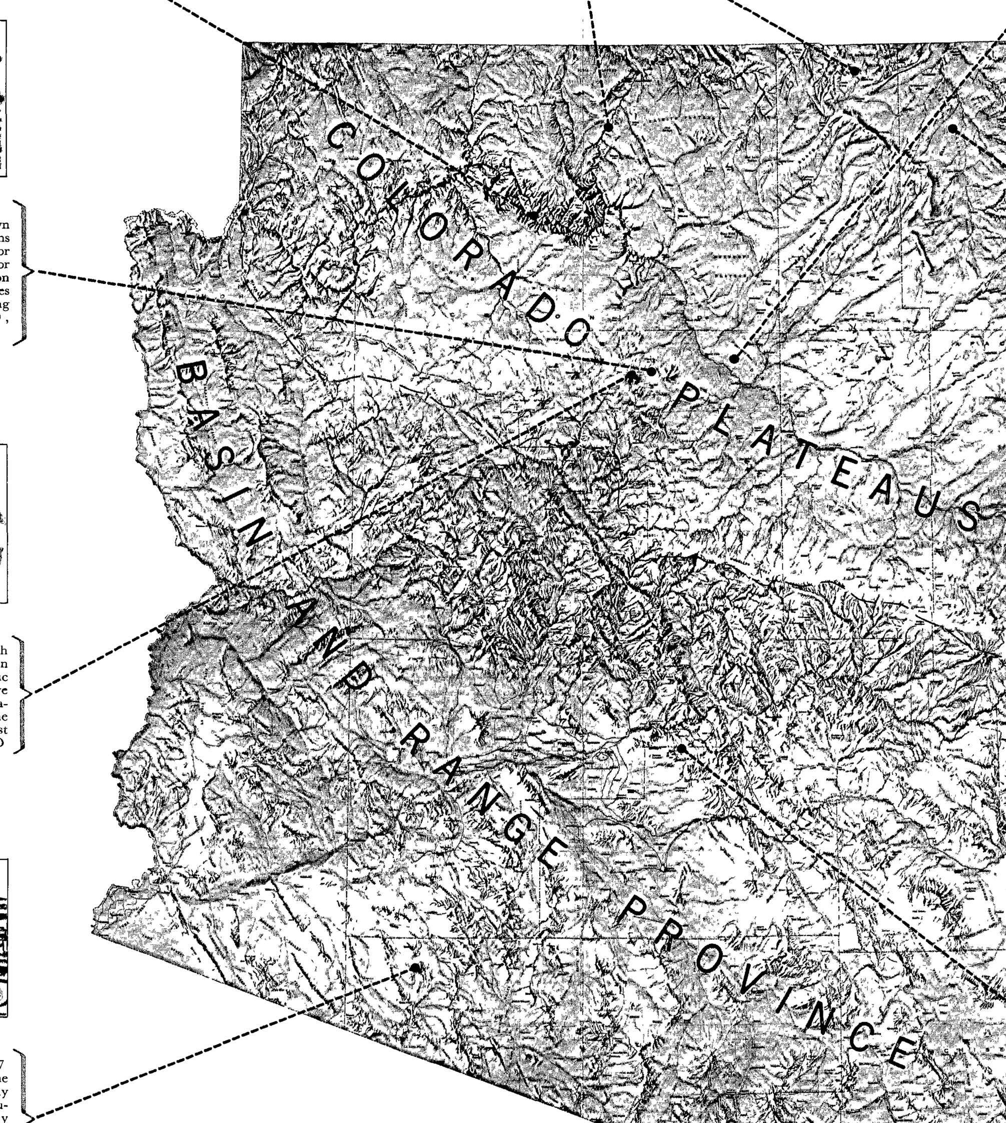
Sunset Crater is a typical cinder cone and is probably the best known example of such a feature in the United States The pink and red stains formed by escaping gases near the rim add to its beauty and account for its name The unique feature of Sunset Crater is the fact that the last major explosive eruption can be dated Volcanic ash and cinder from the eruption buried prehistoric Indian pit houses in the area and affected growth rates of trees for miles around Studies of archaeological ruins and tree-ring chronologies have established the date of the eruption at about 1067 A D, or approximately at the time of the Norman Conquest of England

SAN FRANCISCO MOUNTAIN

The San Francisco Peaks (properly "San Francisco Mountain") north of Flagstaff include Humphreys Peak, the highest point in Arizona, at an altitude of 12,670 feet They form the central eminence in a huge volcanic field that contains scores of cinder cones and other vents that were active during the latter part of the Cenozoic Era During Pleistocene time, glaciers formed at least twice and flowed down the inner basin between the higher peaks Volcanic activity continued after the glaciation, and the last eruption in the vicinity was at Sunset Crater, in the eleventh century A D

AJO

The New Cornelia open-pit copper mine at Ajo was opened in 1917 Several billion tons of material had been removed by 1965 The Ajo mine is a typical porphyry copper deposit, one in which the ore has been widely disseminated in the host rock by ore-bearing solutions from a large intrusive body of igneous rock, called a stock The ore may be of relatively low grade, but the development of efficient techniques of open-pit mining and refinements in metallurgical techniques permit the exploitation of deposits that could not be profitably mined by underground methods Other open-pit mines on or near highways in Arizona are at Bisbee, Globe, Miami, Tucson, Morenci, Bagdad, and Ray



SAND DUNES

Sand dunes are characteristic features of arid and semiarid regions and may be seen at many localities in Arizona and adjacent states They are particularly well developed in parts of northeastern and western Arizona. Formation of sand dunes requires an abundant supply of sand, which may be derived from beach, stream, or lake deposits, or from the erosion of ancient sandstones The shapes of dunes vary with local conditions, but most of them are ridges elongated in the direction of the prevailing winds or are crescents with the open side pointing downwind

WINDOW ROCK

The town of Window Rock, Arizona, the capital of the Navajo Tribe, takes its name from a great arch or window in a ridge of Jurassic sandstone immediately back of the tribal headquarters This window, carved by wind and rain operating on a weakly cemented part of the sandstone, is typical of natural arches and bridges in other parts of northern Arizona and southern Utah By no means among the largest of its kind, it is one of the most readily accessible by highway, and notable for its symmetry and graceful proportions and setting

SUPERSTITION MOUNTAINS

The Superstition Mountains east of Phoenix combine scenic grandeur, interesting geologic features, and legends and traditions of the Old West. A sacred shrine of Indian tribes, the mountains are popularly supposed to be the site of the legendary Lost Dutchman Gold Mine (which was probably near Wickenburg) The mountains are a great uplifted fault block composed of multiple flows of volcanic ash deposits of Cenozoic age The ash deposits, known as welded tuffs, were formed when great masses of hot volcanic fragments were poured out of volcanic vents Similar welded tuffs are exposed along the highway to the east of the Superstition Mountains between Superior and Globe, along the Apache Trail west of Roosevelt Dam, and in several mountain ranges near highways in southern and western Arizona.

Sketches by Rose Mary Mack

Text for sketches by J. F. Lance

PHYSIOGRAPHIC MAP OF ARIZONA

Arizona includes parts of two physiographic provinces, the Colorado Plateaus province in the northeastern part of the State and the Basin and Range province in the southern and western parts The Basin and Range province is dominated by mountain chains and alluviated valleys that have evolved from generally complex structural movements and associated erosional and depositional events. Most of the province in Arizona is drained externally by the Colorado River or its main tributary the Gila River These and other streams have cut sharp deep gorges across mountain ranges or flow on broad flood plains in the valleys In the part of the province bordering the Colorado Plateaus, to the south of the Mogollon Rim, the area occupied by valleys is small and the mountain area is correspondingly large. Few large valleys are present and many streams head in narrow canyons. The southwestern part of the State, however, displays buttes and ranges of generally small areal extent that protrude above wide alluviated plains and valleys. The valleys may be considered as consisting of a series of interlocking basins that are partially filled by alluvium. The basin rims are formed by the mountain ranges, which consist of all types of rocks—sedimentary, granitic, volcanic, and metamorphic—that usually have been subjected to recurrent faulting and tilting and in places also to multiple igneous intrusions. As a result, many ranges consist of masses of rock that are strongly inclined, lying on end, or locally overturned. Differential erosion of these rocks has given the ranges an irregular appearance

The Colorado Plateaus province is characterized by alternating cliffs and slopes formed as a result of different rates of erosion on the resistant and weak sedimentary rocks. Ledges, cliffs, or rock benches formed of resistant beds of sandstone and limestone are separated by slopes, valleys, and badlands carved on the weaker intervening shaly strata The whole province has similar rock formations, which are inclined slightly or are nearly horizontal, and is drained by one master stream, the Colorado River The physiographic features are related to their distance from the Colorado River and to the amount of downcutting. In areas adjacent to the Colorado River, canyon lands are developed extensively. In the area surrounding the canyon lands and in part of the upland adjoining the canyon rims, rock terraces form a series of platforms and high cliffs that include Marble Platform, Coconino Plateau, Echo Cliffs, Black Mesa, and Defiance Plateau. In the southern part of the province beyond the belt of rock terraces and plateaus, the relief is rather subdued and broad slopes and low mesalike features predominate.

THE GEOLOGIC HISTORY OF ARIZONA

Introduction

The age of the earth is estimated to be about 4,500 to 5,000 million years. Although the rocks that are exposed in Arizona record the geologic events of only about half this time, collectively they comprise one of the most complete geologic sections in the North American Continent The rocks are displayed superbly in the canyon, mesa, and mountain country in the Indian lands and in the national parks and forests, but the most spectacular exposures are in the Salt River and Grand Canyons, where millions of years are represented by the strata that form the canyon walls

Precambrian Era—the First 4,000+ Million Years

The dawn of geologic history began with the solidification of the materials that now comprise the earth's crust. At some time before 2,500 million years ago, the granitic basement rocks of middle North America were emplaced in the crust. From this basement the North American Continent evolved. Whether these rocks extended southward as far as Arizona is an open question, because at the present time none are recognized in Arizona or in the adjoining States. However, by 1,800 million years ago Precambrian basement rocks had been formed in what is now Arizona[1] and also metamorphosed, and the continental mass of North America, for the most part, had its present general outline

The rocks of Older Precambrian age in Arizona consist of granitic and highly deformed metamorphic types. The metamorphic rocks are represented by the Mazatzal Quartzite, Red Rock Rhyolite, and by other metamorphosed sedimentary and volcanic rocks, which make up the Yavapai, Pinal, and Vishnu Schists and their equivalents. Before metamorphism all these rocks were shale and sandstone interbedded with volcanic tuff and lava flows and some conglomerate and limestone. The volcanic rocks are principally rhyolite but in places are basalt and other types Little is known concerning the extent and nature of the Older Precambrian depositional troughs and seaways in which these strata were laid down, except that most of Arizona was within the trough and that part of the rock sequence was deposited during the earliest known invasions of the seas into Arizona.

About 1,600 to 1,800 million years ago a major pulse of granitic intrusion and structural deformation, termed the "Mazatzal Revolution," took place, although intermittent structural and igneous activity of lesser intensity probably had occurred during all of Older Precambrian time. As a result of the deformation, major changes in the landscape must have evolved, and at the end of the Older Precambrian time and for an indeterminate period of Younger Precambrian time Arizona was an upland area that was eroded extensively.

In the early part of Younger Precambrian time, the uplands that had resulted from the Mazatzal Revolution were reduced to a nearly featureless plain Regional subsidence then lowered the land surface and resulted in the accumulation of the Younger Precambrian rocks—the Apache Group and Troy Quartzite in central and southern Arizona and the Grand Canyon Series in northern Arizona These Younger Precambrian rocks aggregate a thickness of about 3,000 feet in central Arizona and more than 10,000 feet in the Grand Canyon area. They consist of quartzite, shale, limestone, and some basalt. Part of the sediments was deposited in an ancient sea that at times extended over much of the State Uplands east and northeast of central Arizona probably supplied detritus for the Younger Precambrian sediments that accumulated along the margins and in the seaways, which were deeper to the west and northwest.

Toward the end of Precambrian time, most of Arizona was uplifted and in places was subjected to faulting and diabase intrusion This structural episode, occurring sometime between 1,200 and 600 million years ago, is often referred to as the Grand Canyon Disturbance

[1] In discussing geologic events the present geographic boundaries and terms will be used as if they had already been designated

Paleozoic Era—the Next 375 Million Years

By the beginning of the Paleozoic Era the highlands formed during the Grand Canyon Disturbance were worn down, and probably mountainous areas did not exist in Arizona. The surface on which the Cambrian deposits were laid down, however, was apparently not nearly as smooth as the one on which the Younger Precambrian sediments had been deposited. In places, as seen in the walls of the Grand Canyon area and in central Arizona, resistant quartzite formed hills and ridges that withstood erosion until they were buried by the Paleozoic deposits.

During the Paleozoic Era sedimentation and erosion were controlled regionally by two large seaways One seaway occupied the Cordilleran geosyncline, which at times covered much of the western United States to the west and northwest of Arizona The other seaway was in the Sonoran geosyncline, which extended part way into southeastern Arizona, from southwestern New Mexico and northern Sonora, Mexico. During Paleozoic time, Arizona was either a shelf area containing shallow seas or a low upland area between these two great geosynclines (figs. 1 and 2). Periodically during this era, the seas transgressed southeastward from the Cordilleran geosyncline or northwestward from the Sonoran geosyncline across the shelf area, and what is now Arizona was inundated at least five times.

Cambrian to Mississippian Periods—290(?) Million Years

As the land subsided in Early Cambrian time, the sea gradually encroached southeastward over the Arizona upland from the Cordilleran geosyncline. The basal unit which was deposited around the margin of the sea as it advanced inland is now the sandy and conglomeratic Tapeats Sandstone. Continued subsidence maintained the southeastward advance of the sea, as the sea deepened, finer material was deposited which is now called the Bright Angel Shale Eventually, when further deepening of the seas resulted in clear open water, the deposition of limy sediments produced the Muav Limestone

The seas of the Sonoran geosyncline did not inundate the southeastern part of Arizona until Middle Cambrian time In this sea the first deposit was also sandy and is named the Bolsa Quartzite (Coronado Quartzite in Greenlee County). This deposit was followed by shaly and limy deposits, which comprise the Abrigo Limestone In Late Cambrian time, during maximum inundation, the seas coalesced and may have covered the entire State, except for small areas in southwestern, central, and northeastern Arizona.

From Cambrian to Early Ordovician time, in parts of southeastern and northwestern Arizona, sedimentation was continuous. The Longfellow Limestone in Greenlee County and the upper part of the El Paso Limestone that overlies the Abrigo Limestone in eastern Cochise County contain fossils of Ordovician age In the Virgin Mountains of northwestern Arizona a limestone unit is correlated with the Ordovician Pogonip Group of southern Nevada. How far the Ordovician seas in which these limestone units were deposited extended into Arizona is unknown because erosion during the ensuing Silurian and Devonian Periods probably removed much of the Ordovician deposits There is, however, reason to believe that the extent of the seas during Ordovician time was considerably greater than the limited distribution of the Lower Ordovician limestone would indicate.

Gentle, broad upwarping accompanied by erosion that began during the later part of the Ordovician Period and continued into the Middle Devonian caused a recession of the seas from Arizona toward the central areas of the Sonoran geosyncline in New Mexico and Sonora and the Cordilleran geosyncline in Nevada As a result, rocks of Silurian age are present to the southeast in southwestern New Mexico and the adjacent part of Sonora and to the northwest in Nevada, but none are known in Arizona.

During the Silurian Period, Arizona probably was a broad upland between the two geosynclines because Silurian strata appear to wedge out beyond its borders. In southeastern Arizona the erosion surface on which the Devonian sediments were deposited is exceptionally flat, and over considerable distances, the relief on it could have been measured in inches Perhaps the strongest relief on this surface was in central Arizona, where resistant Precambrian quartzite formed hills and small uplands that were islands in the Devonian seas much as they had been in the Cambrian seas.

In Middle Devonian time Arizona was again invaded by seas from both the Cordilleran and the Sonoran geosynclines. Limestone and dolomite in the Martin Limestone or its equivalents are the main rock types formed in the shallow but clear-water part of the marine environment of this period. However, the lower part of the Devonian sequence in the shelf area of central Arizona contains considerable sandstone in lenticular beds, and in part of northeastern Arizona limy shale and sandstone are present, indicating deposition characteristic of seaway margins. Southward into Mexico and northwestward into Nevada the limestone and dolomite contain progressively less impurities because they accumulated in open seaways some distance from the land

During part of Late Devonian and most of Early Mississippian time, another upwarping pulse occurred, and the seas withdrew from most of Arizona. This upwarping caused the formation of a widespread plain that was not far above sea level. Locally, the limestone that was exposed on this plain is deeply weathered

In Early Mississippian time slight regional downwarping allowed the seas to transgress into most of Arizona, except possibly for a small area in northeastern Arizona. The chief formations of Mississippian age are the Redwall and Escabrosa Limestones, which were laid down contemporaneously in northern and southern Arizona, respectively. They are composed of limestone and dolomite that contain considerable chert, as well as corals, brachiopods, and other fossils that indicate an environment of shallow clear marine water. Apparently, in Late Mississippian time the seas withdrew northwestward and southeastward toward the central reaches of the Cordilleran and Sonoran geosynclines. Near the end of the Mississippian Period, some deposition, now represented by part of the Black Prince Limestone and Paradise Formation, may have taken place in southeastern Arizona

Pennsylvanian and Permian Periods—85(?) Million Years

The rise of the Uncompahgre Highlands in Colorado and the depression of the Paradox basin in the Four Corners region of Utah, Colorado, Arizona, and New Mexico in late Paleozoic time were important events that affected Pennsylvanian and Permian erosion and sedimentation in the Southwest (fig 2). Especially in Permian time, great influxes of stream-transported, generally reddish-brown, detrital sediments spread outward from the Uncompahgre Highlands to the shores of and into the nearby seas in the adjacent parts of Utah, Arizona, and New Mexico.

The seas expanded during Pennsylvanian time, spreading outward from the geosynclinal areas. Interbedded limy and shaly sediments were laid down over much of Arizona—resulting in the Callville Limestone equivalent (part), Hermosa Formation, and Rico Formation (part) in northern Arizona, Naco Formation (part) in central Arizona, and Horquilla Limestone and Earp Formation (part) in southern Arizona The thickest deposits accumulated in the areas of (1) the Paradox basin in the Four Corners region, (2) the Sonoran geosyncline bordering southeastern Arizona, and (3) the Cordilleran geosyncline in southern Nevada These deposits and those laid down during the succeeding Permian Period are thinnest in central Arizona, suggesting that this area was elevated slightly with respect to the surrounding region.

At the beginning of Permian time, limestone deposition in northern Arizona was followed by accumulations of red beds in a broad lowland southwest of the Uncompahgre Highlands along the margins of the seaway that extended over most of Arizona These red beds form the Cutler Formation and the De Chelly Sandstone in northern Arizona, the Supai Formation in northern and central Arizona, and the Hermit Shale and Supai Formation in the Grand Canyon area. The Coconino Sandstone is included as a giant wedge in these red beds between the underlying Supai Formation or Hermit Shale and the overlying Toroweap Formation and Kaibab Limestone. This sandstone and the upper part of the De Chelly Sandstone are considered to be wind-laid deposits and as such are among the oldest recognizable accumulations of dune sand in Arizona.

The removal by erosion of the above group of formations south of the Mogollon Rim in east-central Arizona prevents a specific correlation between them and the Permian sedimentary rocks in southeastern Arizona—the Epitaph Dolomite, Colina Limestone, and Scherrer Formation—which were deposited in marine environments. Limestone in the red beds in the Mogollon Rim area indicates fluctuations in the positions of the sea margins During some of these fluctuations, marine embayments were isolated temporarily from the open seas Gypsum, some halite (common table salt), and small amounts of potash salts accumulated by evaporation in the embayments. Such deposits are included in the Supai Formation in east-central Arizona, although only gypsum is known to occur in the more southerly shallow clear-water environment represented by the Epitaph Dolomite which crops out in parts of southeastern Arizona.

In middle Permian time the last major advance of the seas during the Paleozoic Era flooded most of the State, although a fairly deep seaway probably had been present during most of the Permian in southeastern Arizona This inundation is recorded by a sequence of rocks composed principally of impure limestone but subordinately of limy sandstone, siltstone, some sandstone, gypsum, and relatively pure limestone. In northern Arizona it includes the sandstones and limestones of the Toroweap Formation and Kaibab Limestone, and the San Andres Limestone, in southern Arizona it includes the slightly impure Concha Limestone and Rainvalley Formation. Regional upwarping terminated this depositional episode and caused the retreat of the seas from Arizona. As the Permian Period and Paleozoic Era came to a close, widespread erosion dominated the geologic scene in Arizona.

Mesozoic Era—the Next 155 Million Years

The beginning of the Mesozoic Era and the end of the Paleozoic Era were marked by regional structural movements that at first elevated Arizona and the adjacent States. To the northeast in Colorado the Uncompahgre Highlands were rejuvenated In southern Arizona and New Mexico a large upland was outlined—the Mogollon Highlands. These highlands, occupying at times parts or all of southern and central Arizona and parts of New Mexico or California, have been a major influence on erosion and sedimentation in Arizona and western New Mexico throughout the Mesozoic and Cenozoic Eras.

Mesozoic orogenic activity, the first in the Arizona area since Precambrian time, accompanied the uplift of the ancestral Mogollon Highlands. The activity produced many granitic intrusions, considerable volcanism, and some metamorphism. The earliest known Mesozoic volcanism occurred in Late Triassic time and is recorded by flows and tuff in southeastern Arizona and to the northward by altered volcanic ash beds and aggregates of stream-laid pebbles of volcanic rocks in the Chinle Formation of northern Arizona.

Triassic and Jurassic Periods—90 Million Years

In Early and Middle Triassic time the ancestral Mogollon and the Uncompahgre Highlands outlined a broad upwarped area that extended from south-central Arizona to southwestern Colorado Triassic marine, near-shore, and continental sediments, mainly of chocolate-brown siltstone and silty sandstone of the Moenkopi Formation, overlapped eastward from the waning Cordilleran geosyncline onto the slopes of these highlands during the last eastward incursion of the sea from this geosyncline.

Renewed regional upwarping in Middle and Late Triassic time caused the final retreat of the Triassic sea westward from Arizona and uplifted differentially the Uncompahgre and ancestral Mogollon Highlands. Between these highlands lay a west-northwestward-sloping trough or valley, uplift steepened the slopes of its flanks, and erosion removed an unknown amount of the Moenkopi and older sediments The Chinle Formation was deposited subsequently in this valley Its base is marked by coarse conglomerate—the Shinarump Member—which was laid down principally by streams flowing north from the ancestral Mogollon Highlands (fig 3) The deposition of the Shinarump Member was followed by the deposition of varicolored shale, which forms the other members of the Chinle Formation. These formations are being eroded at present to form the colorful badlands of the Painted Desert

During the deposition of the upper part of the Chinle Formation the generally north- and northwest-trending drainage was diverted to the west and southwest, probably because the Uncompahgre Highlands were elevated more than the ancestral Mogollon Highlands. As a result, the drainage from the Uncompahgre area increased, and deposits from this highland buried those deposits laid down earlier by the drainage from the Mogollon Highlands. This major directional change in drainage continued throughout the deposition of the Wingate Sandstone and the Moenave and Kayenta Formations. The bulk of these deposits is orange-red silty sandstone and siltstone, fluviatile in origin. Deposits of this type may have covered much of the State. Locally, the regional drainage on the Uncompahgre Highland slopes was interrupted by thick accumulation of dune sand, these deposits are now the upper part of the Wingate Sandstone and the Navajo Sandstone.

During the early part of Jurassic time, major changes took place in western North America as the Cordilleran geosyncline was destroyed The Uncompahgre Highlands decreased in prominence, but the ancestral Mogollon Highlands occupied a broad area in Arizona and New Mexico north of the Sonoran geosyncline. An arm of the Jurassic seas extended as far south as northeastern Arizona and northwestern New Mexico, and the sea in the Sonoran geosyncline transgressed as far north as the international boundary between Sonora and New Mexico. Volcanic eruptions and igneous intrusions accompanied by local uplift and faulting may have taken place intermittently in southern Arizona throughout the Jurassic Period

Near and along the shores of this ancient Jurassic sea, the sandy and silty sediments of the San Rafael Group were deposited in northeastern Arizona (fig. 4) To the west of the old shorelines a thick blanket of dune sand accumulated, which is represented mainly by the Cow Springs Sandstone At this time the Uncompahgre Highlands were not as high above the seaways as they had been during the Triassic, hence they contributed little sediment. As a result, most of the Jurassic sediments were derived from the ancestral Mogollon Highlands to the south

Near the end of the Jurassic Period the seas withdrew northward from Arizona owing to regional upwarping, and a gigantic flood plain gradually was built northward from the ancestral Mogollon Highlands to the margin of the retreating seas. Generally sluggish streams flowed on this plain and deposited the muddy and sandy detrital material which comprises the Morrison Formation.

Cretaceous Period—65 Million Years

When the Cretaceous Period opened, erosion was the dominant geologic process, although shortly after its beginning the sea invaded Arizona during one of the great marine inundations of the North American Continent. At the beginning of Early Cretaceous time the Sonoran geosyncline extended northwestward into southeastern Arizona (fig 5). Several thousands of feet of rocks, deposited in this geosyncline, crop out in places in southwestern New Mexico and southeastern Arizona. They are mostly shale, arkosic conglomerate, and sandstone and make up the formations of the Bisbee Group. This sequence of rocks is separated by several erosion surfaces that indicate interruptions in deposition Conglomerate in the Lower Cretaceous rock sequence suggests that parts of southern Arizona were mountainous areas with streams that carried coarse debris to the subjacent valleys and basins within the Sonoran geosyncline, and many ranges protruding from the eastern flank of the ancestral Mogollon Highlands may have been islands or peninsulas within the Early Cretaceous sea.

Regional uplift caused the withdrawal of the Early Cretaceous sea from most of Arizona, and erosion followed. Although parts of southern Arizona probably were mountainous, most of northern Arizona was a wide plain. In general, streams flowed from the ancestral Mogollon Highlands located in what is now southern Arizona and southeastern California, northeastward across this plain to the central part of the newly formed Rocky Mountain geosyncline, which lay roughly in what is now Colorado and Wyoming. In Late Cretaceous time, widespread regional downwarping caused the coalescing of the seas in the Rocky Mountain and Sonoran geosynclines and the inundation of much of middle North America. This sea, during its maximum inundation, may have spread as far southwestward as central Arizona, depositing the sediments that now compose the Dakota Sandstone, Mancos Shale, and some of the overlying members of the Mesaverde Group (fig. 5) During the slow withdrawal of the Late Cretaceous seas, many minor transgressions and regressions occurred, probably as a result of pulses of regional upwarping and subsidence The resulting oscillations of the shoreline caused complex interfingering of deposits of silt, sand, swampy muck, and peat that upon consolidation became the siltstone, sandstone, and coal of the Mesaverde Group and the Mancos Shale

In southern Arizona rocks of Late Cretaceous age were deposited near their source, and their distribution and characteristics were markedly affected by local structural movement and volcanic activity; they are mainly sandstone and conglomerate intercalated with some marine shale beds and volcanic rocks. These form the Sonoita Group, Recreation Red Beds, and most of the Amole Arkose Most of southwestern Arizona may have been undergoing erosion, but some scattered remnants of sandstone and conglomerate with flows and tuff interbedded may be of Late Cretaceous age, thus suggesting that deposition may have occurred locally.

The Laramide Orogeny—Late Mesozoic and Early Cenozoic Age

Regional upwarping, perhaps the initial phase of the Laramide orogeny (Late Cretaceous to early Tertiary), became increasingly frequent during latest Cretaceous time and resulted in the Cretaceous sea withdrawing northward into Utah and eastward into New Mexico before the end of Cretaceous time (fig. 6) Continued warping, accompanied in places by igneous activity, uplifted all of western North America and destroyed the Rocky Mountain and Sonoran geosynclines. As a result, landmasses stood high, and erosion, therefore, was widespread and locally severe at the close of the Cretaceous Period.

The Laramide orogeny, occurring during Late Cretaceous and early Tertiary time roughly 80 to 40 million years ago, was a major episode of uplift, igneous intrusion and volcanism, complex thrust and normal faulting, intensive mineralization, and some metamorphism. During this time, igneous activity formed the intrusive porphyritic rocks that are so commonly associated with the large copper deposits of Arizona

In Arizona, the Laramide orogeny produced regional and differential uplift and subsidence that divided the State into localized mountain highs and troughlike structures or basins where generally coarse detrital material accumulated In southern Arizona, as indicated by the distribution of the Cretaceous rocks, these basinlike structures transected the ancestral Mogollon Highlands, and some probably were present in Early Cretaceous time; but in northern Arizona and adjacent States, structural movement that produced the Black Mesa, Kaiparowits, San Juan, and other basins did not begin until late in the Cretaceous Period and was not completed until near the end of early Tertiary time.

In southern Arizona the rocks resulting from the Laramide orogenic activity are andesite flows, tuff, mudflows, sandstone, and conglomerate, which were metamorphosed locally and were intruded in many places by granite and porphyry. Some of these rock units are represented by the Silver Bell Andesite and the Claflin Ranch Formation and their equivalents, such as part of the Bronco Volcanics near Tombstone and the Cat Mountain Rhyolite in the Tucson Mountains All these rocks, in places more than 5,000 feet thick, overlie the prominent erosion surface cut on folded Cretaceous and older rocks. The relief in southern Arizona at that time was rugged, an environment that caused coarse detrital sediments to accumulate in valleys and basins

Northern Arizona probably was again part of a gentle plain that sloped outward from the rugged terrain in southern Arizona Northern Arizona did not receive much deposition, because sedimentation was centered chiefly in the developing Uinta basin of Utah and the developing San Juan basin of northwestern New Mexico, in each of which several thousands of feet of sediments were deposited. Perhaps the only rocks preserved in northern Arizona during Late Cretaceous and early Tertiary time crop out near Springerville. These are reddish-brown mudstone and conglomerate that contain pebbles of andesite similar to the andesite of the Silver Bell Andesite, indicating that much of this material was laid down by generally northward-flowing streams

Cenozoic Era—the Last 70 Million Years

Post-Laramide Cenozoic geology is dominated and controlled by regional and differential upwarping and subsidence and large-scale faulting This activity eventually resulted in the present major physiographic features and drainage The present Mogollon Highlands, the Colorado Plateaus and Basin and Range physiographic provinces, and part of the Mogollon Rim were outlined during middle Tertiary time and probably before the Miocene Epoch (fig. 7). A pulse of large-scale faulting, tilting, and uplift during Miocene and Pliocene time outlined the general positions of many of the present-day mountain ranges and valleys. Concurrent with the development of the mountain ranges and valleys was the gradual evolution of the Colorado River system

Volcanic rocks form an important part of the Cenozoic stratigraphic record because they have similar composition and texture over large areas. Thick accumulations of volcanic rocks of early and middle Tertiary age are dominantly andesitic, rhyolitic, and dacitic flows and tuff and pyroclastic rocks that now cap many mountain ranges and uplands in the Basin and Range province. In contrast, the late Tertiary and Quaternary volcanic rocks are principally basalt flows and cinders, well-shaped cinder cones of this type and age are in the White Mountains, near Flagstaff, and east of Douglas.

Thick sequences of sedimentary rocks of middle Tertiary age were laid down contemporaneously with the eruptions of the volcanic rocks. Locally, near Tucson, such a sequence is more than 10,000 feet thick, and in many parts of the Basin and Range province exposed thicknesses of more than 3,000 feet are common. The Colorado Plateaus received less sediment because they stood higher due to slow, continuing uplift Middle Tertiary rocks, however, are 2,000 feet thick in the Chuska and White Mountains—the chief remnants of middle Tertiary deposition in northeastern Arizona All these sedimentary rocks were deposited by streams that pre-date much of the Colorado River drainage system and the present topography, they are mainly grayish red to brown and consist of siltstone, silty sandstone, and conglomerate Locally, a considerable amount of volcanic tuff and some gypsum or limestone are present. Several different names have been given the middle Tertiary rocks, e g, Helmet Fanglomerate in the Sierrita Mountains, Pantano Formation near Tucson, Whitetail Conglomerate in the Globe-Superior-Ray area, Locomotive Fanglomerate near Ajo, and Chuska Sandstone in the Chuska Mountains.

Beginning in Miocene time and continuing for most of the Pliocene, differential uplift and subsidence accompanied by large-scale normal faulting accentuated the outlines of the Basin and Range and Colorado Plateaus physiographic provinces, formed the mountain chains and valleys, extended the Mogollon Rim as a drainage divide between the two provinces, and integrated the ancestral stages of the Colorado and its tributary river systems (figs. 7 and 8). By the Miocene, the ancestral Colorado River on the Colorado Plateaus apparently drained southwestward and crossed the present Grand Canyon in a broad valley whose general trend was similar to the present drainage. Uplift continuing on the Colorado Plateaus caused all the plateau drainage systems to be entrenched and initiated the cutting of the Grand Canyon by the Colorado River In central Arizona south of the Mogollon Rim, a prominent divide at this time, the upper Salt River drainage system was developed in intermontane basins, but in southeastern Arizona, the upper Gila River drainage was incompletely developed. The ancestral Gila River was mostly imponded in several large and small closed drainage basins until shortly after early Pleistocene time when through-flowing westward drainage was established In southwestern Arizona, the Colorado, Gila, and Salt Rivers probably were not through-flowing streams as they are at present Instead, they also may have been imponded within the numerous valleys of the Basin and Range province. Contemporaneously with these drainage conditions, a marine embayment from the Gulf of California at times covered much of southwestern Arizona and southeastern California. Limestone and detrital sediments containing marine invertebrate fossils of near-shore types record the presence of this embayment By late Pliocene time this embayment receded, and the through-flowing drainage of the Colorado River and also those rivers south of the Mogollon Rim was extended southwestward across Arizona.

In late Tertiary and Quaternary time, as the Colorado Plateaus and Mogollon Highlands of Arizona were elevated with respect to most of the Basin and Range province, streams of the Colorado River system were entrenched progressively along their present courses, and in places the streams cut spectacular canyons The cutting of the Grand Canyon may have started 10 to 15 million years ago. The trenching of Marble and Glen Canyons by the Colorado River and the Salt River Canyon probably began between 5 and 10 million years ago. Canyon de Chelly is perhaps the youngest large canyon, having an age of not more than about 5 million years By 3 or 4 million years ago the streams were flowing several hundreds of feet below the canyon rims, and the Colorado River system existed in nearly its present form, although not to its present depth, across Arizona

During all of late Tertiary and Quaternary time, contemporaneous with the canyon cutting, erosion removed from the Colorado Plateaus a thickness of between 1,000 and 6,000 feet of rock. The erosion was continuous except for temporary interruptions when gravelly sediments were deposited in the Grand Canyon-Glen Canyon area and when the Bidahochi Formation was deposited in the ancestral valley of the Little Colorado River.

In contrast, as a result of the general subsidence of the Basin and Range province in late Tertiary and Quaternary time, thick deposits of alluvium accumulated in its intermontane valleys at the same time that the mountains and the Colorado Plateaus were being eroded. This alluvium in southern and western Arizona is not a single unbroken sequence but consists of several deposits that are clearly exposed in several large stream valleys, namely in the Santa Cruz, San Pedro, Verde, Big Sandy, and others In some of these valleys, the aggregate thickness of the deposits is more than 2,000 feet, and in parts of southwestern Arizona the alluvium buried some of the lower mountain ranges. These alluvial deposits are composed of mixtures of weakly to moderately cemented sand, silt, and gravel. In many of the valleys, such as the San Pedro Valley, clay, gypsum, and some limestone beds also were deposited, and these strata indicate the presence of temporary lakes Deposits of salt and anhydrite laid down in closed basins were penetrated during the drilling of deep wells in Detrital and Hualpai Valleys near Lake Mead and at Safford. Few of the alluvial deposits have been named formally, but some have been designated as the Gila Conglomerate in southern Arizona, the Muddy Creek Formation and Hualpai Limestone near Lake Mead, and the Verde Formation in Verde Valley

These late Tertiary and Quaternary alluvial deposits in the Basin and Range province also were subjected to varying degrees of recurrent uplift, subsidence, large-scale normal faulting, and tilting. The deposits of Tertiary age were involved in major faulting and tilting, but those of Quaternary age have been displaced only locally by minor faults Erosion accelerated by the structural activity removed part of the alluvium, and many valleys were deepened 500 to 1,000 feet or more. After deepening, most of the valleys were refilled by later alluvial deposits, thus, the alluvial sediments in many valleys record several pulses of uplift and erosion alternating with subsidence and alluviation.

The latest episode of the geologic history of Arizona has been one of erosion that resulted from general upwarping during late Quaternary time. Terraces along the main streams were produced in most parts of Arizona, although deposition took place locally Near Phoenix and on the Colorado River delta near Yuma more than 300 feet of alluvium was deposited. Some alluvium and lake beds were deposited at Red Lake in Mohave County and near the Willcox Playa in Cochise County. Dune sand was deposited along the shores of these ephemeral lakes, and the sand dunes that are widespread over the Colorado Plateaus and near Yuma were formed at this time Deposits of flood-plain alluvium, commonly as much as 150 feet thick, form narrow bands along streams. Part of this alluvium merges laterally with local glacial deposits of Pleistocene age. The latter are preserved in parts of the White Mountains and on San Francisco Mountain near Flagstaff and record the only glacial activity in Arizona.

MAPS SHOWING STAGES OF THE GEOLOGICAL EVOLUTION IN ARIZONA THROUGH TIME

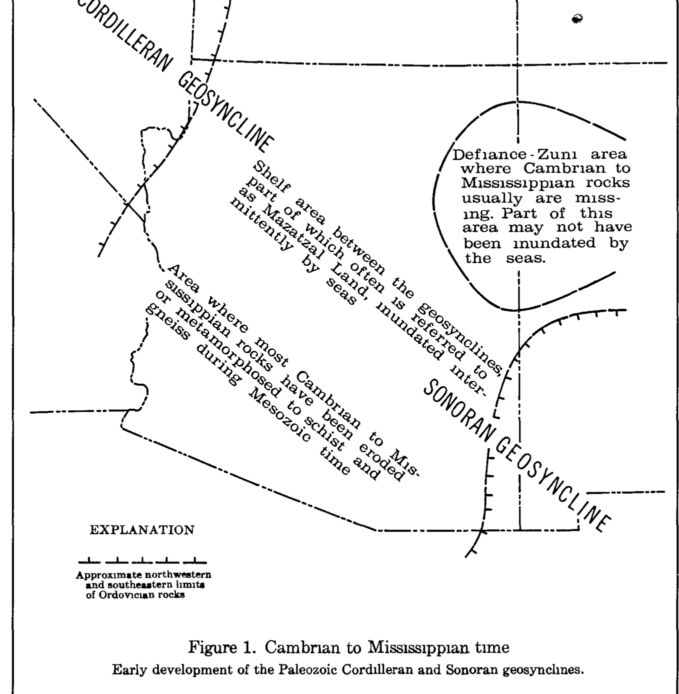


Figure 1. Cambrian to Mississippian time
Early development of the Paleozoic Cordilleran and Sonoran geosynclines.

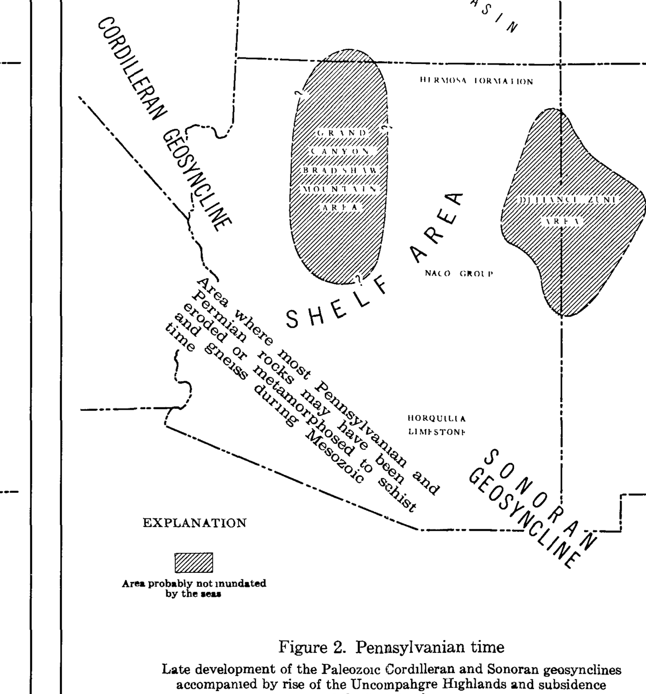


Figure 2. Pennsylvanian time
Late development of the Paleozoic Cordilleran and Sonoran geosynclines accompanied by rise of the Uncompahgre Highlands and subsidence of the Paradox basin

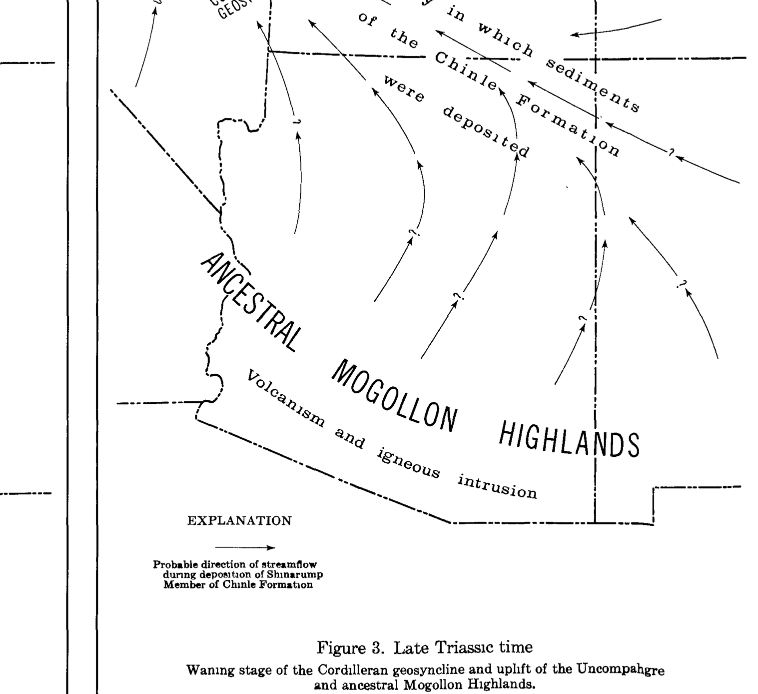


Figure 3. Late Triassic time
Waning stage of the Cordilleran geosyncline and uplift of the Uncompahgre and ancestral Mogollon Highlands.

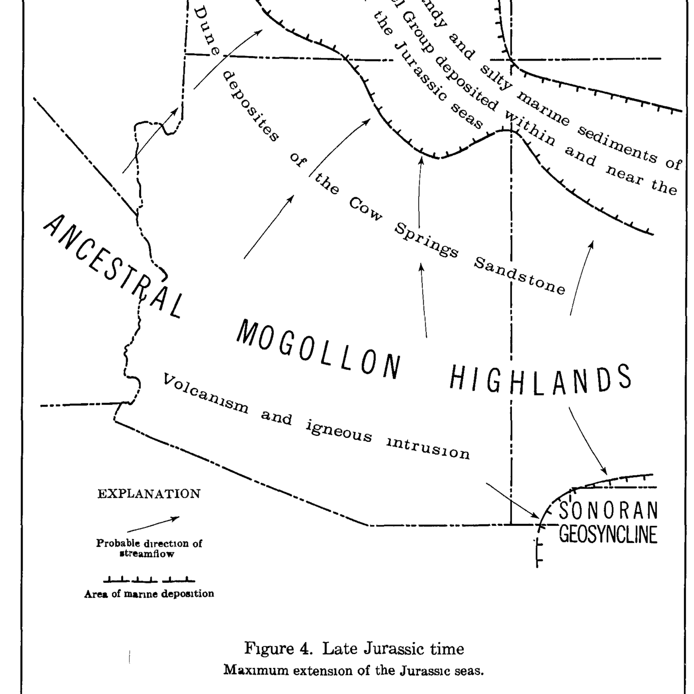


Figure 4. Late Jurassic time
Maximum extension of the Jurassic seas.

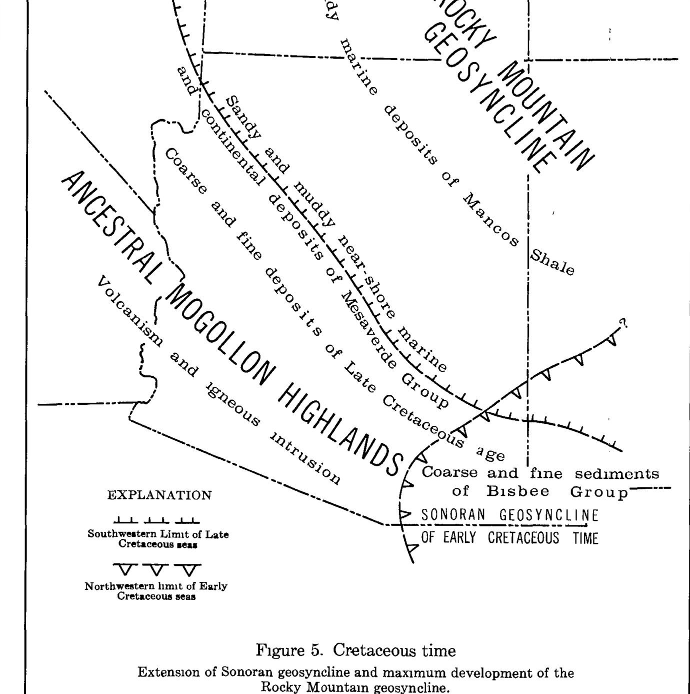


Figure 5. Cretaceous time
Extension of Sonoran geosyncline and maximum development of the Rocky Mountain geosyncline.

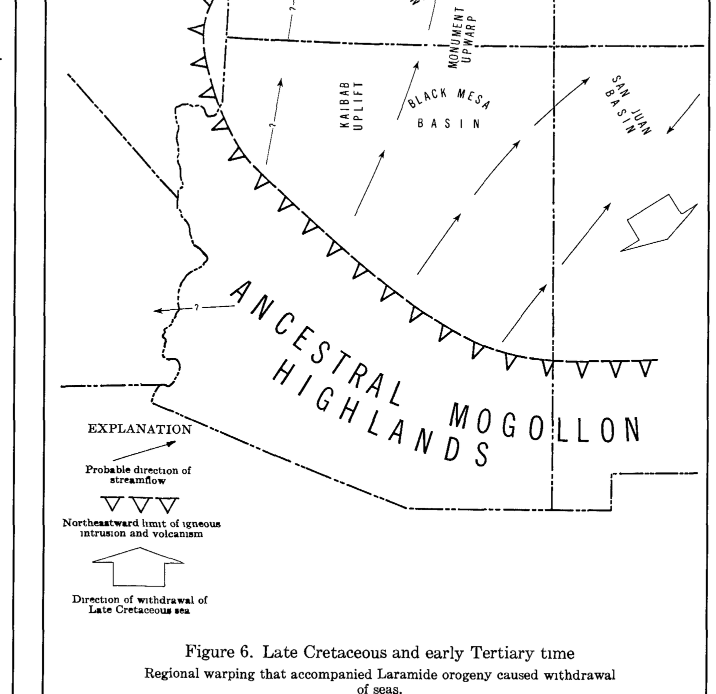


Figure 6. Late Cretaceous and early Tertiary time
Regional warping that accompanied Laramide orogeny caused withdrawal of seas.

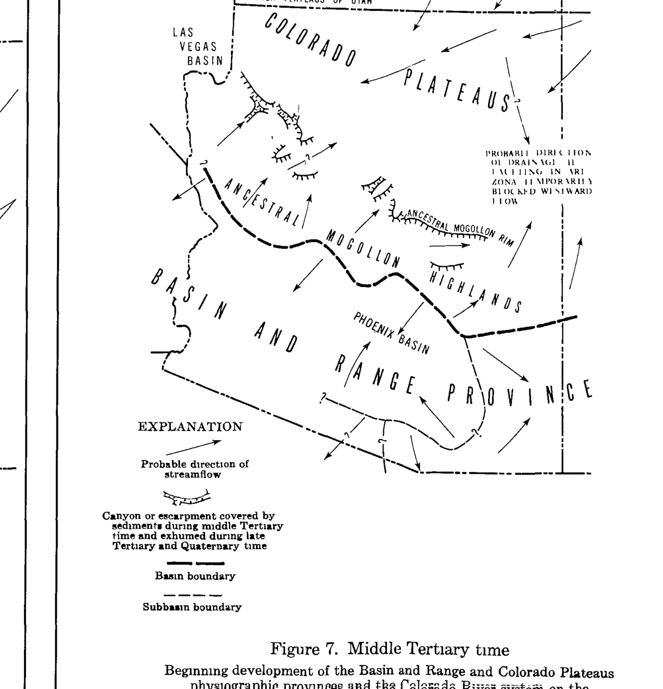


Figure 7. Middle Tertiary time
Beginning development of the Basin and Range and Colorado Plateaus physiographic provinces and the Colorado River system on the Colorado Plateaus.

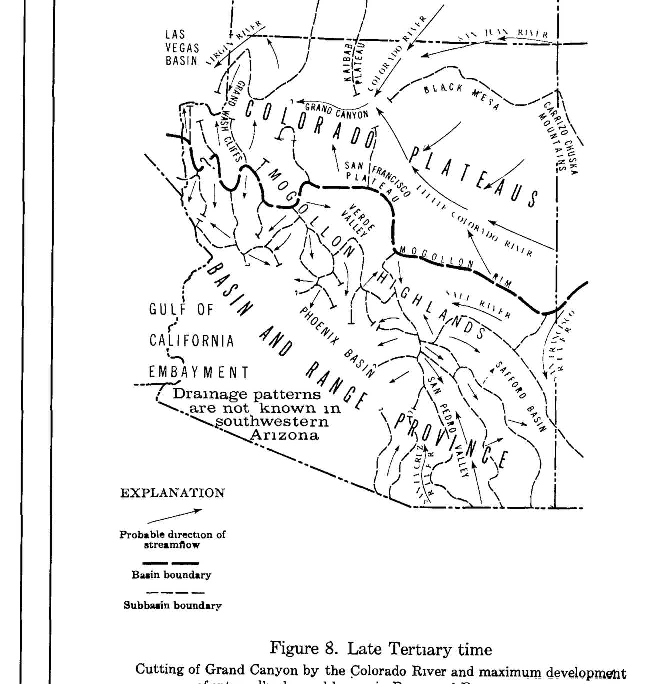


Figure 8. Late Tertiary time
Cutting of Grand Canyon by the Colorado River and maximum development of internally drained basins in Basin and Range provence.

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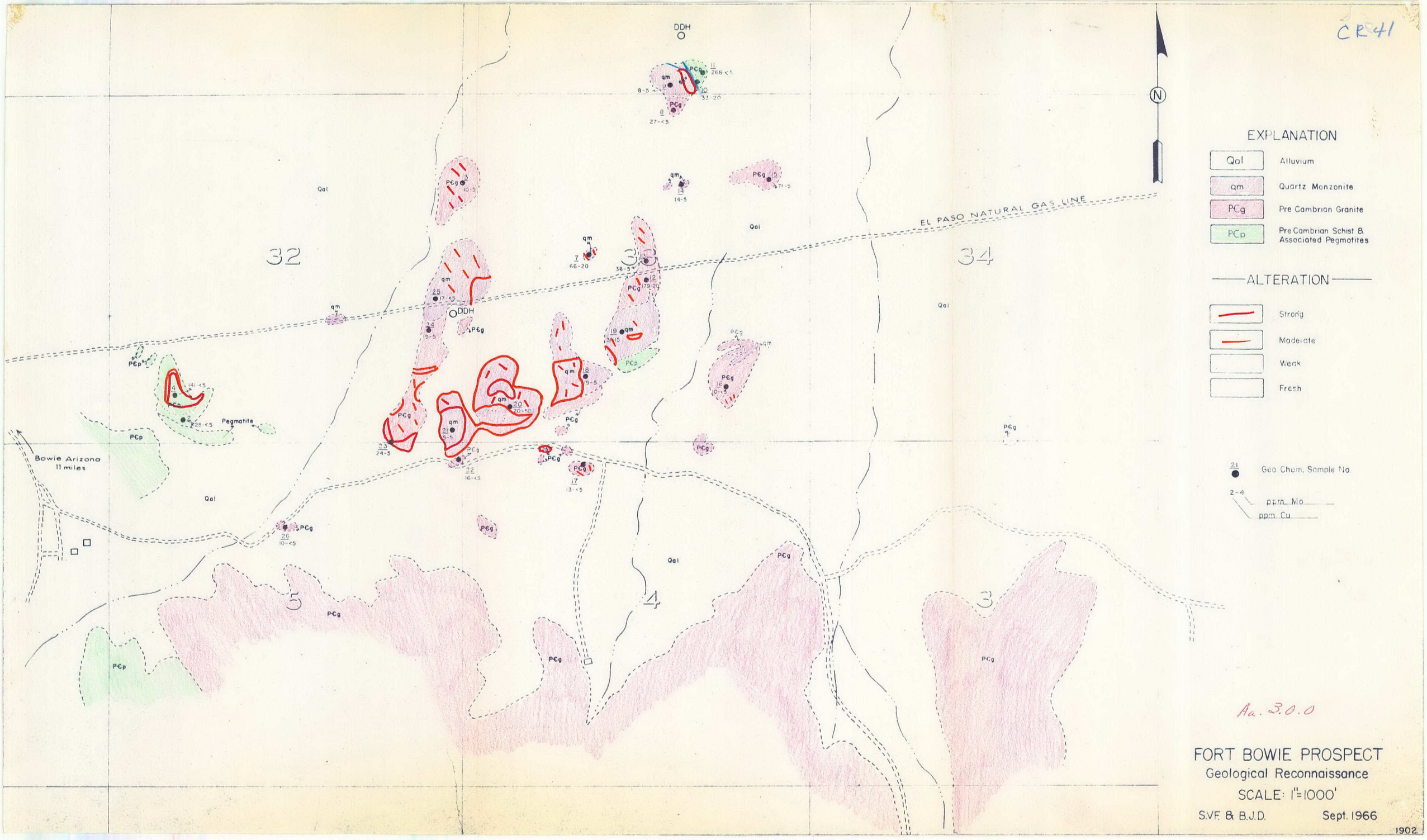

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FORT BOWIE PROSPECT
Geological Reconnaissance
SCALE: 1"=1000'
S.V.F. & B.J.D. Sept. 1966

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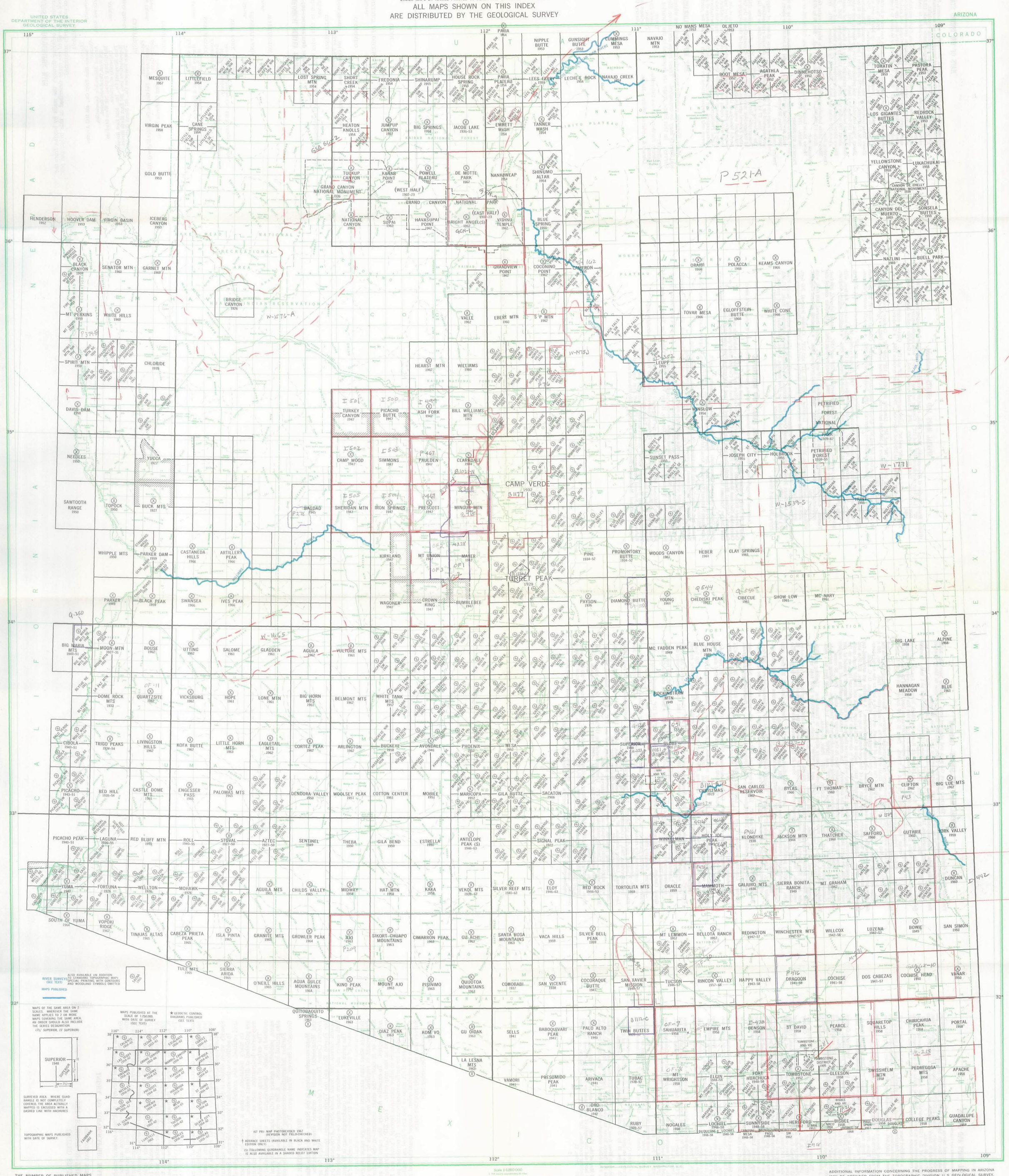

THE NUMBER OF PUBLISHED MAPS SHOWN ON THIS INDEX IS 797

DECEMBER 1968

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SPECIAL MAPS AND SHEETS

[Measurements are approximate

Arizona (State). This map shows counties, location and names of all cities and towns and most of the smaller settlements, railroads, and township and range lines (in black); rivers, many of the smaller streams, and other water features (in blue). It does not show contours. Scale, 1:500,000, or about 8 miles to 1 inch. Size, 47 by 56 inches. 1955. Price, $1. Also published in black and white at the scale of 1:1,000,000, or about 16 miles to 1 inch. Size, 24 by 29 inches. Price, 50 cents.

Arizona (Topographic). This map is an overprint of the 1:500,000-scale base map described directly above, and in addition, shows highways in purple and contours in brown. National parks and monuments, recreational areas, national forests, and Indian reservations are indicated by color patterns. Contour interval, 500 feet. Price, $2.

Arizona (Relief). This map is overprinted on a modified base map which shows only county names and boundaries, the larger cities (in black), and the water features (in blue). The physical features of this map are brought out by shaded-relief in color, on the conventional plan of assumed diagonal illumination from the northwest. It does not show contours. Scale, 1:500,000, or about 8 miles to 1 inch. Size, 47 by 55 inches. 1955. Price, $2.

Bisbee and vicinity, Ariz. This map shows the mining district adjacent to Bisbee. Limiting parallels, 31°24′25″ and 31°26′45″. Limiting meridians, 109°53′30″ and 109°56′30″. Scale, 1:12,000, or 1,000 feet to 1 inch. Contour interval, 20 feet. Size, 17 by 21 inches. 1902. Price, 50 cents.

Black Creek, Ariz. Plan and profile of Black Creek from mouth to mile 20. Scale, 1:24,000, or 2,000 feet to 1 inch. Contour interval on land, 10 feet; on river surface, 2 feet. Vertical scale of profile, 20 feet to 1 inch. Size, 22 by 28 inches. 2 sheets (1 plan, 1 profile). 1937. Price, 50 cents a sheet.

Bridge Canyon, Ariz. This map shows the area adjacent to Spencer Canyon and the part of the Grand Canyon at Bridge Canyon. Limiting parallels, 35°39′30″ and 35°48′. Limiting meridians, 113°29′ and 113°43′. Scale, 1:62,500, or about 1 mile to 1 inch. Contour interval, 100 feet. Size, 17 by 20 inches. 1926. Price, 50 cents.

Bright Angel, Ariz. This map shows part of the Grand Canyon. A brief geologic history of the area covered by the Bright Angel quadrangle is given on the back of the map. Limiting parallels, 36° and 36°15′. Limiting meridians, 112° and 112°15′. Scale, 1:62,500, or about one mile to 1 inch. Contour interval, 80 feet. Size, 17 by 21 inches. 1962. Also published in a shaded-relief edition. Price, either contour or relief edition, 50 cents.

Canyon de Chelly National Monument, Ariz. This map shows the monument and adjacent area. Limiting parallels, 36° and 36°17′. Limiting meridians, 109°08′ and 109°33′. Scale, 1:48,000, or 4,000 feet to 1 inch. Contour interval, 25 feet. Size, 30 by 36 inches. 1938. Price, $1.

Colorado and San Juan Rivers, Ariz.-Utah. Plan and profile of Colorado River, Lees Ferry, Ariz., to mouth of Green River, Utah; San Juan River, mouth to Chinle Creek, Utah; and certain tributaries. Scale, 1:31,680, or ½ mile to 1 inch. Contour interval on land, 20 feet; on river surface, 5 feet. Vertical scale of profiles, 20 feet to 1 inch. Size, 21 by 27 inches. 22 sheets (16 plans, 6 profiles). 1921. Price, 50 cents a sheet.

Geodetic Control Diagrams. The Geological Survey and the Coast and Geodetic Survey are cooperating in preparing and publishing a series of diagrams on a planimetric base of the 1:250,000-scale maps. The diagrams show the location of level and transit-traverse lines, electronic distance measurements, and triangulation stations established by the two agencies. The work of the Geological Survey is shown in red and that of the Coast and Geodetic Survey in black. ★ The dimensions of these diagrams are the same as those stated for the United States Series of Topographic Maps, Scale, 1:250,000, listed below. The final date of control data shown on the diagram is also listed. Price, 50 cents.

Gila River, Ariz. Plan of Gila River from Buttes damsite to Coolidge Dam, and damsite. Scale, 1:31,680, or ½ mile to 1 inch. Contour interval on land, 20 feet; on river surface, 5 feet. Size, 22 by 28 inches. 3 sheets. 1935. Price, 50 cents a sheet.

Gila River, Ariz.-N. Mex. Plan of Gila River from Brown Canal Intake, Ariz., to mile 68 near Virden, N. Mex., and damsites. Scale, 1:31,680, or ½ mile to 1 inch. Contour intervals on land, 10 and 20 feet; on river surface, 5 feet. Size, 22 by 28 inches. 2 sheets. 1935-41. Price, 50 cents a sheet.

Gila River sheet (NI-12), 1:1,000,000 series. This map shows part of Arizona, New Mexico, and Mexico. The altitude of the land is shown by contour lines and tints. *Limiting parallels, 32° and 36°. Limiting meridians,* 108° and 114°. Scale, 1:1,000,000, or about 16 miles to 1 inch. Size, 26 by 27 inches. 1959. Price, $1.

Grand Canyon National Monument, Ariz. This map shows the monument and adjacent area. Limiting parallels, 36°09′ and 36°28′. Limiting meridians, 112°39′ and 113°11′. Scale, 1:48,000, or 4,000 feet to 1 inch. Contour interval, 50 feet. Size, 33 by 42 inches. 1936. Price, $1.

Grand Canyon National Park, Ariz. (east half). This map includes the part of the canyon of the Colorado River that extends from its head southward and westward to Crystal Rapids. Limiting parallels, 35°57′35″ and 36°25′. Limiting meridians, 111°45′ and 112°15′. Scale, 1:48,000, or 4,000 feet to 1 inch. Contour interval, 50 feet. Size, 41 by 46 inches. 1902–23. Price, $1.50.

Grand Canyon National Park, Ariz. (west half). This map includes the part of the canyon of the Colorado River that extends from Crystal Rapids northward and westward to the mouth of Havasu Creek. Limiting parallels, 36° and 36°25′. *Limiting meridians, 112°15′ and 112°46′.* Scale, 1:48,000, or 4,000 feet to 1 inch. Contour interval, 50 feet. Size, 41 by 46 inches. 1902–23. Price, $1.50.

Grand Canyon sheet (NJ-12), 1:1,000,000 series. This map shows part of Arizona, Colorado, New Mexico, and Utah. The altitude of the land is shown by contour lines and tints. Limiting parallels, 36° and 40°. Limiting meridians, 108° and 114°. Scale, 1:1,000,000, or about 16 miles to 1 inch. Size, 27 by 27 inches. 1959. Price, $1.

Little Colorado River, Ariz. Plan and profile of Little Colorado River from mouth to Tolchico damsite. Scale, 1:31,680, or ½ mile to 1 inch. Contour intervals on land, 25 and 100 feet; on river surface, 5 and 25 feet. Vertical scale of profiles, 20 feet to 1 inch. Size, 21 by 27 inches. 5 sheets (3 plans, 2 profiles). 1926. Price, 50 cents a sheet.

Little Colorado River, Ariz. Plan of Little Colorado River from Tolchico damsite to Lyman Reservoir, Cottonwood Wash to mile 43, Leroux Wash to mile 36, Puerco River to mile 39, and damsites. Scale, 1:31,680, or ½ mile to 1 inch. Contour interval, 10 feet, with 5-foot contours added in dashed lines. Size, 22 by 28 inches. 18 sheets. 1934. Price, 50 cents a sheet.

Los Angeles sheet (NI-11) of the International Map of the World. This map shows part of California, Arizona, Nevada, and Mexico. The altitude of the land and the depth of the water are shown by contour lines and tints. Limiting parallels, 32° and 36°. Limiting meridians, 114° and 120°. Scale, 1:1,000,000, or about 16 miles to 1 inch. Size, 28 by 32 inches. 1947. Price, $1.

SPECIAL MAPS AND SHEETS—Continued

Petrified Forest National Park, Ariz. This map shows the park and adjacent area. Limiting parallels, 34°45′ and 35°10′15″. Limiting meridians, 109°40′ and 109°55′. Scale, 1:62,500, or about 1 mile to 1inch. Contour interval, 25 feet. Size, 17 by 32 inches. 1939, limited revision 1967. Price, 50 cents.

Ray and vicinity, Ariz. This map shows the mining district adjacent to Ray. Limiting parallels, 33°09′28″ and 33°11′32″. Limiting meridians, 110°58′32″ and 111°01′26″. Scale, 1:12,000, or 1,000 feet to 1 inch. Contour interval, 25 feet. Size, 16 by 20 inches. 1910. Price, 50 cents.

Salt River, Ariz. Plan and profile of Salt River above Roosevelt Reservoir, Black River to Apache National Forest boundary, White River to mouth of Diamond Creek, East Fork of White River to Sevenmile Canyon, and Carrizo damsite. Scale, 1:31,680, or ½ mile to 1 inch. Contour intervals on land, 20 and 25 feet; on river surface, 5 feet. Vertical scale of profiles, 40 feet to 1 inch. Size, 21 by 25 inches. 10 sheets (5 plans, 5 profiles). 1916-32. Price, 50 cents a sheet.

Set of one hundred topographic maps illustrating specified physiographic features. This set of maps has been selected to illustrate a wide variety of well-portrayed physiographic features. The set generally follows the Physical Divisions Map of the United States, and illustrates most of its 86 subdivisions. 1955. Price, $50 a set. NOTE: An index map showing the location of the maps of this set, as well as a key to the aerial photo-index coverage, may be obtained free on application to the Geological Survey, Washington, D. C. 20242.

Set of twenty-five topographic maps illustrating specified physiographic features. A smaller set arranged for those interested in a less-detailed study than that of the one-hundred map set. 1955. Price, $12.50 a set.

Shaded-relief maps. Besides the regular topographic map, maps of the Antelope Peak and Bright Angle quadrangles have been published in an edition on which the relief is shown both by brown contour lines, as on the regular topographic map, and by shading in brown, which gives the map the appearance of a model of the surface with the light striking it from the northwest. The shading makes the inequalities of the surface more readily apparent to the inexperienced map reader than do the contour lines alone. Price, 50 cents.

Tombstone and vicinity, Ariz. This map shows the mining district adjacent to Tombstone. Limiting parallels, 31°40′53″ and 31°42′52″. Limiting meridians, 110°03′28″ and 110°05′. Scale, 1:6,000, or 500 feet to 1 inch. Contour interval, 10 feet. Size, 20 by 27 inches. 1907. Price, 50 cents.

Tombstone district, Ariz. This map shows part of Cochise County adjacent to Tombstone. Limiting parallels, 31°39′ and 31°43′30″. Limiting meridians, 110°02′ and 110°07′50″. Scale, 1:24,000, or 2,000 feet to 1 inch. Contour interval, 50 feet. Size, 17 by 21 inches. 1905. Price, 50 cents.

United States Series of Topographic Maps, Scale, 1:250,000. This is a series of topographic maps produced by the Army Map Service, and published and distributed for civilian use by the Geological Survey. Price, 75 cents each. Woodland shown by green overprint. Size, 22 by 32 inches, unless otherwise indicated. The following maps cover areas in Arizona:

Ajo. Limiting parallels, 32° and 33°. Limiting meridians, 112° and 114°. Contour interval, 200 feet, with supplementary contours at 100-foot intervals. 1953, limited revision 1962.

Caliente. Limiting parallels, 37° and 38°. Limiting meridians, 114° and 116°. Contour interval, 200 feet. 1954, limited revision 1962. ★ Geodetic control diagram, April 1963.

Cedar City. Limiting parallels, 37° and 38°. Limiting meridians, 112° and 114°. Contour interval, 200 feet, with supplementary contours at 100-foot intervals. 1953, limited revision 1961. ★ Geodetic control diagram, April 1963.

Clifton. Limiting parallels, 33° and 34°. Limiting meridians, 108° and 110°. Contour interval, 200 feet, with supplementary contours at 100-foot intervals. 1954, limited revision 1962. ★ Geodetic control diagram, October 1965.

Cortez. Limiting parallels, 37° and 38°. Limiting meridians, 108° and 110°. Contour interval, 200 feet, with supplementary contours at 100-foot intervals. 1956, limited revision 1961. ★ Geodetic control diagram, December 1963.

Douglas. Limiting parallels, 31° and 32°. Limiting meridians, 108° and 110°. Contour interval, 200 feet, with supplementary contours at 100-foot intervals. 1959, limited revision 1967. ★ Geodetic control diagram, January 1964.

El Centro. *Limiting parallels,* 32° and 33°. Limiting meridians, 114° and 116°. Contour interval, 200 feet, with supplementary contours at 100-foot intervals. 1958.

Escalante. Limiting parallels, 37° and 38°. Limiting meridians, 110° and 112°. Contour interval, 200 feet, with supplementary contours at 100-foot intervals. 1956, limited revision 1962. ★ Geodetic control diagram, July 1965.

Flagstaff. Limiting parallels, 35° and 36°. Limiting meridians, 110° and 112°. Contour interval, 200 feet, with supplementary contours at 100-foot intervals. 1954, limited revision 1962. ★ Geodetic control diagram, February 1964.

Gallup. Limiting parallels, 35° and 36°. Limiting meridians, 108° and 110°. Contour interval, 200 feet, with supplementary contours at 100-foot intervals. 1954, limited revision 1962. ★ Geodetic control diagram, January 1964.

Grand Canyon. Limiting parallels, 36° and 37°. Limiting meridians, 112° and 114°. Contour interval, 200 feet, with supplementary contours at 100-foot intervals. 1953, limited revision 1966. ★ Geodetic control diagram, February 1964.

Holbrook. Limiting parallels, 34° and 35°. Limiting meridians, 110° and 112°. Contour interval, 200 feet, with supplementary contours at 100-foot intervals. 1954, limited revision 1965. ★ Geodetic control diagram, January 1964.

Kingman. Limiting parallels, 35° and 36°. Limiting meridians, 114° and 116°. Contour interval, 200 feet. 1954, limited revision 1963. ★ Geodetic control diagram, April 1963.

Las Vegas. Limiting parallels, 36° and 37°. Limiting meridians, 114° and 116°. Contour interval, 200 feet. 1954, limited revision 1962. ★ Geodetic control diagram, May 1963.

Lukeville. Limiting parallels, 31° and 32°. Limiting meridians, 112° and 114°. Contour interval, 200 feet, with supplementary contours at 100-foot intervals. 1963.

Marble Canyon. Limiting parallels, 36° and 37°. Limiting meridians, 110° and 112°. Contour intervals, 200 feet, with supplementary contours at 100-foot intervals. 1956, limited revision 1963. ★ Geodetic control diagram, April 1963.

Mesa. Limiting parallels, 33° and 34°. Limiting meridians, 110° and 112°. Contour interval, 200 feet, with supplementary contours at 100-foot intervals. 1954, limited revision 1965. ★ Geodetic control diagram, April 1964.

Needles. Limiting parallels, 34° and 35°. Limiting meridians, 114° and 116°. Contour interval, 200 feet, with supplementary contours at 100-foot intervals. 1956, limited revision 1963.

SPECIAL MAPS AND SHEETS—Continued

United States Series of Topographic Maps, Scale, 1:250,000—continued. Nogales. Limiting parallels, 31° and 32°. *Limiting meridians, 110° and 112°.* Contour interval, 200 feet, with supplementary contours at 100-foot intervals. Size, 22 by 34 inches. 1956, limited revision 1962. ★ Geodetic control diagram, January 1964.

Phoenix. Limiting parallels, 33° and 34°. Limiting meridians, 112° and 114°. Contour interval, 200 feet, with supplementary contours at 100-foot intervals. 1954, limited revision 1964. ★ Geodetic control diagram, April 1964.

Prescott. Limiting parallels, 34° and 35°. Limiting meridians, 112° and 114°. Contour interval, 200 feet, with supplementary contours at 100-foot intervals. 1954, limited revision 1962. ★ Geodetic control diagram, March 1965.

St. Johns. Limiting parallels, 34° and 35°. Limiting meridians, 108° and 110°. Contour interval, 200 feet with supplementary contours at 100-foot intervals. 1954, limited revision 1962. ★ Geodetic control diagram, February 1964.

Salton Sea. Limiting parallels, 33° and 34°. Limiting meridians, 114° and 116°. Contour interval, 200 feet, with supplementary contours at 100-foot intervals. 1959, *limited revision 1967.*

Shiprock. Limiting parallels, 36° and 37°. Limiting meridians, 108° and 110°. Contour interval, 200 feet, with supplementary contours at 100-foot intervals. 1954, limited revision 1963. ★ Geodetic control diagram, June 1963.

Silver City. Limiting parallels, 32° and 33°. Limiting meridians, 108° and 110°. Contour interval, 200 feet, with supplementary contours at 100-foot intervals. 1954, limited revision 1962. ★ Geodetic control diagram, April 1966.

Tucson. Limiting parallels, 32° and 33°. Limiting meridians, 110° and 112°. Contour interval, 200 feet, with supplementary contours at 100-foot intervals. 1956, limited revision 1962. ★ Geodetic control diagram, January 1966.

Williams. Limiting parallels, 35° and 36°. Limiting meridians, 112° and 114°. Contour interval, 200 feet, with supplementary contours at 100-foot intervals. 1954, limited revision 1963. ★ Geodetic control diagram, February 1964.

Williams River, Ariz. Plan and profile of Williams River above a point 8 miles above its mouth, Big Sandy River to mile 10, Santa Maria River, Kirkland Creek to Kirkland, and miscellaneous damsites. Scale, 1:31,680, or ½ mile to 1 inch. Contour interval on land, 20 feet; on river surface, 5 feet. Vertical scale of profiles, 40 feet to 1 inch. Size, 21 by 27 inches. 9 sheets (4 plans, 4 profiles, 1 sheet showing damsites). 1934. Price, 50 cents a sheet.

NATIONAL PARKS AND MONUMENTS

[Additional information can be obtained from the National Park Service, *Department of the Interior, Washington, D. C. 20240.*]

Canyon de Chelly National Monument: See "Special maps and sheets," page 2.
Casa Grande Ruins National Monument: Shown on the Coolidge and Sacaton quadrangle maps.
Chiricahua National Monument: Shown on the Chiricahua Peak and Cochise Head quadrangle maps.
Coronado National Memorial: Shown on the Hereford SW and Montezuma Pass quadrangle maps.
Glen Canyon National Recreation Area, Utah-Ariz.: Located on the Escalante and Marble Canyon 1:250,000-scale maps.
Grand Canyon National Monument: See "Special maps and sheets," page 2.
Grand Canyon National Park: See "Special maps and sheets," page 2.
Lake Meade National Recreation Area, Ariz.-Nev.: Shown on the Grand Canyon, Kingman, Las Vegas, and Williams 1:250,000-scale maps.
Montezuma Castle National Monument: Shown on the Camp Verde quadrangle map.
Navajo National Monument: Shown on the Marble Canyon 1:250,000-scale map.
Organ Pipe Cactus National Monument: Shown on the Agua Dulce Mountains, Diaz Peak, Kino Peak, Lukeville, Mount Ajo, and Quitobaquito Springs quadrangle maps.
Petrified Forest National Park: See Petrified Forest National Monument under "Special maps and sheets," page 2.
Pipe Spring National Monument: Shown on the Fredonia quadrangle map.
Saguaro National Monument: Shown on the Cortaro, Happy Valley, Rincon Valley, San Xavier Mission quadrangle maps.
Sunset Crater National Monument: Shown on the Flagstaff 1:250,000-scale map.
Tonto National Monument: Shown on the Theodore Roosevelt Dam and Windy Hill quadrangle maps.
Tumacacori National Monument: Shown on the Tubac quadrangle map.
Tuzigoot National Monument: Shown on the Clarkdale quadrangle map.
Walnut Canyon National Monument: Shown on the Flagstaff East quadrangle map.
Wupatki National Monument: Shown on the Flagstaff 1:250,000-scale map.

MAPS OF THE UNITED STATES

BASE MAPS:

A wall map, showing State and county boundaries and names, State capitals, and county seats (in black); and water features (in blue). State boundaries are accentuated by green overprint. A buff background distinguishes the United States from adjoining countries. Insets show Alaska and Hawaii, and the Canal Zone, Puerto Rico, and the Virgin Islands. Scale, 1:2,500,000, or about 40 miles to 1 inch. 2 sheets, each 41 by 54 inches (when trimmed and assembled to make a single sheet, 54 by 80 inches.) 1961. Price, $2.00.

A wall map, showing State boundaries and names, State capitals, cities, towns, and villages (in black); and water features (in blue). State boundaries are accentuated by gray overprint. National parks and *monuments, Indian reservations, wildlife refuges, and national forests are named and outlined.* Insets show Alaska, Hawaii, the Canal Zone, Puerto Rico, the Virgin Islands, Guam, Samoa, and island possessions in the Pacific. Scale, 1:3,168,000, or 50 miles to 1 inch. One sheet, 42 by 65 inches. 1965. Price, $1.50.

Shows State and county boundaries and names, and water features (in black). Scale, 1:5,000,000, or about 80 miles to 1 inch. Size, 27 by 41 inches. 1933. Price, 75 cents.

Shows State and county boundaries and names (in black), and water features (in blue). Scale, 1:5,000,000, or about 80 miles to 1 inch. Size, 27 by 41 inches. 1933. Price, 75 cents.

Shows State boundaries and names (in black), county boundaries and names, and water features (in blue). Scale, 1:5,000,000, or about 80 miles to 1 inch. Size, 27 by 41 inches. 1933. Price, 75 cents.

Shows State boundaries and principal cities (in black); and water features (in blue). Scale, 1:7,000,000, or about 110 miles to 1 inch. Size, 20 by 30 inches. 1916. Price, 50 cents.

Shows State boundaries and principal cities (in black), and water features (in blue). Scale, 1:11,875,000, or about 190 miles to 1 inch. Size, 13½ by 20 inches. 1906. Price, 20 cents.

Shows State boundaries and principal cities (in black); and water features (in blue). Scale, 1:16,500,000, or about 260 miles to 1 inch. Size, 9½ by 13 inches. 1911. Price, 10 cents.

CONTOUR MAP:

Shows State boundaries and principal cities (in black); water features (in blue); and contours (in brown). Scale, 1:7,000,000, or about 110 miles to 1 inch. Size, 20 by 30 inches. 1916. Price, 50 cents.

OUTLINE MAP:

Shows State boundaries and names only. Scale, 1:5,000,000, or about 80 miles to 1 inch. Size, 27 by 41 inches. 1940. Price, 50 cents.

PHYSICAL DIVISIONS:

Shows physical divisions outlined in red on a base map 20 by 30 inches. Subdivisions and characteristics of each are listed on the margin. Scale, 1:7,000,000, or about 110 miles to 1 inch. Size, 28 by 32 inches. 1946. Price, 50 cents.

STATUS INDEX MAPS:

A series of maps showing the status of various phases of mapping in the United States. Each map is accompanied by a text which gives a detailed explanation. Scale, 1:5,000,000, or about 80 miles to 1 inch. Size, 27 by 41 inches. Free on application to the Geological Survey, Washington, D. C. 20242. The following maps are available:

Topographic Mapping-Status and Progress of Operations (7½ and 15 minute series). Shows the status *of topographic mapping and progress of operations in the United States, by the Geological Survey and* other Federal agencies. A general appraisal of the adequacy of these maps is indicated by color patterns. Published semiannually.

Aerial Mosaics of the United States. Shows all areas in the United States for which mosaics or photo maps have been prepared from aerial photographs, scale of negatives, dates of photography, and agencies from which copies may be obtained. Color patterns indicate the holdings of the various Federal and state agencies and commercial firms that have reported their coverage to date.

Aerial Photography of the United States. Shows the status of aerial photography, areas that have been photographed, and agencies holding the film. Coverage of aerial photography is shown to the extent known only if reproductions are generally available for purchase.

MAP REFERENCE LIBRARIES

Many libraries maintain map reference facilities where the published maps of the Geological Survey may be consulted. These maps are also on file in the field offices of the Geological Survey. In this State, maps are deposited in the libraries listed below.

FLAGSTAFF:
Library, Northern Arizona University.

PHOENIX:
Library & Archives, 309 State House.

TEMPE:
Social Science Service, Arizona State University.

TUCSON:
Arizona Bureau of Mines, University of Arizona Library, University of Arizona.

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ARIZONA

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

ARIZONA

INDEX TO TOPOGRAPHIC MAPS OF ARIZONA

The Geological Survey is making a series of standard topographic maps to cover the United States, Puerto Rico, Guam, American Samoa, and the Virgin Islands. Under the plan adopted, the unit of survey is a quadrangle bounded by parallels of latitude and meridians of longitude. Quadrangles covering 7½ minutes of latitude and longitude are published at the scale of 1:24,000 (1 inch=2,000 feet). Quadrangles covering 15 minutes of latitude and longitude are published at the scale of 1:62,500 (1 inch=approximately 1 mile), and quadrangles covering 30 minutes of latitude and longitude are published at the scale of 1:125,000 (1 inch=approximately 2 miles). A few special maps are published at other scales, as listed in this index under special headings. Each quadrangle is designated by the name of a city, town, or prominent natural feature within it, and on the margins of the map are printed the names of adjoining published quadrangle maps.

The maps are printed in three colors. The cultural features, such as roads, railroads, cities, and towns, as well as the lettering, are in black; the water features are in blue; and the features of relief, such as hills, mountains, and valleys, are shown by brown contour lines. The contour interval differs according to the scale of the map and the relief of the country. On maps that contain supplemental information additional colors are used, such as green for woodland areas and red for highway classification, urban areas, and United States land lines. A booklet describing topographic maps and symbols is available free upon request.

Most topographic maps are available either with or without green woodland overprint. Specify which edition is desired and whether substitution of the other edition is acceptable.

In addition to the standard topographic map, a Special Printing with both contours and woodland omitted, is also available for those quadrangles shown on the index with the symbol ⊗.

In many instances, an area is covered by 2 or more maps which carry the same name, but are published at different scales. Wherever this occurs, the map order should also include the map series designation, such as 7½-minute, 15-minute, or 30-minute series.

The extent of map coverage is shown on the index map, on which the mapped areas are outlined in black. Quadrangles for which published maps are available have the quadrangle name, publishing agency (if other than the Geological Survey), and the date or dates of survey also printed in black. A list of special maps and sheets is given on the following pages.

Further information concerning maps may be obtained from the Map Information Office, Geological Survey, Washington, D. C. 20242.

HOW TO ORDER MAPS

Maps covering areas in the States west of the Mississippi River (including all of Louisiana and Minnesota) should be ordered directly from the *Distribution Section, Geological Survey, Federal Center, Denver, Colorado 80225.* Maps for areas east of the Mississippi River (including Puerto Rico and the Virgin Islands) should be ordered from the *Distribution Section, Geological Survey, 1200 South Eads Street, Arlington, Virginia 22202.* A single order combining both eastern and western maps may be placed with either office.

The price of a standard quadrangle map is 50 cents, but a discount of 20 percent is allowed on orders of $20 or more, and 40 percent on orders of $100 or more, based on the retail price. All published maps distributed by the Geological Survey are subject to the discount rates. Prices for maps other than standard quadrangle maps are given on the following pages of this text. Prepayment is required and may be made by money order or check, payable to the Geological Survey, or in cash—the exact amount—at the sender's risk. Postage stamps or coupons are not accepted. To expedite delivery, the name and address of the purchaser should be typed or printed on the map order. Your ZIP Code is required.

On orders to other countries (except Canada and Mexico) a surcharge of 25 percent of net bill is added for surface transportation. If purchaser pays airmail costs, the surcharge is waived. Shipments of six maps or less are folded and mailed in envelopes unless unfolded copies are requested in the original order. Larger quantities of maps are sent unfolded. The Geological Survey does not supply mounted maps.

Revised December 1968

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DEALERS FOR TOPOGRAPHIC MAPS

Purchasers may save delay incident to ordering through the mails by buying from the following dealers, who carry in stock some or all of the maps described in this index and sell them at prices usually in advance of rates herein mentioned.

ARIZONA

FLAGSTAFF:
NAU Bookstore, Northern Arizona University.

PHOENIX:
Ace Photo Copy Service, Inc., 124 W. McDowell Road.
Arizona Automobile Association, 748 East McDowell Road.
Arizona Blue Print Co., 333 North 3rd. Avenue.
High Adventure Headquarters, 3215 E. Camelback Road.
Phoenix Blueprint Co., 4141 North Seventh Street.

TEMPE:
Phoenix Blue Print Co., 408 Mill Avenue

TUCSON:
Arizona Automobile Association, 228 West Drachman Street.
Multilithing Bureau, 102 West Stadium University of Arizona.
Pima Blueprint Co., Inc., 4655 East Broadway.
Reproductions Inc., 284 East Sixth Street.
Tucson Blueprint Co., 537 North Sixth Avenue.

CALIFORNIA

LOS ANGELES:
California Map Center, 1100 South Hope Street.
Westwide Maps Co., 114 West Third Street.

PALM DESERT:
Desert Agents, Del Gagnon Co., 73-612 Highway 111.

SOUTH GATE:
E. R. Jacobsen, 9322 California Avenue.

COLORADO

MONTROSE:
Burton Map Service, Post Office Bldg.

NEVADA

BOULDER CITY:
Mead-Mohave Association, 601 Nevada Avenue.

LAS VEGAS:
Mercury Blueprint & Supply Co., 1600 So. Commerce Street.

NEW MEXICO

ALBUQUERQUE:
Holman's, 401 Wyoming Boulevard, NE.

FARMINGTON:
Excelsior Reproductions & Engineering Supplies, 412 West Broadway.
San Juan Reproduction Co., 135 N. Airport Drive.

NEW YORK

NEW YORK CITY:
International Map Co., Inc., 140 Liberty Street.

PENNSYLVANIA

PHILADELPHIA:
J. L. Smith Co., 27 South Eighteenth Street.

WASHINGTON

SEATTLE:
Max Kuner Co., 1324 Second Avenue.

GEOLOGICAL SURVEY OFFICES

(over-the-counter map sales only)

Some or all of the maps described in this index may be purchased over-the-counter only at the following Geological Survey offices:

CALIFORNIA

LOS ANGELES:
Room 7638 Federal Bldg., 300 N. Los Angeles Street.

SAN FRANCISCO:
504 Custom House, 555 Battery Street.

MENLO PARK:
345 Middlefield Road.

COLORADO

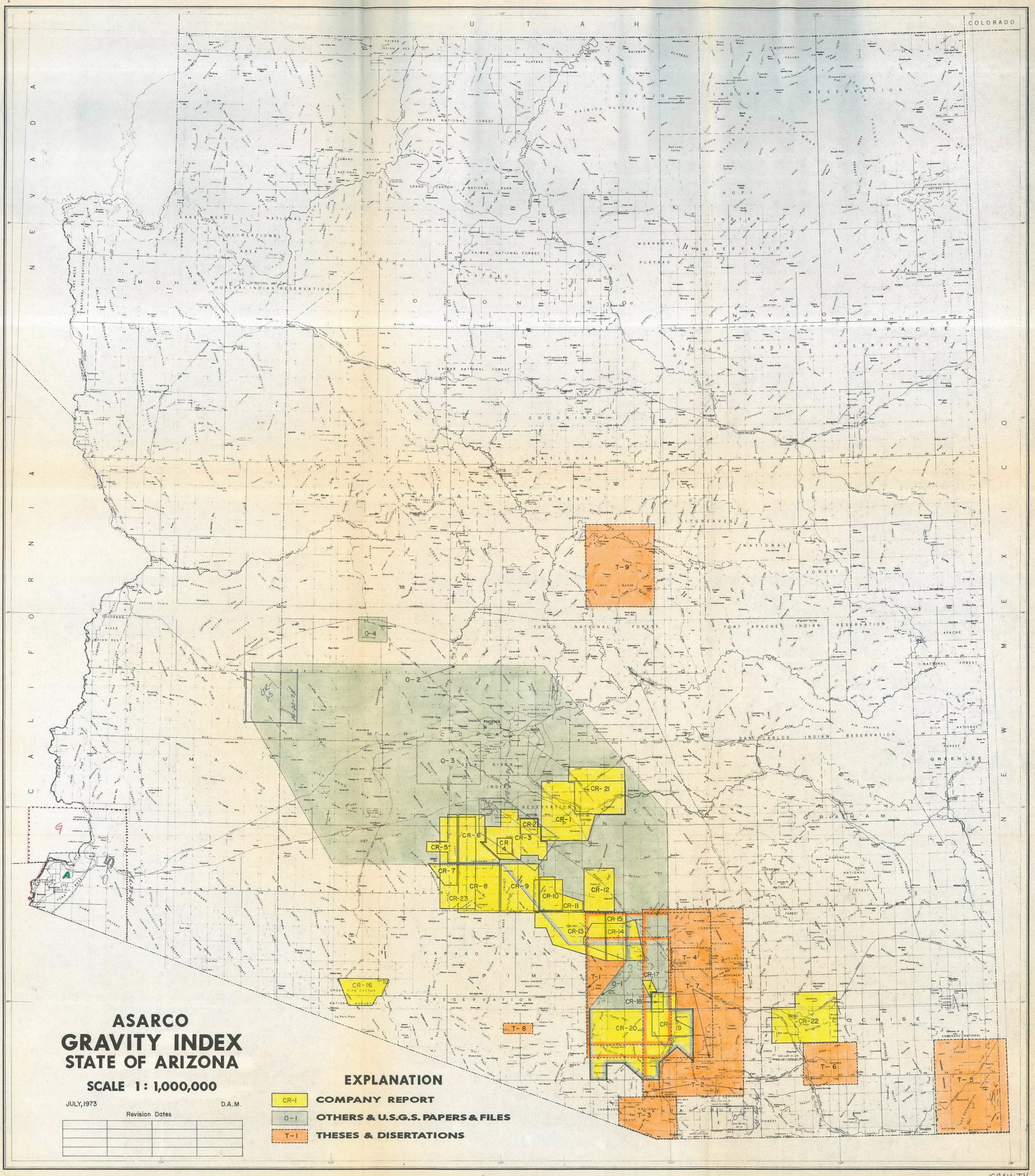
DENVER:
Room 1021, Federal Building, 1961 Stout Street.

DISTRICT OF COLUMBIA

WASHINGTON:
1028 GSA Bldg., 19th & F Streets, NW.

UTAH

SALT LAKE CITY:
8102 Federal Bldg., 125 South State Street.


ASARCO
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STATE OF ARIZONA
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JULY, 1973
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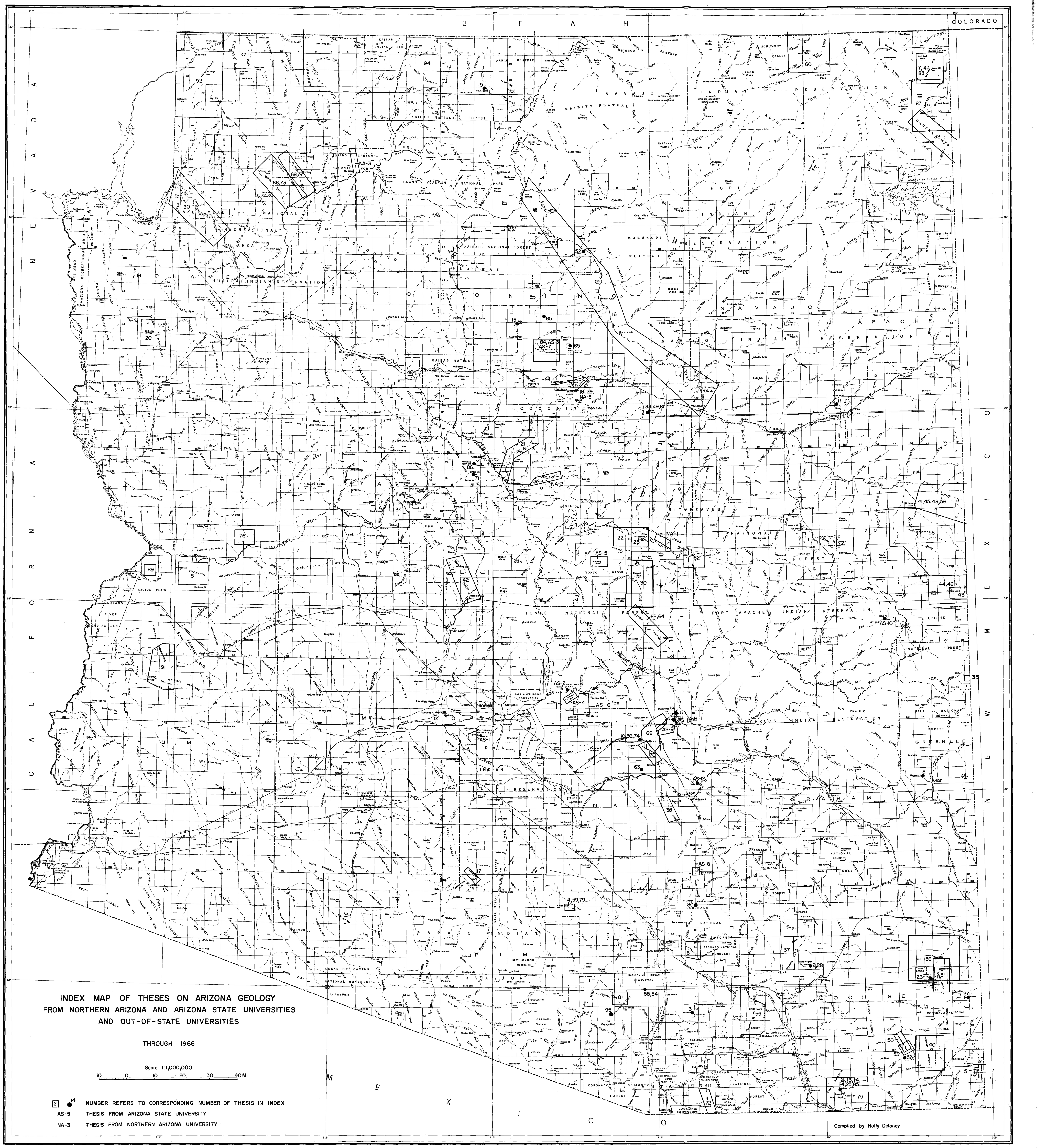
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FROM NORTHERN ARIZONA AND ARIZONA STATE UNIVERSITIES
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Compiled by Holly Deloney
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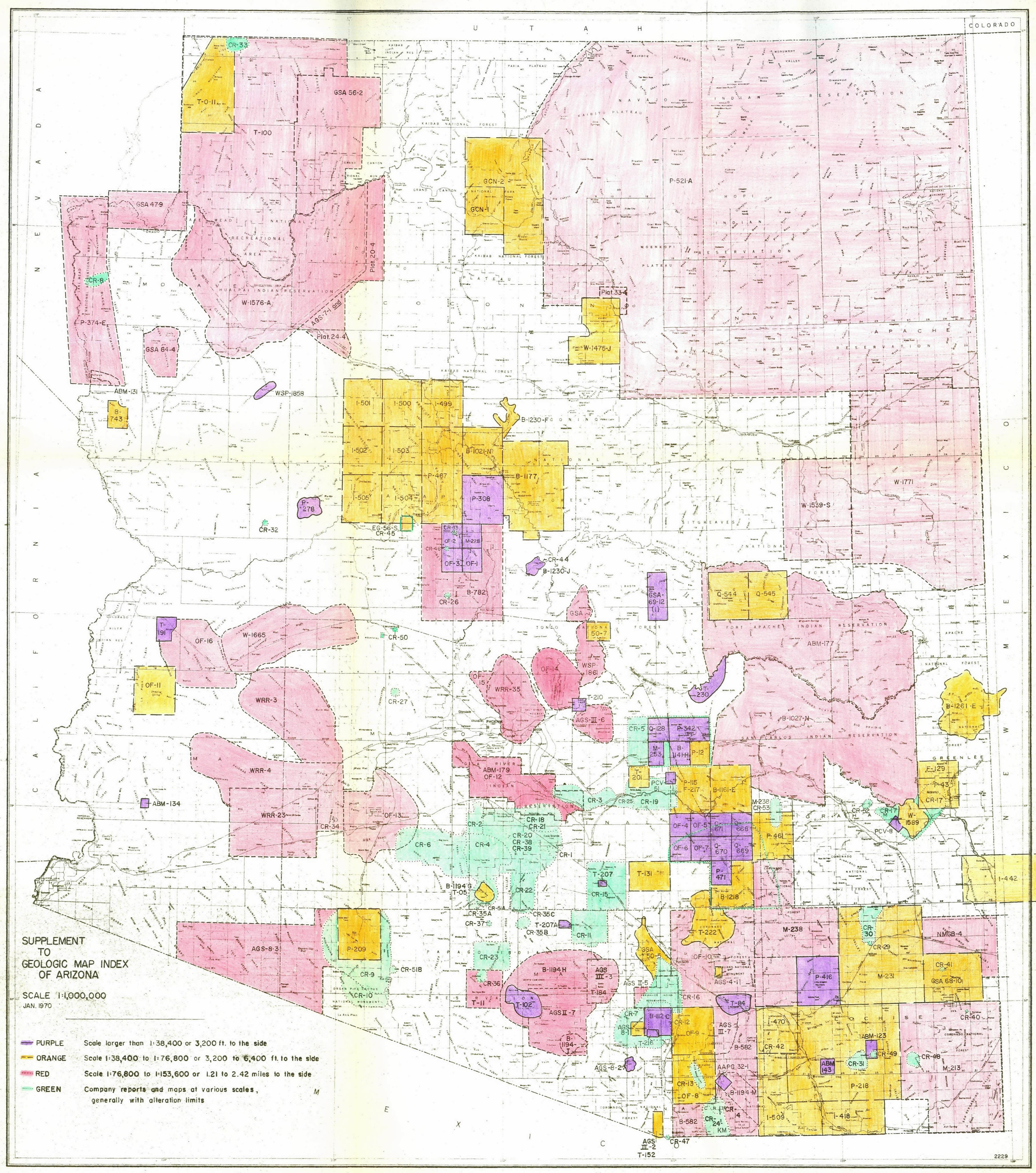
MEXICO


SUPPLEMENT
TO
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ORANGE Scale 1:38,400 to 1:76,800 or 3,200 to 6,400 ft. to the side
RED Scale 1:76,800 to 1:153,600 or 1.21 to 2.42 miles to the side
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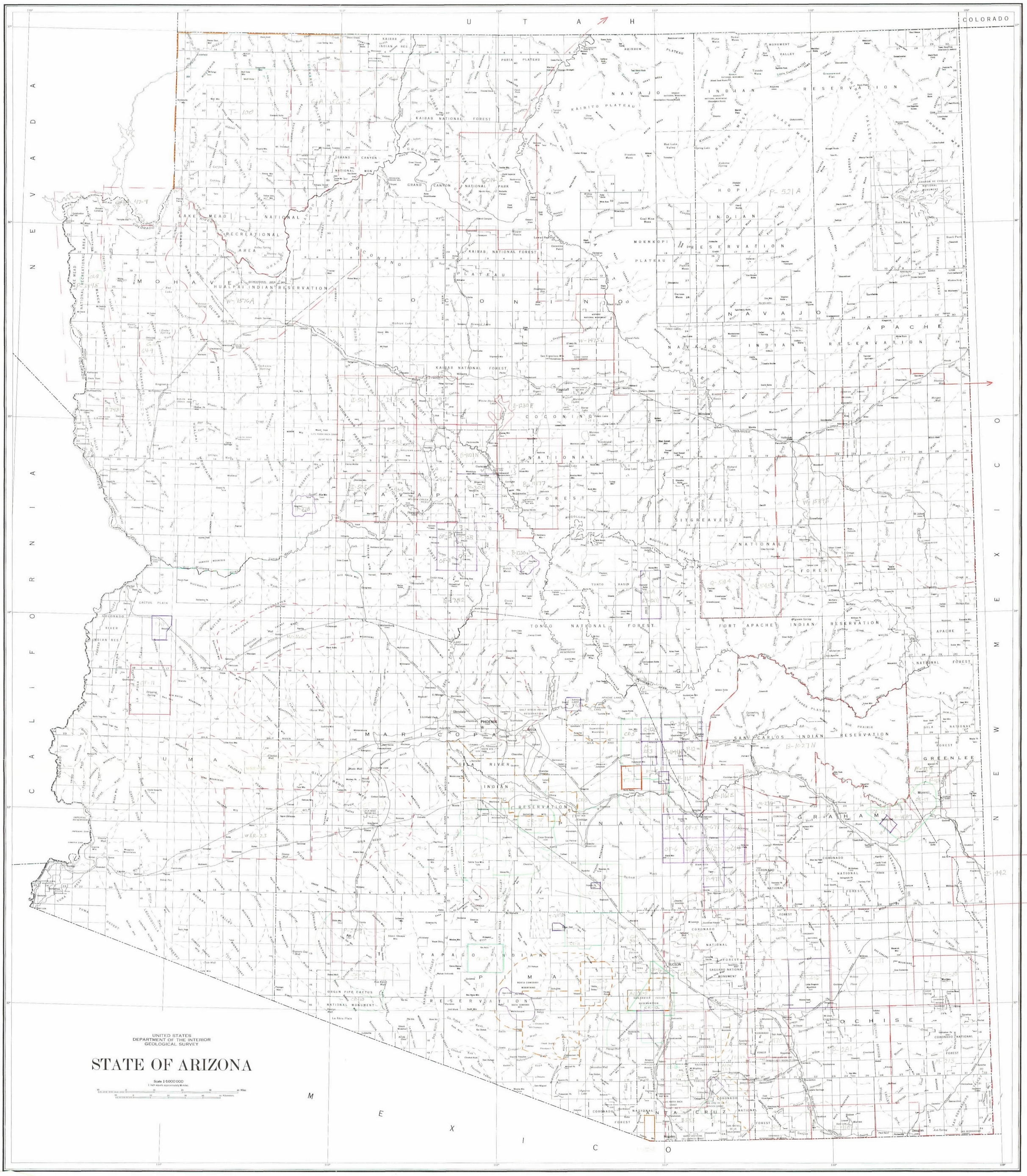
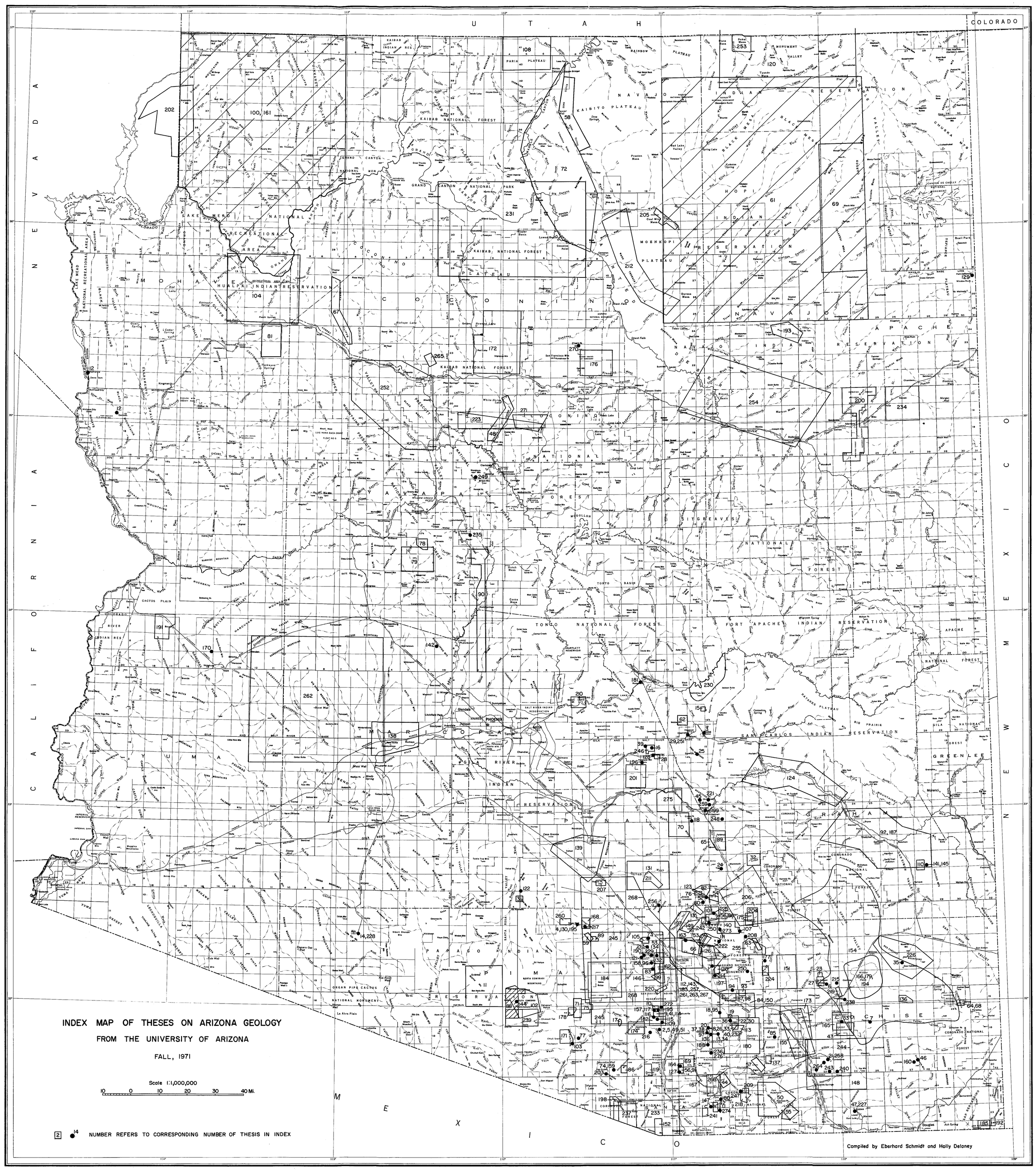
ABM 143
CR-31
M-213
CR-13
OF-8
B-1194-M
P-218
CR-4
CR-24
KM
B-582
I-509
I-418
AGS III-2
T-152
CR-47
2229


UTAH
COLORADO
NEVADA
CALIFORNIA
NEW MEXICO
MEXICO
KAIBAB NATIONAL FOREST
GRAND CANYON NATIONAL PARK
LAKE MEAD NATIONAL RECREATIONAL AREA
HUALPAI INDIAN RESERVATION
COCONINO NATIONAL FOREST
NAVAJO INDIAN RESERVATION
HOPI INDIAN RESERVATION
APACHE NATIONAL FOREST
FORT APACHE INDIAN RESERVATION
SAN CARLOS INDIAN RESERVATION
GILA RIVER INDIAN RESERVATION
PIMA INDIAN RESERVATION
TONTO NATIONAL FOREST
PRESCOTT NATIONAL FOREST
Flagstaff
Winslow
Prescott
PHOENIX
Globe
TUCSON
Nogales
Douglas
Yuma
Ajo
UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
STATE OF ARIZONA
Scale 1:1000 000
1 inch equals approximately 16 miles


INDEX MAP OF THESES ON ARIZONA GEOLOGY
FROM THE UNIVERSITY OF ARIZONA
FALL, 1971
Scale 1:1,000,000
10 0 10 20 30 40 Mi.
NUMBER REFERS TO CORRESPONDING NUMBER OF THESIS IN INDEX
Compiled by Eberhard Schmidt and Holly Delaney
UTAH
COLORADO
NEVADA
CALIFORNIA
ARIZONA
NEW MEXICO
MEXICO