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OFFICE OF

Oil and Gas Conservation Commission

STATE OF ARIZONA

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July 12, 1972

Mr. James D. Sell
American Smelting and Refining
Company
Southwestern Exploration Division
P. O. Box 5747
Tucson, Arizona 85703

Dear Mr. Sell:

I appreciate very much your letter of July 5th regarding your stratigraphic work west of the Vekol and Slate Mountains.

Your remark in your abstract of the paper given at the GSA Tucson meeting in 1968 that Paleozoic rocks extended at least 25 miles west of previously described units arouses my curiosity. This would seem to put these outcrops in the Sauceda Mountains or under some of the adjoining basalt hills. I wonder if you could give us a more definite location by section, township and range or some other identification for the outcrops you describe without revealing any information of economic value to your company.

The reason we are anxious to secure this information is that the purpose of the Geology Section of the Commission, in addition to its work as advisor to the Regulatory Section, is to encourage oil, gas, helium and geothermal exploration in the state. From time to time we have inquiries regarding outcrops of sedimentary rocks by geologists for oil companies following the play by Humble, so we are anxious to know of all areas in the state where sedimentary rocks may be examined.

Under separate cover we are sending you a copy of a Preliminary Tabulation of Stratigraphically Significant Water Wells in Basin and Range Province of Arizona, which may be of some interest to you. We have had a little cooperation from the mining companies regarding drilling in mineral exploration.

Again we are primarily interested in stratigraphic information and, of course, have no interest in the mineral content of any rocks found. If you could send us the logs of any such drill holes or let us know of any holes drilled by other companies, we would greatly appreciate your cooperation.

Sincerely yours,

Ed. Koester

Edward A. Koester
Staff Geologist

EAK:st

JDS - for your file

THE GEOLOGY AND ORE DEPOSITS OF THE VEKOL MOUNTAINS

PINAL COUNTY, ARIZONA

Stanford University Ph.D. thesis submitted by Robert Halstead Carpenter,
July, 1947.

GENERAL GEOLOGY

Summary

The rocks in the Vekol Mountains range in age from pre-Cambrian to Quaternary, and comprise one of the most complete columner sections in the Basin Range province of Arizona.

The oldest rock is the fine-grained, greenish-gray schist, which has been correlated with the pre-Cambrian Pinal schist of southern Arizona. It is intruded by a granite which is believed to be of Tertiary age.

The Apache group, estimated to be more than 1,500 feet thick, includes the Pioneer shale, the Barnes conglomerate, the Dripping Spring quartzite and the Mescal limestone. A basalt flow, which is usually included in the Apache group, overlies the Mescal limestone. This group rests unconformably on the schist basement.

The overlying Troy quartzite, of doubtful age, was deposited on the eroded surface of the Apache basalt and Mescal limestone. This formation, the Apache group, and the basement rocks, have been intruded by diabase tentatively regarded as Middle or Lower Cambrian age.

The upper fifty-foot cross-bedded member of the Troy quartzite, the Santa Catalina formation, and the thin Southern Belle quartzite lie above the lower Troy. All contain Cambrian brachiopods. These are succeeded by the Upper Cambrian Abrigo formation. Resting on the Cambrian rocks is an Upper Devonian section composed of three units tentatively designated by the writer as the Picacho de Calera formation, the Martin limestone, and the Lower Ouray formation. The Lower Mississippian Escabrosa limestone follows, and is separated from the Lower Pennsylvanian Naco limestone by a distinct shale marker bed. The Paleozoic section, measured at Promontory Ridge and at the Vekol mine, is approximately 1,681 feet thick. (See Plates 4 and 8.) The entire section of Paleozoic and Apache rocks is essentially conformable in dip and strike, but is separated by at least five disconformities.

Red beds, quartzites and boulder conglomerates exceeding 400 feet in thickness were deposited on eroded Naco limestone. They probably are Cretaceous continental deposits.

The red beds and quartzites appear to grade upward into loosely cemented conglomerates and sandstones. The latter are interbedded with andesitic lavas near the top.* Dacite porphyry, sills, dikes, and flows of intermediate composition

* Hadley, J. B. Copper deposites of the Reward Area, Pinal County, Arizona. Preliminary Report, Strategic Minerals Div., U.S.G.S., 1942.

and rhyolite porphyry are referred to the Tertiary. Tuff, conglomerate, agglomerate and basalt are believed to be Quaternary. Terrace gravels and recent alluvium are distributed throughout the area on pediments and alluvial slopes.

Sedimentary Rocks --- Algonkian Apache Group

The rocks of the Apache group were described and designated as Cambrian by Ransome* in his work in the Ray and Miami area of central Arizona. He

* Ransome, F. L. The Copper Deposits of Ray and Miami, Arizona. U.S.G.S. P.P. 115, 1912. pg. 39.

included the Scanlan conglomerate, the Pioneer shale, the Barnes conglomerate, the Dripping Spring quartzite and the Troy quartzite within this group. Darton* and others, however, consider the Apache group as equivalent to the

* Darton, N. H. Resume of Arizona Geology. Bull. 119 Arizona Bureau of Mines, 1925. pg. 36.

Grand Canyon series. Furthermore, Darton* found evidence, pointed out under

* Idem pg. 36.

the heading "Troy quartzite", page 21 which separates the Troy from the Apache group. For that reason, the Troy quartzite is not considered a part of the Apache group in this report.

In the Vekol Mountains, the rocks of the Apache group are well-exposed in the south-central part of the main range and, to a limited extent, along the southern fringe of the range and the northeastern edge of the east ridges. (See Plate 3.) All are well represented except the Scanlan conglomerate. They form a section estimated at more than 1,500 feet in thickness, and rest unconformably on the schist basement.

Scanlan conglomerate (?)

A few scattered patches of conglomerate consisting of white quartz pebbles in a sandy matrix containing numerous schist fragments were noted along the contact between the schist and the Pioneer shale at the southeast end of Bitter Wells Basin. These patches are but a few inches thick, and they can be traced laterally not more than ten to fifteen feet. They grade upward into maroon, sandy shale containing occasional quartz pebbles.

Pioneer shale

This formation consists largely of maroon, somewhat sandy shale and impure sandstone and quartzite. The lower part is predominantly arenaceous with numerous impure quartzite beds and occasional sandy shales and shaly sandstones; the bedding is moderately thick, ranging from six inches to three feet. In the central and upper part of the formation impure, sandy shales predominate. Toward the top of the formation, the beds contain abundant round or elongated spots of white or tan color. According to Ransome*, these

* Ransome, F. L. The Copper Deposits of Ray and Miami, Arizona. U.S.G.S. P.P. 115, 1912. pg. 40.

are caused by the local reduction and removal of ferruginous pigment. This characteristic marking of the Pioneer shale identifies it from similar beds in the Dripping Spring quartzite. The estimated thickness of this formation is 400 feet.

Barnes conglomerate

This formation is made up of well-rounded, ellipsoidal quartzite pebbles ranging up to 6 inches in diameter embedded in a coarse, arkosic matrix which contains occasional fragments of red jaspar. The pebbles generally lie with their flat sides roughly parallel to the trend of bedding. The sorting is poor and, locally, the formation consists of coarse, arkosic sandstone with only a few pebbles.

The maximum thickness of the formation is 18 feet at the southern end of Bitter Wells Basin. Southward, it thins rapidly, and, along the southern flank of the main range, no Barnes conglomerate is present. It appears to overlie the Pioneer shale conformably.

Dripping Spring quartzite

This formation consists of three members: the lower massive quartzite, the central, thin-bedded impure shale, and the upper banded quartzite. It lies conformably above the Barnes conglomerate and Pioneer shale and conformably below the Mescal limestone.

The lower member consists of hard, medium to fine-grained, reddish, arkosic quartzite. The bedding is indistinct, although occasional shaly partings are evident. Toward the top, the beds become thin and are intercalated with shaly sandstone and sandy shales. The thickness of this unit is estimated at 225 feet.

The central member is made up largely of gray to tan, thinly-bedded, arenaceous shale, which often is well-banded and frequently somewhat platy. The individual beds range from $\frac{1}{4}$ of an inch to 2 inches thick. They grade upward into thinly-bedded, medium to fine-grained, brown quartzite. It is difficult to estimate the thickness of this unit because of faulting and poor exposure, but it is believed to be over 400 feet thick.

The upper member ranges from pinkish-gray, massive, fine-grained, arkosic quartzite near the base, to medium-grained, banded, gray to tan quartzite beds near the top. The latter are from four to ten feet thick, with shaly partings between. At the top, the beds become thin, flaggy and rusty brown and are interbedded with strongly ribbed, impure limestone at the base of the Mescal limestone. The transition zone is generally ten to twenty feet wide. The thickness of the upper unit is 140 feet at the southern end of Bitter Wells Basin.

The Dripping Spring quartzite was deposited in shallow water, for worm casts and ripple marks were noted. It is composed mainly of fine material. Pebbles were found only in a few narrow bands just above the Barnes conglomerate. The thin-bedded shale member in the middle of the formation helps to distinguish it from the Troy quartzite described below.

Mescal limestone

In the Vekol Mountains, this formation consists of tan, buff or gray, often dolomitic limestone. It usually has a ribbed appearance characteristic of exposures in other areas. (See Print 3.) The ribbing is caused by cherty or siliceous layers $\frac{1}{2}$ inch thick interbedded with thin-banded limestone. In some exposures, the more resistant cherty layers are so numerous that the weathered surface has a rough, gnarled appearance. In others, the ribbing is weak or absent.

As illustrated on Plate 4., the Mescal limestone has a thickness of 466 feet, including two diabase sills, which total 175 feet. This thickness probably represents the maximum in the area for in this traverse, the Mescal limestone has a normal contact with the underlying Dripping Spring quartzite. Over 75 feet of Apache basalt lies above. Along the southern end of the Range, the Mescal limestone is only a few feet thick, and the Apache basalt is missing. Apparently, early Cambrian erosion stripped the basalt and much of the Mescal limestone from that area.

The true thickness of the Mescal limestone is probably represented by the actual limestone thickness shown on Plate 4., for there seems to have been very little assimilation of the limestone by the diabase. Wedging appears to have been the main intrusive process exhibited by the diabase.

A remarkable pattern has developed in the Mescal limestone just south of Promontory Ridge. Dr. A. C. Waters* and the writer concur that this arcuate

* Personal communication

pattern has been developed by fracturing, solution and subsequent compaction. The following steps are proposed:-

1. Fracturing normal to the bedding.
2. Solution of the limestone along the fractures.
3. Subsequent compaction with arching of the unaffected intermediate areas into the arcuate pattern.
4. Recrystallization along the fractures.

This phenomenon can be traced laterally to normal, banded limestone in adjacent unfractured areas. In some cases, particularly in horizons of strong ribbing, it has developed with such intensity as to form a rock similar in appearance to an intraformational conglomerate. (See Print 6.)

Paleozoic Rocks

The Paleozoic section in the Vekol Mountains, as measured on Promontory Ridge and at the Vekol mine, is approximately 1,681 feet thick. It includes quartzites and shale of Middle Cambrian age, and limestone of Upper Cambrian, Upper Devonian, Lower Mississippian and Lower Pennsylvanian age. The Ordovician, Silurian, and much of the Devonian are not represented.

These rocks are essentially conformable in dip and strike with the underlying rocks of the Apache group. There is an angular unconformity between the Lower Pennsylvanian Naco limestone and the overlying Cretaceous? red beds.

Troy quartzite

Distribution

In the Vekol Mountains, the Troy quartzite is well-exposed in the cliffs along the southwestern edge of Bitter Wells Basin, and, to a limited extent, along the southern fringe of the main range and at the northern end of the east ridges. (See Plate 3.)

Lithology

The formation consists of two distinct members, the lower massive, cliff-forming member and the upper cross-bedded unit. They are separated by a bench-forming shaly marker. The section at the east end of Promontory Ridge, shown on Plate 4., is as follows:

Upper Member	a.	Strongly cross-bedded, rusty, medium-grained calcareous quartzite in 1 to 5-foot beds with occasional sandy, yellow-brown limestone near the top.	(Top) 39 feet
	b.	Thin-bedded shaly zone with abundant brachiopods.	10 feet
		----------Unconformity?----------	
	c.	Well-banded 1-foot quartzite beds interbedded with calcareous quartzite.	30 feet
Lower Member	d.	Massive, vitreous, cliff-forming quartzite with occasional indistinct shale partings.	71 feet
	e.	6-inch to 2-foot beds of quartzite and siliceous, buff sandstone.	52 feet
	f.	Banded, buff sandstone with $\frac{1}{8}$ inch to 3-inch banding.	48 feet
		Total	252 feet

The upper, brown, highly cross-bedded quartzite (a.) consists mainly of calcareous sandstone. The latter often contain small, poorly preserved brachiopods. The individual beds range from one to five feet in thickness, and consist of medium-grained, rusty sandstone. They form cliffs. (See Print 9.) Toward the top are occasional yellow-brown limestone beds interbedded with cross-bedded quartzites. It is difficult to place the contact of this upper Troy unit and the overlying Santa Catalina formation, for the quartzite beds become less numerous, and finally, and succeeded by impure, brown limestone and micaceous sandstone and shale. The contact is arbitrarily placed at the top of the highest prominent quartzite bed.

The bench-forming shale zone (b.) consists of quartzite and sandstone beds ½ inch to 1 inch in thickness, thin-bedded paper shales, and knotty sandstone nodules embedded in a shaly matrix. In places, patches of grit were noted along the base. Small, poorly preserved brachiopods were found in this shale marker horizon.

Age and Correlation

In his early work in the Globe area*, Ransome considered the Troy quartzite

* Ransome, F. L. The Geology of the Globe Copper District, Arizona. U.S.G.S. P.O. 12, 1903. pg. 28.

a part of the Dripping Spring quartzite. Later, in the Ray quadrangle*, he

* Ransome, F. L. The Copper Deposits of Ray and Miami, Arizona. U. S. G. S. P. P. 115, 1912. pg. 44.

designated the Troy as a distinct formation. He considered the Troy as the youngest formation of the Apache group, and believed this group of rocks included the Ordovician and Silurian and was gradational into the Upper Devonian Martin limestone. For that reason, he placed both the Troy and the Apache group in the Cambrian.

Subsequent work has shown that the Apache group is not gradational into the Devonian. Stoyanow* has measured over 700 feet of fossiliferous

* Stoyanow, A. A. Correlation of Arizona Paleozoic Formations. Bull., G. S. A. Vol. 42, 1947. pg. 459-540. pg. 474.

Middle and Upper Cambrian beds between the Troy and the Martin limestone. In the Vekol Mountains, about 360 feet of Middle and Upper Cambrian beds separate the Troy from the Upper Devonian. Darton is also opposed to the Cambrian

* Darton, N. H. Resume of Arizona Geology, Bull. 119 Ariz. Bureau of Mines, 1925. pg. 36.

age of the Apache group. He believes it is comparable to the Grand Canyon series of Proterozoic time.

Darton* points out an unconformity between the Mescal limestone and

* Darton, N. H. Resume of Arizona Geology. Bull. 119 Ariz. Bureau of Mines, 1925. pg. 36.

the Troy quartzite with thinning of the Troy toward central Arizona. This unconformity is confirmed by the presence of the vesicular, Apache basalt flows and by channelling of the basalt and Mescal limestone in the Vekol Mountains, in the Superior district* in the Santa Catalina Mountains,** and in other areas.

* Short, M. N. and others. Geology and Ore Deposits of the Superior Mining Area, Arizona. Bull. 151, Ariz. Bureau of Mines, 1943. pg. 34.

** Stoyanow, A. A. Correlation of Arizona Paleozoic Formations. Bull. G.S.A., Vol. 42, pp. 459-540. 1947. pg. 474.

Stoyanow* separates the Troy from the Apache group "not only because

* idem. pg. 474.

it overlaps the Mescal limestone, but because it carries Cambrian fossils and conformably underlies younger Middle Cambrian strata." Fossils were found by M. R. Campbell as early as 1904 in the Troy in Deer Creek Canyon south of the Mescal Mountains in central Arizona.* They were determined by Walcott

* Same reference. pg. 475.

as Lingulella pogonipensis (Walcott) and Dicellomus politus (Hall) and were classified as "probably Middle Cambrian".

Stoyanow* also mentions that in the Mescal Mountains near the top of

* Same reference.

the Troy, there are abundant, but poorly preserved brachiopods.

In the Vekol Mountains the following evidence can be pointed out regarding the age of the Troy quartzite:

1. Although it apparently is conformable in strike and dip with the Mescal limestone, it is separated from that formation by the vesicular Apache basalt flows.

2. There appears to be marked channelling of the Apache basalt and Mescal limestone. The basalt is missing locally along the southern fringe of the range, and the Mescal limestone is not more than 50 feet thick in the same area. The overlying lower Troy is at least 100 feet thick.

3. The top, cross-bedded member of the Troy and the underlying shaly zone not only contain numerous Cambrian Brachiopods, but also are conformable with the overlying Santa Catalina beds and appear to grade upward into them.

4. Diabase has intruded all of the units of the Apache group and penetrates the lower Troy to within a few feet of the shale zone which separates the main, massive, cliff-forming Troy from the upper cross-bedded fossiliferous member.

5. Also, this same shaly zone and the upper cross-bedded member overlap a well-exposed diabase erosion surface. A definite basal conglomerate consisting largely of diabase pebbles, cobbles and fragments in a cross-bedded sandy, cherty and calcareous matrix has been deposited on the old surface.

The writer believes the upper Troy may represent middle Cambrian deposition in the Vekol Mountains which continued through Santa Catalina and Southern Belle time.

The age of the lower massive, cliff-forming and sandy horizons is questionable. As outlined above, there appears to be a definite erosional break at the top and bottom of this member of the Troy. No fossils have been found to date it as Middle or Lower Cambrian; nor is there any evidence in the Vekol Mountains to date it as immediately post Apache basalt. On the contrary, the apparent channelling of the Mescal erosion surface in the southern part of the range would tend to date this unit as definitely post Apache basalt.

In the opinion of the writer, further regional work should be carried out to see if the unconformity separating the upper from the lower Troy in the Vekol Mountains can be traced to central Arizona. If so, are the fossils found by Hall, Stoyanow, and others restricted to the upper Troy? Also, does the unconformity pointed out by Darton involve the entire Troy as described

* Darton, N. H. Resume of Arizona Geology. Bull. 119, Arizona Bureau of Mines, 1925. pg. 36.

BY THE WRITER IN THE Vekol Mountains?

Santa Catalina Formation

This formation is well-exposed along the east front of the main range, and, to a limited extent, along its southern fringe and at the base of the east ridges in the northeastern part of the Vekol Mountains.

The section on the east end of Pronghorn Ridge is typical. (See Plate 4.) It is 265 feet thick. The lower sixty feet consist largely of yellow-brown, impure limestone containing numerous intraformational conglomerate horizons of fine-grained, arenaceous limestone fragments.

The central 175 feet is largely greenish-gray, micaceous shale interbedded with thin, ½ to 1 inch, brown, micaceous sandstone, shaly sandstone, and occasional brown limestone beds containing intraformational conglomerate structure.

In the top 30 feet, the sandstone beds are thicker, occur more frequently and usually are cross-bedded. Small brachiopods are numerous in this part of the section.

The Santa Catalina formation was first described by Stoyanow[*] in the

* Stoyanow, A. A. Correlation of Arizona Paleozoic Formations. Bull. G.S.A., Vol. 42, pp. 459-540, 1947. pg. 476.

Santa Catalina Mountains north of Tucson. He designates the Santa Catalina as a separate formation of Middle Cambrian age on paleontologic evidence.

An unusual trilobite persists through the entire formation, but does not occur either in the overlying Abrigo or the underlying Troy quartzite. No diagnostic fossils were found in the Santa Catalina formation in the Vekol Mountains, although numerous small Cambrian brachiopods and a few fragments of trilobites were collected. The correlation is based largely on comparable lithology and stratigraphic position.

Southern Belle quartzite

In the Vekol Mountains, this formation is well-exposed along the east front of the main range and in the east ridges. It consists of well-cross-bedded, medium-grained, brown quartzite with a siliceous to calcareous cement. The beds range from 1 to 8 feet thick. Like the upper member of the Troy, however, it grades laterally into patches of sandstone with strong calcareous cement. These areas often contain numerous small brachiopods similar to those found in the Santa Catalina and upper Troy.

The maximum thickness of approximately 30 feet was measured at the northern end of the main range. To the south, at Promontory Ridge, the thickness is 21 feet, while farther south, in the vicinity of 2865 peak, it is but 5 feet thick and may be missing locally. This change appears to be caused by a lateral gradation of the lower part of the Southern Belle into deposition of Santa Catalina type rather than to an unconformity. The upper member of the Troy is very similar lithologically to the Southern Belle. Both probably represent similar depositional conditions.

This formation is described by Stoyanow in the Santa Catalina Mountains, and is considered by him to be of Middle Cambrian age.

Abrigo formation

Infrequent exposures of these beds are found along the east front, through the central section and along the southern flank of the main range. Scattered outcrops were found in the east ridges. The Abrigo is poorly exposed because of the soft nature of the beds.

At Promontory Point, in the Vekol Mountains, the base of the Abrigo consists of light brown limestone beds a few inches to a foot in thickness. They frequently show pronounced intraformational conglomerate structure. Approximately five feet from the base, the character of the beds changes to thin-bedded limestones and brown sandy shales. The thickness of the beds ranges from a fraction on an inch to 6 inches. This zone is about fifty feet thick. At the top, the 2 to 5 foot tan limestone beds which lie above the thin-bedded Abrigo may be comparable to the Rincon limestone, described by Stoyanow* in southern Arizona. No fossils were found, however, and the writer tentatively includes these beds in the Abrigo.

*Stoyanow, A. A. Correlation of Arizona Paleozoic Formations. Bull. G.S.A., Vol. 42, pp. 471.

The thickness of the Abrigo formation at Promontory Ridge is [illegible] (See Plate 4.) In the southern edge of the area, on the south side of [illegible] peak, the Abrigo is well-exposed. It is approximately 240 feet thick and consists almost entirely of rusty-brown, thin-bedded, sandy limestone and calcareous sandstone. Beds comparable to the Rincon are missing here. At the Vekol mine, toward the northern end of the main range, the Abrigo is 95 feet thick. Immediately south of Promontory Ridge in the vicinity of Diabase Traverse #3, the Abrigo is estimated at less than 40 feet. This thinning may be caused by local, pre-Upper Devonian erosion of the Abrigo surface.

This formation was first described by Ransome* at Bisbee, and was named

* Ransome, F. L. The Geology and Ore Deposits at Bisbee, Arizona. U.S.G.S. P. P. 21, 1904.

the Abrigo limestone. As described, it included the section between the Cambrian, Bolsa quartzite and the Devonian, Martin limestone. Because of lithologic changes northward, Stoyanow*, in the Santa Catalina Mountains, has divided

* Stoyanow, A. A. Correlation of Arizona Paleozoic Formations. Bull. G.S.A., Vol. 42, 1947. pg. 480.

this section into the following formations:

Upper Cambrian	Peppersauce sandstone Abrigo formation
Middle Cambrian	Southern Belle quartzite Santa Catalina formation Troy quartzite (Bolsa equivalent?)

In this report, the writer follows Stoyanow's restricted use of the Abrigo because of the lithologic similarity between the Cambrian rocks in the Vekol Mountains and those in the Santa Catalina Mountains.

No identifiable fossils were found in this formation in the Vekol Mountains, but Obolus and Lingulella and trilobite fragments were reported by Hogue*

* Hogue, W. G. The Geology and Ore Deposits of the northern end of the Slate Mountains, Pinal County, Arizona. Masters Thesis, Univ. of Ariz., 1940.

in the Slate Mountains ten miles southeast of the Vekol Mountains. The rocks of the Abrigo formation exposed in these two areas are similar lithologically, and occupy identical stratigraphic positions.

Upper Devonian rocks

At Promontory Ridge, rocks of Upper Devonian age include a 211 foot section of light brown limestone, gray dolomitic limestone and calcareous sandstone. The writer has tentatively divided this section into three units, on the basis of lithologic and paleontologic correlation with nearby areas.

These rocks are well-exposed along the east front of the main range and east ridges.

Picacho de Calera formation?

Seventy feet of cliff-forming, black dolomitic limestone and banded blue and tan limestone overlies the Abrigo formation. Throughout the central part of the range these beds are separated from the Abrigo by a distinctive tan, coarse-grained calcareous sandstone with well-rounded grains. This sandstone is missing in the northern and southern sections. The Picacho de Calera? is separated from the overlying Martin limestone by a coarse-grained, calcareous sandstone with sub-rounded grains. This sandstone bed ranges from 3-18 feet in thickness and is a continuous marker throughout the area.

The following section, measured on the cliffs about 500 feet southwest of Promontory Ridge is characteristic of the Picacho de Calera? in the Vekol Mountains:

		(Top)
a.	Tan, medium to coarse-grained, cross-bedded sandstone with calcareous cement.	14 feet
b.	Soft, nodular, reddish-brown, sandy limestone.	4 feet
c.	Dark gray dolomitic limestone with algal bands and faint outlines of brachiopods.	23 feet
d.	Black, sugary dolomite.	2 feet
e.	Alternate blue and tan limestone. Sandy toward base.	22 feet
f.	Tan, calcareous sandstone with well-rounded grains.	2 feet
	Total	67 feet

The above section compares favorably with Stoyanow's description of the Picacho de Calera formation in the Picacho de Calera Hills twenty-five miles northwest of Tucson.* Stoyanow's section is as follows:

* Stoyanow, A. A. Correlation of Arizona Paleozoic Formations, Bull., G.S.A. Vol. 42, 1947. pg. 488.

		(Top)
a.	Brown calcareous sandstone replete with fish teeth, *Ptyctodus* aff. *calceolus* (Newberry and Worthen), two species of *Cladodus*, and one species of *Lambodus* (?) have been identified.	2 feet
b.	Black dolomite.	25 feet

c. Yellow, crystalline limestone largely made of small calcified algal bodies and interbedded with thin, flaggy, blue limestone; small goniatites are sporadically found; no closer identification has yet been possible. 2 feet

d. Blue limestone in beds, 2 to 4 feet thick composed of large spherical stromatoporoids and algae with abundant, but poorly preserved zaphretoid and favositoid corals. 40 feet

e. Yellow calcareous sandstone with well-rounded sand grains probably of sub-eolian origin. 4 feet

73 feet

No identifiable fossils were found in this part of the Upper Devonian section in the Vekol Mountains. However, because of the similarity of the section in the Vekol Mountains with the Picacho de Calera formation in the Picacho de Calera Hills and comparable stratigraphic position, the writer tentatively designates this part of the Upper Devonian section as Picacho de Calera formation.

Martin limestone

In the Vekol Mountains, the Martin limestone is well-exposed in the east ridges, along the east front and in the central and southern sections of the main range. Its thickness ranges from 85 feet along the southern end of the main range to 125 feet in the central area.

The section exposed on Promontory Ridge is as follows:

a.	Muddy, gray limestone in 1-3 foot beds.	13 feet (Top)
b.	Buff, thin-bedded limestone, 6 inch to 1 foot beds.	17 feet
c.	Buff, massive, cliff-forming limestone.	38 feet
d.	Thin-bedded, buff limestone with ½ inch quartz-lined geodes.	18 feet
e.	Thin-bedded, buff limestone.	20 feet
f.	Soft, shaly limestone, poorly exposed.	12 feet
	Total	118 feet

The upper part of unit 3 is highly fossiliferous. Atrypa reticularis Linne was found in abundance with wide variation. Spirifer hungerfordi Hall was found occasionally, together with other poorly preserved forms which have not been identified. Cladopora prolifica Hall and Whitfield occur sporadically in this same horizon.

The Martin limestone was first described by Ransome* at Bisbee. There,

* Ransome, F. L. The Geology and Ore Deposits of Bisbee, Arizona. U.S.G.S. P.P. 21, 1904. pg. 35-38.

it consists largely of dark gray, hard, compact limestone 340 feet thick. It is underlain by the Abrigo limestone and overlain by the Escabrosa limestone. The Martin limestone is Upper Devonian in age. **

* Ransome, F. L. Same reference as above.
* Stoyanow, A. A. Correlation of Arizona Paleozoic Formations, Bull., G.S.A. Vol. 42, pg. 487. 1937.

Lower Ouray Formation?

The soft, bench-forming limestones which lie directly above the Martin limestone in the Vekol Mountains, range from 38 to 57 feet in thickness. On Promontory Ridge, the following section is exposed:

a.	Roughly-banded, light tan to white, cliff-forming, medium-grained quartzite with sandy, calcareous bands.	(Top) 12 feet
b.	6 inch to 3 feet beds of pinkish-gray limestone.	16 feet
c.	½ inch to 6 inch, yellowish- to reddish-tan, soft, highly-jointed, poorly bedded limestone, mudstone, and calcareous shale. Atrypa reticularis (Linne).	23 feet
		51 feet

The upper quartzite member is missing at the northern end of the east ridges and along the southern fringe of the main range. There is a gradual thinning from the central part of the range outward. The remainder of the section ranges from 38 to 45 feet, and is thicker toward the fringes of the mountains.

Stoyanow* describes this formation in Peppersauce Canyon in the Santa

* Stoyanow, A. A. Correlation of Arizona Paleozoic Formations, Bull., G.S.A. vol. 42, pg. 489. 1937.

Catalina Mountains, twenty-five miles north of Tucson. It also is described by Hogue* in the Slate Mountains, ten miles east of the Vekol Mountains.

* Hogue, W. G. The Geology and Ore Deposits of the northern end of the Slate Mountains, Pinal County, Arizona. Masters Thesis, Univ. of Ariz. 1940.

Hogue's section is as follows:

"a. Thin-bedded, pink mudstone, sandstone, limestone and shale with some thicker yellow sandstone and light gray limestone beds. About 25 feet below the top is a 4-foot sandstone bed of coarse-grained, pink and yellow, friable sandstone. (Top) 80 feet

b. Light blue, fossiliferous limestone with Schizoporia striatula, Retzia sp., Schuchertella sp. and several small brachiopods. 4 feet

c. Yellow and pink, thin-bedded sandstone, limestone and shale. 12 feet

Total 96 feet"

The writer has examined the section described above. He believes the rocks lying between the Martin limestone and the Escabrosa limestone in the Vekol Mountains are equivalent to the Lower Ouray formation described by Hogue in the Slate Mountains, even though no characteristic Lower Ouray fossils were found in the Vekol section.

Escabrosa limestone

This resistant limestone forms prominent outcrops along the southern and eastern sides of the main range and along the crests of the east ridges and hills.

It is a thick-bedded, non-magnesian, light to dark gray limestone and is generally granular, although some beds are fine-grained. Crinoid stems are prevalent at certain horizons.

This limestone averages about 400 feet in thickness in the Vekol Mountains. In the center of the main range, at Promontory Ridge, it is 353 feet thick; at the Vekol mine toward the northern end of the main range, it is 410 feet thick; and at 2854 Peak, just south of Copperosity Basin, it is approximately 415 feet thick. Hadley* reports a maximum of 420 feet in the Reward area

* Hadley, J. B. Copper Deposits of the Reward Area, Pinal County, Arizona. Preliminary Report, Stratigic Minerals Division, U.S.G.S., 1942.

on the eastern edge of the mountains.

Generally, the lower 125 feet is massive, gray or bluish-gray limestone; the succeeding 75 feet is banded limestone with alternate dark gray, tan and bluish-gray beds ranging from 6 inches to 5 feet; the upper 200 feet is a massive, gray limestone with occasional cherty horizons.

The top 20 to 100 feet of Escabrosa is altered to a pinkish-tan color. Measurements from a gray marker bed in the central banded zone show that the contact with the overlying Naco limestone is irregular, and probably represents and old erosion surface. Pre-Naco jointing appears to be present, and undoubtedly, weathering and ground water action were effective in the formation of the zone of alteration. The bedding gradually fades upward into this zone. On 2854 peak, clastic dikes occur in the upper five feet of the Escabrosa limestone.

Well-preserved fossils were difficult to find in the Escabrosa. Spirifer centronatus Winchell, the guide fossil of the Escabrosa and a Syringopora coral were the only two definitely identifiable fossils found by the writer. Hadley* reports numerous Pentremites 300 feet from the base of the formation

* Hadley, J. B. Copper Deposits of the Reward Area, Pinal County, Arizona. Preliminary Report, Stratigic Minerals Division, U. S. G. S., 1942.

in the Reward area.

According to Stoyanow*, the Escabrosa limestone is Lower Mississippian

* Stoyanow, A. A. Correlation of Arizona Paleozoic Formations, Bull., G.S.A. Vol. 42, pg. 505. 1937.

in age. He states "Upper Mississippian deposits are known only in southeastern Arizona".

The Escabrosa limestone was first described by Ransome at Bisbee. He describes it as "rather thick-bedded, nearly white to dark gray, granular limestones, which close examination often shows to be made up very largely of crinoid stems". The average thickness at Bisbee is 700 feet.

Naco limestone

In the Vekol Mountains, the Naco limestone consists of light gray limestone beds from 1 to 5 feet thick, separated by shaly partings. The shale partings usually are a few inches thick, but a few are several feet thick. The shale is fine-textured, and reddish-brown in color. On a steep slope, it weathers readily to form a series of step-like benches.

The following section, exposed on the ridge at the Vekol mine, is the most complete in this area:

a.	Alternate ½ foot beds of light gray limestone with a variable degree of silicification and included layers of chert nodules interbedded with 1 inch to 1 foot red shale beds. Abundant fossils occur on the weathered surfaces of many beds. The top is not exposed.	(Top) 100 feet
b.	Coral marker bed containing numerous Campophylum torquium (Owen).	2-8 feet
c.	1 to 4 foot beds of light gray limestone with occasional fossils, separated by red shaly partings. Chert horizons every few feet.	97 feet
d.	Soft, brick red shale with nodules of limestone and occasional thin limestone bands. Generally very poorly exposed.	40 feet
e.	Gray, massive beds 2 to 8 feet thick with infrequent bands of chert nodules or irregular chert lenses.	120 feet
f.	Red shale with zoned chert nodules and grit lenses.	10 feet
	Total	415 feet

The majority of the identifiable fossils were collected from limestone beds of unit a. Among these are:

Spirifer cameratus Morton
Dictyoclostus americanus Dunbar and Condra
Spirifer occidentalis Girty
Spirifer rockymontanus Marcou
Squamularia perplexa McChesney
Composita subtilita (Hall)
Campophylum torquium (Owen)
Rhynchopora sp.
Cleiothyridina sp.

Numerous bryozoans were found locally, as well as plates and spines of sea urchins. Well-preserved Orthoceras sp., and unidentified gastropodes were found in the topmost exposed beds just north of the Vekol ghost town. Crinoid stems ½ inch in diameter are numerous in the upper part of the Naco.

The following forms were collected by Bryan* from the south slope of

* Bryan, Kirk. Erosion and Sedimentation in the Papago Country, Arizona, with a sketch of the Geology. U. S. G. S. Bull. 730b, 1922.

the mountains at the Vekol mine and were determined by G. H. Girty*:

* Darton, N. H. Resume of Arizona Geology, Bull. 119 Arizona Bureau of Mines, pg. 74, 1926.

Cladochonus sp.	Productus semireticulatus
Campophylum torquium	Marginifera splendens
Rhombophora lepidodendroides	Spirifer cameratus
Schizophoria? sp.	Spirifer rockymontanus
Chonetes vernueilianus	Composita subtilita

Girty considered them as Lower Pennsylvanian, corresponding to the lower part of the Naco limestone of the Bisbee district.

According to Stoyanow*, the forms collected in the Vekol Mountains by

* Personal communication.

the writer also represent the Lower Pennsylvanian phase of the Naco and probably are equivalent to the Wewoka fossils of Oklahoma.

The thickness of the Naco limestone varies greatly throughout the area because of post-Naco erosion. On the east side of Bitter Wells Basin, it is estimated at less than 100 feet thick. On the south side of Copperosity Basin, the measured thickness is 270 feet. At Vekol mine, the exposed thickness is 415 feet. The top is covered by terrace gravels and alluvium.

The contact bed at the base of the Naco limestone is from 5 to 10 feet. thick, and consists of soft, highly-jointed and "squeezed" red shale with rounded area of reddish-brown and gray sandstone, finely crystalline limestone $\frac{1}{8}$ of an inch to 1 foot in diameter, and zoned chert nodules which have white centers and reddish halos 1/16 to $\frac{1}{4}$ inch wide. Grit lenses and bands consisting largely of chert fragments occur irregularly in this zone. There usually is a rough banding in this bed parallel to the contact, and bedding movement has been effective locally. It is a persistent horizon throughout the area.

Toward the south end of the range on 2854 peak, the contact bed is somewhat different in appearance. The following section was noted at the base of the Naco limestone:

1.	Pebbly breccia with angular chert fragment in a somewhat silicified, shaly matrix.	1 foot
2.	Brick red to chocolate colored, splintery shale with a few zoned chert nodules.	5 feet
3.	Tan, medium-grained quartzite.	1 foot
4.	Impure red shale with numerous zoned chert nodules, and with an occasional thin shaly sandstone bed $\frac{1}{2}$ inch to 4 inches thick.	7 feet
	Total	14 feet

A. C. Waters has suggested to the writer that this horizon, in the vicinity of the Vekol mine, resembles the cherty soils which are now developing in some parts of Oklahoma and Arkansas. They are said to consist of red and gray soils with interspersed chert fragments and nodules. They are believed to be the result of weathering of limestone in place, and of the deposition of eroded material from adjacent hills of cherty limestone.

If the contact bed is an ancient soil, rapid submergence of a gently sloping plain would have been necessary to prevent it from being removed by wave action.

Correlation

The Naco limestone was described by Ransome* at Bisbee from the section

* Ransome, F. L. The Geology and Ore Deposits of Bisbee, Arizona. U.S.G.S. P.P. 21, 1904. pg. 44.

in the Naco Hills near the Mexican border. There, it is characterized by light colored beds, which consist largely of calcium carbonate and range in thickness from a few inches to 10 feet. They are described as being usually thinner than the Escabrosa and are more aphanitic in texture. The thickness at Bisbee is estimated at 3,000 ft.

Mesozoic Rocks

Cretaceous Red Beds

Siliceous red beds and quartzites, resting with a slight angular unconformity on the Naco limestone are found in the southwestern part of the main range in the Copperosity Basin. Plane Table Traverse D shown on Plate 5 illustrates this section.

The measured thickness exceeds 400 feet. Several hundred feet of additional section is believed to be present, but no measurement was attempted because of faulting in the upper beds.

A basal conglomerate usually is present. It consists of sub-rounded to sub-angular pebbles ranging from ¼ inch to 1 inch in diameter in a coarse- to medium-grained, sandy matrix. Silicification in many areas has resulted in a conglomerate consisting largely of chalcedonic pebbles held together in a chert or jasper matrix. The original identity of the constituent pebbles is largely obscured. The thickness of this unit varies from a few inches to more than twenty-five feet. Locally, it fills channels in the Naco erosion surface. (Print 13.)

The major part of the section illustrated on Plate 5. consists largely of brick red to yellow-brown, splintery, siliceous shale and shaly siltstone with occasional 5 to 10 foot beds of massive, medium-grained to pebbly quartzite. A 5 foot bed of coarse, gray, arkosic sandstone is located about 190 feet from the base.

The first boulder conglomerate was found at 278 feet from the base. It is 3 feet thick, and is made up of sub-rounded quartzite and limestone boulders, cobbles and pebbles in a loosely cemented matrix of coarse sand. A second boulder conglomerate was found at the top of the measured part of the section. This boulder horizon is approximately 25 feet thick and is comparable to the one just described. A third, at least 200 feet thick, occurs in the upper, unmeasured part of the section.

These rocks are believed to be continental. The section illustrated on Plate 5. probably represents deposition of fine-grained muds, silts, and thin sandy and pebbly beds on a flood plain. The loosely cemented, rounded, boulder horizons would indicate deposition under conditions in which stronger currents prevailed.

The writer has not done sufficient work in the upper part of this group of rocks to determine its contact with the rocks tentatively designated as Gila conglomerate. It is possible that the topmost vitreous quartzite, which lies directly beneath the 200 feet of bouldery conglomerate in the Copperosity Basin, is the upper contact of this unnamed Cretaceous? formation. Or, it may be that this conglomerate and the 2,000 feet of conglomerate described by Hadley* in the Reward area should be included. Further work will be required

* Hadley, J. B. Copper Deposits of the Reward Area, Pinal County, Arizona. Preliminary Report, Stratigic Minerals Division, U. S. G. S., 1942.

to solve this problem. For purposes of mapping, the writer tentatively places the contact at the top of the highest vitreous quartzite occurring in the Copperosity Basin.

Age and Correlation

The writer has no evidence of the age of these rocks except that they overlie the Naco limestone unconformably, and in turn, are overlain by volcanics believed to be largely Tertiary in age. The Recreation Red Beds, described by Brown* in the Tucson Mountains are somewhat similar and may be contemporaneous.

* Brown, W. H. Tucson Mountains, An Arizona Basin Range Type. Bull. G.S.A. Vol. 50, pp. 697-760, 1939.

No fossils were found in the Vekol section, however. The writer expects to make a further study of this problem.

Tertiary-Quaternary Rocks

Gila Conglomerate?

Exposures of the bouldery conglomerate described above, occur at frequent intervals along the west front of the main range. Just west of the Pomona mine, they appear to lie unconformably above the red beds and quartzites.

At the northern end of the main range, this conglomerate is well-exposed beneath the Quaternary volcanics. It consists of sub-rounded boulders and cobbles averaging between 4 and 5 inches in diameter with occasional boulders as much as 3 feet in diameter. Limestone and quartzite are the main constituents, but a few volcanic and diabase pebbles usually are present. The matrix grades from pebbles to coarse sand. The cementing material is somewhat limy. The trend of this exposure roughly parallels the Vekol ridge, and the beds dip about 45 S.W. This conglomerate appears to rest directly on a Naco limestone erosion surface and on scattered patches of the basal Cretaceous conglomerate. At the pass, where the Bitter Wells road crosses the divide north of the Vekol mine, the Gila conglomerate is well-exposed. (See Plate 2.) It consists of a 40 feet pebble and cobble horizon, which may grade laterally northward into the thick tuff beds on the flank of 2917 peak.

III. STRUCTURAL GEOLOGY

Summary

The foliation and the schistosity of the basement rocks in the Vekol Mountains indicates strong structural activity during pre-Cambrian time. The general structural trend of these rocks, shown on Plate 3., probably influenced the development of later structures.

The base of the Algonkian, Apache group appears to rest on a surface of low relief, indicating a period of long erosion and quiescence. This period of "calm" continued throughout the Apache time and the Paleozoic except for possible disturbances due to the emplacement of the diabase. During the Ordovician, Silurian, and much of the Devonian, this area, like most of southern Arizona was uplifted and was being eroded, or at least not receiving sediments. Late Paleozoic rocks are essentially conformable in strike and dip with the rocks of the Apache group.

During the Permian, Triassic and Jurassic, the area must have undergone a second extended period of erosion, for no rocks of those ages appear to be represented. The basal conglomerate of the non-marine red bed unit of probable Cretaceous age rests with angular unconformity on the Naco limestone, indicating the end of the long period of quescence and probably, the beginning of the extensive Jurassic, Laramide and Tertiary structural disturbances common to the Basin Range province.

The Vekol Mountains represent the eastern flank of a northwest trending synclinal structure. The axis of the syncline is located along the southeastern edge of the main range. An anticlinal fold is indicated by the trend of the beds on the northern end of the Slate Mountains about ten miles southeast of the Vekol Mountains. These structures probably represent the first step in the structural evolution of the mountains in this part of Arizona. The granite intrusives may have accompanied this folding, or followed soon after it developed.

Block faulting along two major systems is the controlling structural feature in the structural development of the Vekol Mountains. Northwest trending, east dipping, normal faults have formed the northwest trending blocks including the main range and the sharp ridges on the northeast. Somewhat later, the east-west and northwest trending Copperosity and Bitter Wells faults divided the mountains into three distinct structural blocks: the northeastern, and the central, and the southern. East-west faults of moderate displacement appear to have been adjustment faults related to both major systems. Steep, north-south faults play a minor role in the structural picture. Faulting on the two major systems is believed to have continued intermittently through the late Tertiary into Quaternary time.

Dacite porphyry forms large sills, sheets and dikes which trend northwest. Also, it intrudes many of the east-west fault zones. An east-west trending rhyolite porphyry plug and dike cuts the Paleozoic and Cretaceous rocks and the dacite porphyry.

The pronounced northeast trend and northwest dip of the Quaternary volcanics along the northwestern edge of the area may be due to recent tilting to the northwest.

Folding

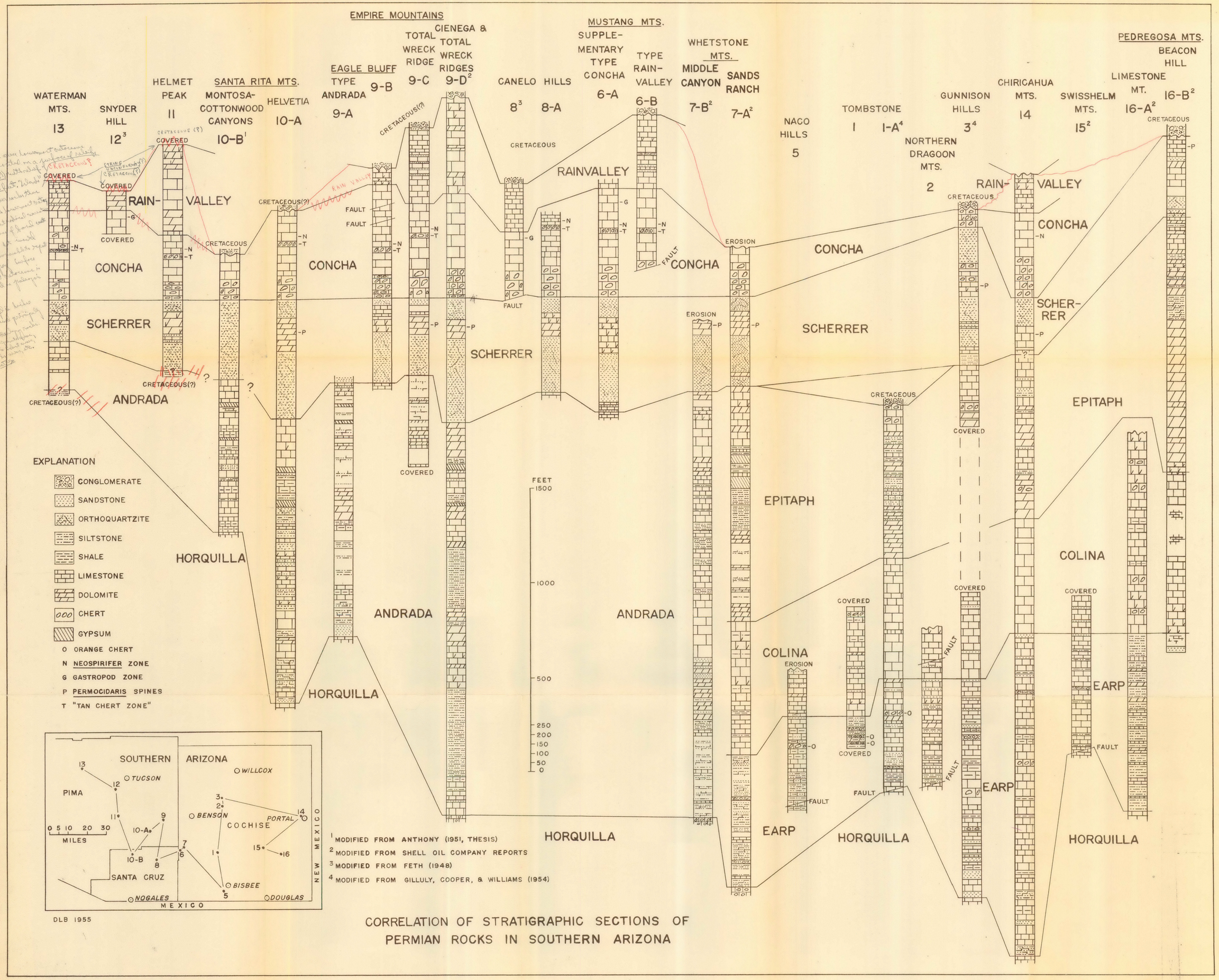
The synclinal fold, of which the Vekol Mountains are a part, trends northwest-southeast, and plunges northwestward. (See Plate 3.) The axis of the syncline is located along the southern edge of the main Vekol range. The synclinal nose, illustrated by the curving trend of the Cretaceous? red beds is clearly visible around the edges of Copperosity Basin. The trend of the beds on the east limb is shown on Plate 3. Their strike along the east ridges in the vicinity of the pipe line road at the northern edge of the area is southeastward. Farther south, in the hills of the Reward area, it is north-south. In the main range, the beds strike southwestward and even east-west along the extreme southern fringe.

Minor folding is suggested along the east front of the main range near its northern end. The beds along the exposed edge of the pediment are approximately horizontal, and, in some instances, dip slightly to the northeast. The beds on the adjacent ridge to the west, dip slightly to the northeast. The beds on the adjacent ridge to the west, dip from 35 to 50 southwesterly. This

folding may represent minor flexures on the synclinal flank or may have developed by faulting.

The marked drag folding on the north side of 3231 peak north of the Hinsdow mine and adjacent to the Copperosity fault is believed to be the result of drag along a fault rather than to regional folding. Its southeast trend roughly parallels the trend of the spur faults, and it dies out within a few hundred feet. The beds are badly contorted and broken by small faults within the drag-fold. (See Print 25.)

PLATE 2



CORRELATION OF STRATIGRAPHIC SECTIONS OF PERMIAN ROCKS IN SOUTHERN ARIZONA

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

1150 NORTH 7TH AVENUE
TELEPHONE 602-792-3010

July 20, 1972

Mr. Edward A. Koester
Geologist, OGCC
State of Arizona
4515 North 7th Avenue
Phoenix, Arizona 85013

Dear Sir:

Your letter of July 12 has been received. The various units of the Apache Group and Paleozoic sediments are found in scattered outcrops in the Sand Tank Mountain Range (Maricopa County). The following tabulation lists the major outcrops (mapped on 1" = 1 mile topo sheets) but they may extend into an adjacent section for a minor distance. As mapped, no outcrop contains a full sequence of all units and rarely is any specific unit entirely exposed in any outcrop.

In this tabulation "Apache Group" includes the Apache Group and/or Troy Quartzite, "Lower Paleozoic" is Bolsa Quartzite and/or Martin Limestone, and "Middle Paleozoics" is Escabrosa Limestone and/or Naco Limestone.

T.7S., R.1W.	
SW 1/4, Section 27	Lower Paleozoics
SW 1/4, Section 35	Apache Group (?) and Lower Paleozoics
T.8S., R.1E.	
SE 1/4, Section 6	Lower Paleozoics
NE 1/4, Section 7	Lower Paleozoics
SE 1/4 and N 1/2, Section 8	Lower Paleozoics
T.8S., R.1W.	
NW 1/4, Section 2	Apache Group and Lower Paleozoics
NE 1/4, Section 3	Apache Group and Lower Paleozoics
Center, Section 20	Middle Paleozoics
SE 1/4, Section 20	Apache Group
S 1/2, Section 21	Apache Group
SE 1/4, Section 23	Lower Paleozoics) See: Bryan, K., 1925, USGS
SW 1/4, Section 24	Lower Paleozoics) Water Supply Paper 499, p.56
SW 1/4, Section 25	Apache Group

NE 1/4, Section 26	Lower Paleozoics
N 1/2, Section 28	Apache Group
NE 1/4, Section 35	Apache Group and Lower Paleozoics
NW 1/4, Section 36	Apache Group and Lower Paleozoics

The farthest west exposures were not ground checked, but were spotted during a helicopter flight. These are probably Apache Group and Lower Paleozoics and were found along the north-south boundary between the tier of Sections 14-23 and Sections 15-22 in T. 8 S., R. 3 W.

I would be interested in hearing of any further detailed work being done in the region.

I would also appreciate another copy of your report "Preliminary Tabulation of Stratigraphically Significant Water Wells in the Basin and Range Province of Arizona".

Sincerely,

James D. Sell

James D. Sell

JDS:lad

OFFICE OF
Oil and Gas Conservation Commission
STATE OF ARIZONA
4515 NORTH 7TH AVE.
PHOENIX, ARIZONA 85013
PHONE: (602) 271-5161

July 25, 1972

Mr. James D. Sell
American Smelting and Refining Company
Southwestern Exploration Division
P. O. Box 5747
Tucson, Arizona 85703

Dear Mr. Sell:

We wish to thank you very much for your letter of July 20 and the information regarding the detailed location of outcrops of rocks of the Apache Group and Paleozoics in the Sand Tank Mountain Range. I assume that this information is not of a confidential nature and that we may release it to any interested geologist.

We are sending you another copy of our recent report on stratigraphically significant water wells, as well as a new dry hole map of the state.

Hoping we can further reciprocate your kindness, I am

Sincerely,

Edward A. Koester
Staff Geologist

EAK:st

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

1150 NORTH 7TH AVENUE
TELEPHONE 602-792-3010

July 31, 1972

Mr. Edward A. Koester
Geologist, OGCC
State of Arizona
4515 North 7th Avenue
Phoenix, Arizona 85013

Dear Sir:

Your letter of July 25th and the Well Location Map No. 3 arrived. Thank you for this additional information.

As you assume, the information regarding the Apache Group and Paleozoic outcrops in the Sand Tank Mountain Range is not a confidential nature. However, ASARCO would appreciate acknowledgment of the information source wherever it is appropriate.

Sincerely,

James D. Sell

James D. Sell

JDS:lad

OFFICE OF
Oil and Gas Conservation Commission
STATE OF ARIZONA
4515 NORTH 7TH AVE.
PHOENIX, ARIZONA 85013
PHONE: (602) 271-5161

June 15, 1972

Mr. James D. Sell
American Smelting and Refining
Company
1130 North Seventh
Tucson, Arizona 85705

Dear Mr. Sell:

We are interested in your paper "Sedimentation in Southwest Pinal County", the abstract of which is published in the program of the 1968 meeting of GSA. I have not found any publication of this article, and if there has been publication I would appreciate receiving a separate of it. If not, could you send us copies of your measured sections in this area. Of course, we are not interested in the mineral content of any of the units, merely the stratigraphic information.

You probably know that Humble Oil and Refining Company has started a deep test in Section 2-T8S-R8E. The fact that they expect to drill this well to a depth of 12,000 feet indicates a thick stratigraphic interval here, and we wish to obtain any information pertaining to measured sections in the mountains of southern Arizona.

North of Peoche, East of Eloy

Thanking you for your cooperation, I am

Sincerely yours,

Edward A. Koester

Edward A. Koester
Staff Geologist

EAK:st

reached 10,200 feet
with thick section of Cret + sediments
Verbal report of on job geol — "This will revise Ariz geologists' thinking!"

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

1150 NORTH 7TH AVENUE
TELEPHONE 602-792-3010

July 5, 1972

Mr. Edward A. Koester
Staff Geologist, State of Arizona
Oil and Gas Conservation Commission
4515 North 7th Avenue
Phoenix, Arizona 85013

Dear Mr. Koester:

Please pardon the delay in answering your letter of June 15th, as I have been on vacation.

The paper you refer to was only presented verbally at the 1968 meeting in Tucson, with the abstract printed in the GSA Abstracts. No other publication of the material is anticipated.

During our reconnaissance the stratigraphic sections were not measured, but were only estimated as to thickness of the various units. All units are much thinner than those found by Carpenter in the Vekols and Hammer in the Slate Mountains to the southeast and east. (Carpenter, R. H., 1947, The Geology and Ore Deposits of the Vekol Mountains, Pinal County, Arizona: Stanford Univ., PhD Thesis, 110 pages. Hammer, D. F., 1961, Geology and Ore Deposits of the Jackrabbit Area, Pinal County, Arizona: Univ. of Arizona, MS Thesis, 156 pages.)

The Humble test will be of interest and I presume information will ultimately be available.

Sincerely,

James D. Sell

James D. Sell

JDS:lad

March 3, 1973 p. 22-Sec. B

THE ARIZONA DAILY STAR

Exxon Halts Test-Well Drilling

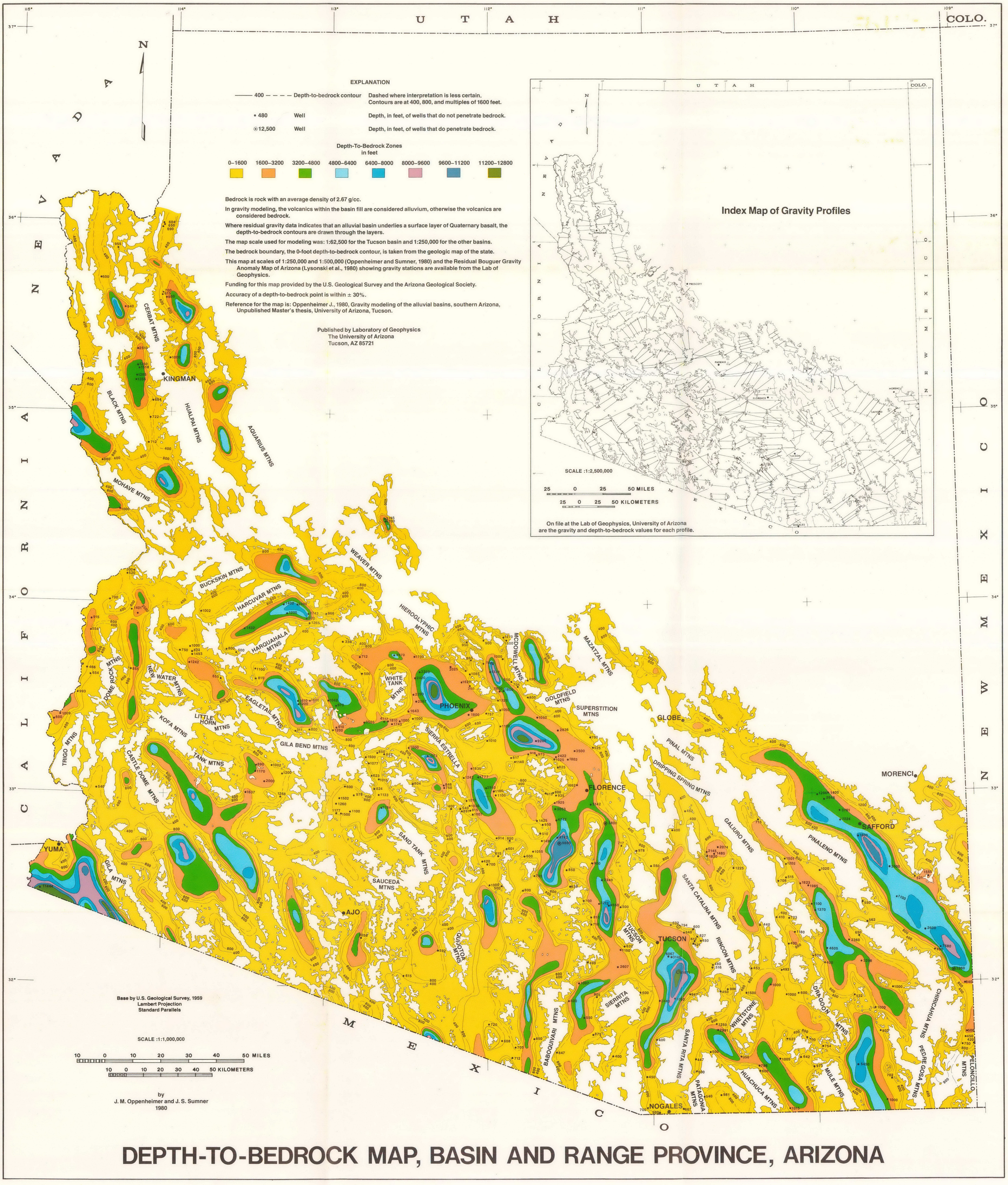
Exxon Corp. has stopped drilling test wells in Southern Arizona while it analyzes geological data taken from its four existing holes, a company spokesman said yesterday.

D. I. Bolding, public relations manager, said the firm's fourth stratographic test well, near the border town of San Luis, about 18 miles south of Yuma, was plugged last Saturday at a depth of 11,444 feet. Drilling had begun on Jan. 15.

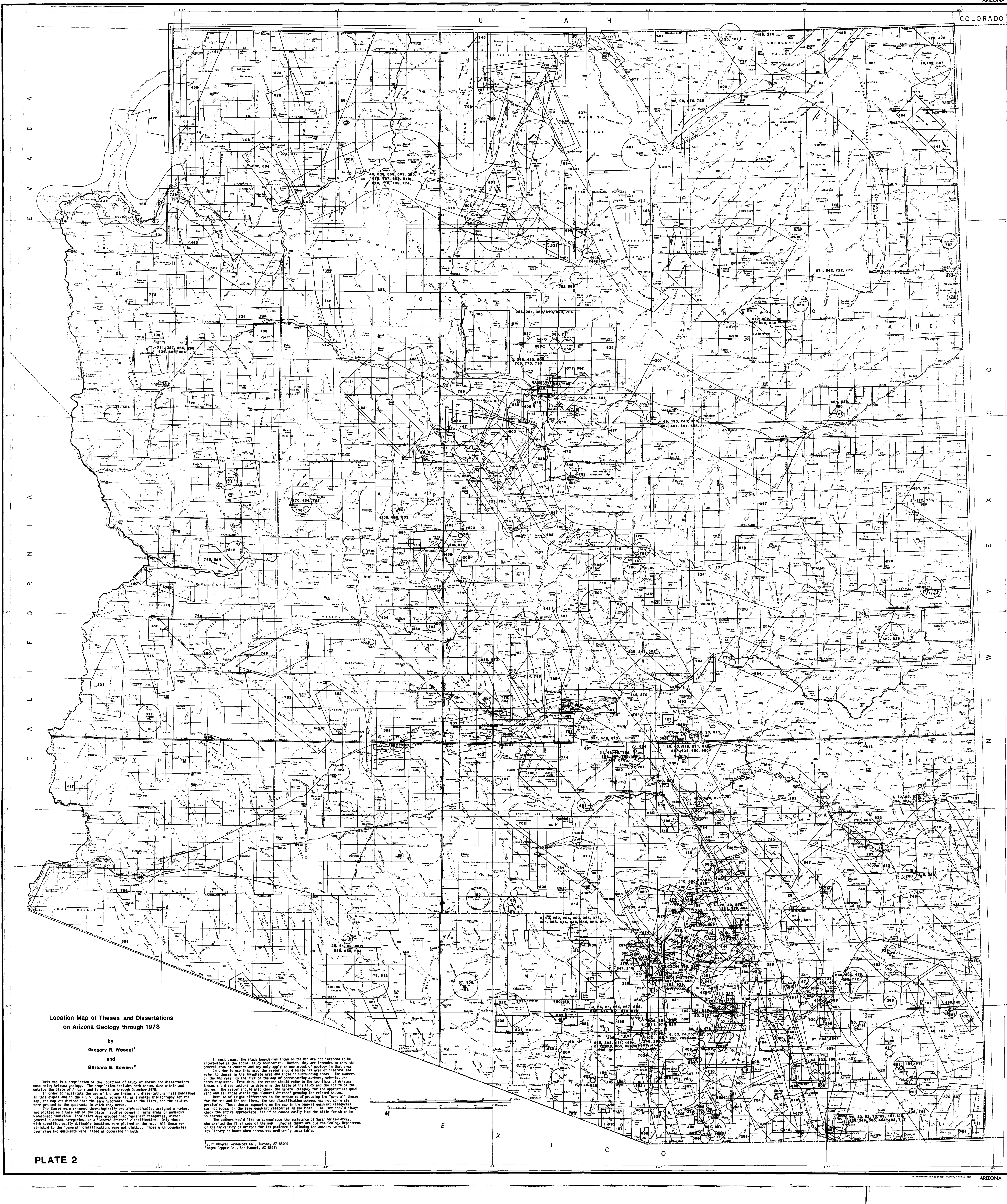
Bolding said Exxon is analyzing the earth samples taken from the four wells in order to come up with a map of the layers of rock beneath the earth's surface in Southern Arizona. The area is one about which geologists know little.

The samples are to be compared with the results of extensive geophysical testing done throughout the area by Teledyne Corp. for Exxon during the past two years. Teledyne set off small explosions and then recorded the shock waves in an attempt to gain a rough picture of the state's geology.

Exxon drilled its first well last June near Eloy. Since then, it has drilled three others: a shallow well located about 60 miles, northwest of Gila Bend; a 12,000-foot well in Tucson, which Bolding said is the deepest in the state; and the well near Yuma.



DEPTH-TO-BEDROCK MAP, BASIN AND RANGE PROVINCE, ARIZONA



Location Map of Theses and Dissertations on Arizona Geology through 1978

by

Gregory R. Wessel[1]

and

Barbara E. Bowers[2]

This map is a compilation of the locations of study of theses and dissertations concerning Arizona geology. The compilation includes both theses done within and outside the State of Arizona and is complete through December 1978.

In order to facilitate the use of the two theses and dissertations lists published in this digest and in the A.G.S. Digest, Volume XII as a master bibliography for the map, the map was divided into the same quadrants used in the lists, and the studies were grouped by the quadrants in which they occur.

The theses were arranged chronologically and alphabetically, assigned a number, and plotted on a base map of the State. Studies covering large areas or numerous widespread individual localities were grouped into "general" categories, either general quadrant categories, or a "General Arizona" classification. Only those with specific, easily definable locations were plotted on the map. All those restricted to the "general" classifications were not plotted. Those with boundaries overlying two quadrants were listed as occurring in both.

In most cases, the study boundaries shown on the map are not intended to be interpreted as the actual study boundaries. Rather, they are intended to show the general area of concern and may only apply to one aspect of geology in that area.

In order to use this map, the reader should locate his area of interest and refer to theses in the immediate area and those in surrounding areas. The numbers on the map refer to the list *on the map of corresponding authors, schools, and* dates completed. From this, the reader should refer to the two lists of Arizona theses and dissertations to determine the title of the study and the nature of the degree. The reader should also check the general category for the appropriate quadrant and all those within the "General Arizona" grouping for related theses.

Because of slight differences in the mechanics of grouping the "general" theses for the map and for the lists, the two classification schemes may not correlate precisely. Those theses appearing on the map in the general quadrant categories *may not appear in the same quadrant categories in the lists.* The user should always check the entire appropriate list if he cannot easily find the title for which he is searching.

The authors would like to acknowledge the assistance of Sarah White-Harvey, who drafted the final copy of the map. Special thanks are due the Geology Department of the University of Arizona for its patience in allowing the authors to work in its library at hours when access was ordinarily unavailable.

[1]Gulf Mineral Resources Co., Tucson, AZ 85705
[2]Magma Copper Co., San Manuel, AZ 85631

PLATE 2

1. Farrington, Yale University, 1891.
2. Robinson, Yale University, 1903.
3. Kellogg, Columbia University, 1906.
4. Noble, Yale University, 1909.
5. Steubing, Columbia University, 1912.
6. Stewart, Columbia University, 1912.
7. Blanchard, Columbia University, 1913.
8. *Chapin, Stanford University, 1913.*
9. Cochran, University of Arizona, 1914.
10. Emery, Yale University, 1914.
11. Joseph-Haskevitch, University of Arizona, 1916.
12. Reber, Yale University, 1916.
13. Bryan, Yale University, 1920.
14. Longwell, Yale University, 1920.
15. Gordon, University of Arizona, 1922.
16. Wilson, University of Arizona, 1922.
17. Benedict, Mass. Inst. of Technology, 1923.
19. *Lausen, University of Arizona, 1923.*
20. Legraye, Stanford University, 1923.
21. Short, Harvard University, 1923.
23. Shoemaker, University of Arizona, 1924.
25. Webber, University of Arizona, 1925.
26. Brown, University of Arizona, 1926.
27. Ayres, University of Michigan, 1927.
28. Bruhn, University of Arizona, 1927.
29. Heineman, University of Arizona, 1927.
30. Smith, University of Arizona, 1927.
31. *Woodell, University of Arizona, 1927.*
33. Feiss, University of Arizona, 1929.
34. Park, University of Arizona, 1929.
35. Eckel, University of Arizona, 1930.
36. Householder, University of Missouri-Rolla, 1930.
37. Gebhardt, University of Arizona, 1931.
38. Lausen, University of Arizona, 1931.
39. Thomas, University of Arizona, 1931.
40. Hernon, University of Arizona, 1932.
42. Titcomb, University of Minnesota, 1932.
44. Stewart, University of Arizona, 1933.
45. Hernon, University of Arizona, 1934.
46. Keppel, Columbia University, 1934.
47. Bishop, University of Arizona, 1935.
48. Galbraith, University of Arizona, 1935.
49. Higdon, University of Arizona, 1935.
50. Lee and Borland, University of Arizona, 1935.
51. Gillingham, University of Arizona, 1936.
52. Kartchner, Stanford University, 1936.
53. Dunham, University of Arizona, 1937.
54. Rasor, University of Arizona, 1937.
56. Alberding, University of Arizona, 1938.
57. Cook, University of Arizona, 1938.
58. Peterson, University of Arizona, 1938.
59. Simmons, University of Arizona, 1938.
60. Sklar, California Inst. of Technology, 1938.
61. Alexis, University of Arizona, 1939.
62. Enlows, University of Arizona, 1939.
63. Legge, University of Arizona, 1939.
64. Hack, Harvard University, 1940.
65. *Harshman, University of Arizona, 1940.*
66. Hogue, University of Arizona, 1940.
67. Kuhn, University of Arizona, 1940.
68. Mayuga, University of Arizona, 1940.
69. Popoff, University of Arizona, 1940.
70. Shields, University of Arizona, 1940.
71. Sopp, University of Arizona, 1940.
72. Strahler, Columbia University, 1940.
73. Carpenter, Stanford University, 1941.
74. Johnson, University of Arizona, 1941.
75. *Jones, University of Arizona, 1941.*
77. Wardell, University of Arizona, 1941.
79. Kauffman, Columbia University, 1942.
80. Marvin, University of Arizona, 1942.
81. Mayuga, University of Arizona, 1942.
82. Mintz, Columbia University, 1943.
83. Kartchner, University of Arizona, 1944.
85. Koons, Columbia University, 1945.
87. Cederstrom, University of Arizona, 1946.
89. Carpenter, Stanford University, 1947.
90. *Feth, University of Arizona, 1947.*
91. Kiersch, University of Arizona, 1947.
92. Loring, University of Arizona, 1947.
93. Pattison, Stanford University, 1947.
95. Adams, Pennsylvania State University, 1948.
96. Harshbarger, University of Arizona, 1948.
97. Miller, Columbia University, 1948.
98. Price, University of Arizona, 1948.
99. Walker, Harvard University, 1948.
100. Whitcomb, University of Arizona, 1948.
101. Winters, Columbia University, 1948.
102. Alexis, University of Arizona, 1949.
103. Creasey, University of California-Los Angeles, 1949.
105. Houser, University of Arizona, 1949.
106. Mahard, Columbia University, 1949.
107. Peng, University of Arizona, 1949.
108. Thomas, California Inst. of Technology, 1949.
109. Bromfield, University of Arizona, 1950.
110. Coulson, University of Arizona, 1950.
111. Hughes, University of Arizona, 1950.
113. *Ludden, University of Arizona, 1950.*
114. Mears, Columbia University, 1950.
115. Ostrander, Iowa State University, 1950.
116. Weber, University of Arizona, 1950.
117. Anthony, University of Arizona, 1951.
119. Bryant, University of Arizona, 1951.
120. Callahan, University of Arizona, 1951.
122. Ruff, University of Arizona, 1951.
123. Satterthwaite, Iowa State University, 1951.
124. Wallace, University of Arizona, 1951.
125. *Williams, University of Illinois, 1951.*
126. Williams, University of Arizona, 1951.
127. Bejnar, University of Arizona, 1952.
128. Chen, University of Arizona, 1952.
129. Navias, Pennsylvania State University, 1952.
130. Papke, University of Arizona, 1952.
131. Waller, University of Tulsa, 1952.
132. Zirkle, University of Illinois, 1952.
133. Baker, Stanford University, 1953.
134. Chronic, Columbia University, 1953.
135. Evensen, University of Arizona, 1953.
136. Gould, University of So. California, 1953.
137. Grundy, University of Arizona, 1953.
138. Hillebrand, University of Arizona, 1953.
139. Raydon, University of California-Berkeley, 1953.
140. Voelger, University of Arizona, 1953.
141. Appledorn, University of Minnesota, 1954.
142. Belden, University of Arizona, 1954.
143. Brittain, University of Arizona, 1954.
144. Dickerman, University of Arizona, 1954.
145. Gastil, University of California-Berkeley, 1954.
146. Harding, University of Wisconsin - Madison, 1954.
148. Merrin, University of Arizona, 1954.
149. Schwartz, University of Arizona, 1954.
150. Wargo, University of Arizona, 1954.
151. Anderson, University of Arizona, 1955.
153. Bollin, University of Arizona, 1955.
154. Britt, University of Arizona, 1955.
156. Davis, University of Arizona, 1955.
158. Johnston, University of Utah, 1955.
159. Kurtz, University of Arizona, 1955.
160. Maise, University of Utah, 1955.
161. Packard, University of Wisconsin-Madison, 1955.
162. Sabins, Yale University, 1955.
163. Silver, California Inst. of Technology, 1955.
164. Storm, Iowa State University, 1955.
165. Wallace, University of Arizona, 1955.
166. White, University of California-Berkeley, 1955.
168. Ziebell, University of Illinois, 1955.
169. Clark, University of Arizona, 1956.
171. Epis, University of California-Berkeley, 1956.
172. Green, University of Texas-Austin, 1956.
173. Hook, University of Arizona, 1956.
174. Jerome, University of Utah, 1956.
175. O'Brien, University of Texas-Austin, 1956.
176. Plafker, University of Arizona, 1956.
177. Rehkemper, University of Texas-Austin, 1956.
178. Robertson, University of Texas-Austin, 1956.
179. Rutledge, University of Texas-Austin, 1956.
180. Smith, University of Arizona, 1956.
181. Smith, University of Texas-Austin, 1956.
182. Strobell, Yale University, 1956.
184. Underwood, University of Texas-Austin, 1956.
186. Witkind, University of Colorado, 1956.
187. Wood, P. A., University of Arizona, 1956.
188. Wood, W. H., University of Arizona, 1956.
189. Woodyard, University of Texas-Austin, 1956.
190. Banerjee, University of Arizona, 1957.
191. Bennett, University of Arizona, 1957.
192. Brennan, University of Arizona, 1957.
193. Brereton, St. Louis University, 1957.
194. Burnette, University of Arizona, 1957.
196. Dunne, Columbia University, 1957.
197. Gillerman, University of Texas-Austin, 1957.
198. Hinckley, University of Utah, 1957.
199. Jones, University of Arizona, 1957.
200. Kidwai, University of Arizona, 1957.
201. Layton, University of Arizona, 1957.
202. MacKallor, University of Arizona, 1957.
203. McClymonds, University of Arizona, 1957.
204. Rogers, University of California-Berkeley, 1957.
205. St. Clair, University of Arizona, 1957.
206. Sirvas, Indiana University, 1957.
207. Smith, University of Arizona, 1957.
208. Sulik, University of Arizona, 1957.
209. Tyrrell, Yale University, 1957.
210. Van Horn, University of Arizona, 1957.
211. Weider, University of Arizona, 1957.
212. Whitney, University of Arizona, 1957.
213. Acker, University of Arizona, 1958.
215. Browne, University of Arizona, 1958.
216. Colby, University of Arizona, 1958.
217. Crutcher, University of Texas-Austin, 1958.
219. Heindl, University of Arizona, 1958.
220. Heyman, University of Arizona, 1958.
221. Kerns, University of Arizona, 1958.
222. Kinnison, University of Arizona, 1958.
223. Loney, University of California-Berkeley, 1958.
225. Moore, University of Arizona, 1958.
226. Pierce, University of Arizona, 1958.
228. Sirrine, University of Texas-Austin, 1958.
229. Williams, Columbia University, 1958.
230. Wilson, Stanford University, 1958.
231. Bryner, University of Arizona, 1959.
232. Buseck, Columbia University, 1959.
233. Donald, University of Arizona, 1959.
234. Gray, University of Arizona, 1959.
235. Hodgson, Yale University, 1959.
237. Imsiler, University of Arizona, 1959.
239. Michel, University of Arizona, 1959.
241. Raabe, University of Arizona, 1959.
242. Sears, University of Arizona, 1959.
243. Shoemaker, Princeton University, 1959.
244. Abdel-Gawad, Columbia University, 1960.
245. Akers, University of Arizona, 1960.
247. Bohmer, University of Cincinnati, 1960.
248. Burroughs, University of Arizona, 1960.
249. Cherukupalli, Columbia University, 1960.
250. Clay, University of Arizona, 1960.
252. Hedge, University of Arizona, 1960.
253. Hodges, University of Wisconsin- Madison, 1960.
254. Horvath, University of Utah, 1960.
255. Laughlin, University of Arizona, 1960.
256. Maddox, University of Arizona, 1960.
257. Mathias, University of Arizona, 1960.
258. Moore, University of Arizona, 1960.
261. Sabels, University of Arizona, 1960.
262. Schleh, University of Kansas, 1960.
264. Studebaker, University of Arizona, 1960.
265. Taylor, University of Arizona, 1960.
266. *Thacpaw, University of Arizona, 1960.*
267. Waller, University of Arizona, 1960.
268. Wilson, University of Arizona, 1960.
269. Barrington, Columbia University, 1961.
270. Buchi, University of Michigan, 1961.
271. Evensen, University of Arizona, 1961.
273. Gibbs, University of Oklahoma, 1961.
274. Gordon, University of Kansas, 1961.
275. Gray, University of Arizona, 1961.
276. Greenstein, University of Arizona, 1961.
278. Hammer, University of Arizona, 1961.
279. Jinks, University of Arizona, 1961.
281. McColly, University of Arizona, 1961.
282. Marlowe, University of Arizona, 1961.
283. Miller, University of Arizona, 1961.
285. Olson, University of Arizona, 1961.
286. Peterson, Stanford University, 1961.
287. Portugal, University of Cincinnati, 1961.
289. Sell, University of Arizona, 1961.
291. Steinkraus, Michigan State University, 1961.
293. Yildiz, University of Arizona, 1961.
294. Agenbroad, University of Arizona, 1962.
295. Baker, University of Michigan, 1962.
297. Barter, University of Arizona, 1962.
298. Bikerman, University of Arizona, 1962.
299. Bock, University of Arizona, 1962.
300. Buseck, Columbia University, 1962.
301. Champney, University of Arizona, 1962.
302. Erickson, University of Arizona, 1962.
303. Ettinger, University of Arizona, 1962.
304. Fisher, University of Kansas, 1962.
305. Graybeal, University of Arizona, 1962.
306. Green, University of Arizona, 1962.
307. Gustafson, Harvard University, 1962.
308. Ibrahim, University of Arizona, 1962.
309. Keim, Pennsylvania State University, 1962.
311. MacKenzie, Pennsylvania State University, 1962.
312. Mouat, University of Wisconsin-Madison, 1962.
313. Peterson, University of Arizona, 1962.
314. Pilkington, University of Arizona, 1962.
315. Seff, University of Arizona, 1962.
316. Sharp, University of Arizona, 1962.
317. Sorauf, University of Kansas, 1962.
318. Stein, University of Arizona, 1962.
319. Still, Harvard University, 1962.
320. Streits, University of Arizona, 1962.
321. Wertz, University of Arizona, 1962.
322. Williams, University of Arizona, 1962.
323. Wood, University of Arizona, 1962.
324. Badon, University of Kansas, 1963.
325. Bondurant, University of Kansas, 1963.
326. Catanzaro, Columbia University, 1963.
327. Crawford, Pennsylvania State University, 1963.
328. Davenport, University of Arizona, 1963.
330. Giles, Miami University of Ohio, 1963.
331. Handverger, University of Arizona, 1963.
332. Hoffman, University of Arizona, 1963.
333. Hollyday, University of Arizona, 1963.
334. Knight, South Dakota School of Mines and Tech., 1963.
335. McCullough, University of Arizona, 1963.
336. Metz, University of Arizona, 1963.
337. Meyers, University of California-Berkeley, 1963.
338. Montgomery, University of Arizona, 1963.
339. Nelson, University of Arizona, 1963.
340. Peterson, University of Arizona, 1963.
341. Pine, University of Arizona, 1963.
342. Platt, University of Arizona, 1963.
343. Smith, University of Arizona, 1963.
345. Wood, University of Arizona, 1963.
346. Arnold, University of Arizona, 1964.
347. Assadi, University of Arizona, 1964.
348. Brooke, University of Utah, 1964.
349. Bryant, Stanford University, 1964.
350. Chaffee, University of Arizona, 1964.
352. Cunningham, University of Arizona, 1964.
353. Diery, University of Arizona, 1964.
354. Dubin, University of Arizona, 1964.
356. Glassell, Stanford University, 1964.
357. Hevley, University of Arizona, 1964.
358. Hickey, University of Arizona, 1964.
359. Kothavala, Harvard University, 1964.
360. Lovejoy, University of Arizona, 1964.
361. Lowery, Arizona State University, 1964.
362. McCoy, University of Arizona, 1964.
363. Medhi, University of Arizona, 1964.
364. Perry, University of Arizona, 1964.
365. Petersen, Columbia University, 1964.
366. Pipkin, University of Arizona, 1964.
367. Rohrbacker, University of Arizona, 1964.
368. See, University of Arizona, 1964.
370. Tahmazian, University of Arizona, 1964.
372. Watson, University of Arizona, 1964.
373. Whitacre, University of Arizona, 1964.
374. Al-Hashimi, University of Missouri-Rolla, 1965.
375. Ayer, San Diego State University, 1965.
376. Bhuyan, University of Arizona, 1965.
377. Bikerman, University of Arizona, 1965.
378. Blagbrough, University of New Mexico, 1965.
380. Ciancanelli, University of Arizona, 1965.
381. Clarke, University of Arizona, 1965.
382. Fair, University of Arizona, 1965.
383. Fernandez, University of Missouri-Rolla, 1965.
384. Gale, Stanford University, 1965.
385. Gilman, University of Arizona, 1965.
386. Gray, University of Arizona, 1965.
387. Lootens, University of Arizona, 1965.
388. McKenna, University of Arizona, 1965.
389. McLain, University of Arizona, 1965.
391. Miles, University of Arizona, 1965.
392. Min, University of Arizona, 1965.
394. Robinson, University of Arizona, 1965.
395. Schafroth, University of Arizona, 1965.
396. Uy, New Mexico Inst. of Mining and Tech., 1965.
397. Weaver, University of Arizona, 1965.
398. Weiss, Columbia University, 1965.
399. Wells, University of Arizona, 1965.
400. Zambrano, University of Missouri-Rolla, 1965.
401. Abu Ajamieh, University of Arizona, 1966.
402. Avedisian, Arizona State University, 1966.
403. Cooley, University of Arizona, 1966.
404. Dirks, University of Arizona, 1966.
405. Hanson, University of Arizona, 1966.
406. Harbour, University of Arizona, 1966.
407. Hardas, University of Arizona, 1966.
408. Heatwole, University of Arizona, 1966.
409. Horton, University of Arizona, 1966.
410. Jemmitt, University of Arizona, 1966.
411. Kelley, University of Arizona, 1966.
412. Laidley, University of Arizona, 1966.
413. Long, University of Arizona, 1966.
414. *Mauger, University of Arizona, 1966.*
415. Miller, Stanford University, 1966.
416. Nelson, University of Arizona, 1966.
417. Parker, San Diego State University, 1966.
418. Pashley, University of Arizona, 1966.
419. Reed, University of Arizona, 1966.
420. Reid, University of Arizona, 1966.
421. Roadifer, University of Arizona, 1966.
422. Seager, University of Arizona, 1966.
423. *Sheikh, University of Arizona, 1966.*
424. Smith, University of Arizona, 1966.
425. Thoms, University of Michigan, 1966.
426. Tilford, Arizona State University, 1966.
427. Young, Washington University, 1966.
428. Agasie, University of Arizona, 1967.
429. Agenbroad, University of Arizona, 1967.
430. Briscoe, University of Arizona, 1967.
431. Broderick, University of Arizona, 1967.
432. Burgoyne, University of New Mexico, 1967.
433. *Cantwell, University of Arizona, 1967.*
434. Cetinay, University of Arizona, 1967.
435. Davis, University of Arizona, 1967.
436. Durand, University of Arizona, 1967.
437. Hatchell, University of New Mexico, 1967.
438. Johnson, University of Arizona, 1967.
439. Knight, University of Arizona, 1967.
440. Lease, University of New Mexico, 1967.
441. Lee, University of Arizona, 1967.
442. Leger, University of Arizona, 1967.
443. Lucchitta, Pennsylvania State University, 1967.
444. Luepke, University of Arizona, 1967.
445. Lynch, University of Arizona, 1967.
446. Merz, University of Arizona, 1967.
447. Moore, Stanford University, 1967.
448. Mullens, University of Arizona, 1967.
449. Nassereddin, University of Arizona, 1967.
451. Regan, Boston College, 1967.
452. Schmidt, University of Arizona, 1967.
453. Smoor, University of Arizona, 1967.
454. Beane, University of Arizona, 1968.
455. Blacet, Stanford University, 1968.
456. Brennan, University of Nevada-Reno, 1968.
458. Denney, University of Arizona, 1968.
459. Estes, University of Arizona, 1968.
460. Hench, University of Arizona, 1968.
461. Jones, University of Arizona, 1968.
462. May, University of Arizona, 1968.
463. Nye, University of Arizona, 1968.
464. Percious, University of Arizona, 1968.
465. Perry, University of Arizona, 1968.
466. Peterson, University of Arizona, 1968.
467. Pfirman, University of Arizona, 1968.
469. Plut, University of Arizona, 1968.
472. Scholtz, Northern Arizona University, 1968.
473. Szabo, University of New Mexico, 1968.
474. Thompson, Northern Arizona University, 1968.
475. Waag, University of Arizona, 1968.
476. Braun, University of Arizona, 1969.
477. Brown, University of Arizona, 1969.
478. Butler, University of Arizona, 1969.
480. Deal, Arizona State University, 1969.
481. Dunlap, University of Arizona, 1969.
482. Erickson, University of Arizona, 1969.
483. Evensen, University of Arizona, 1969.
484. Fodor, Arizona State University, 1969.
485. Gavasci, Columbia University, 1969.
486. Gornitz, Columbia University, 1969.
487. Gross, University of Arizona, 1969.
488. Kuck, University of Arizona, 1969.
489. Laughlin, University of Arizona, 1969.
491. Lees, Texas Tech, 1969.
492. Livingston, University of Arizona, 1969.
493. Marjaniemi, University of Arizona, 1969.
494. Matter, University of Arizona, 1969.
495. Micklin, University of Arizona, 1969.
496. Moger, University of Arizona, 1969.
497. Nicholls, University of California-Berkeley, 1969.
499. Patch, University of Arizona, 1969.
500. Pederson, Arizona State University, 1969.
502. Smith, California Inst. of Technology, 1969.
503. Spangler, University of Arizona, 1969.
504. Stuckless, Arizona State University, 1969.
505. Updike, Arizona State University, 1969.
506. Wilt, University of Arizona, 1969.
507. Young, Colorado School of Mines, 1969.
509. Billingsley, Northern Arizona University, 1970.
510. Brown, Arizona State University, 1970.
511. Carson, Stanford University, 1970.
512. Clary, Arizona State University, 1970.
513. Clay, University of Arizona, 1970.
514. Eastwood, University of Arizona, 1970.
515. Frank, University of Arizona, 1970.
516. Knight, University of Arizona, 1970.
517. Lammers, University of Arizona, 1970.
518. Laughon, University of Arizona, 1970.
521. Matis, University of Arizona, 1970.
522. Merrill, Arizona State University, 1970.
523. Pettengill, Northern Arizona University, 1970.
524. Puckett, University of Arizona, 1970.
527. Throop, Arizona State University, 1970.
528. West, University of Arizona, 1970.
529. Arnold, University of Arizona, 1971.
531. Benfer, Northern Arizona University, 1971.
532. Blake, University of Arizona, 1971.
533. Cameron, Arizona State University, 1971.
534. Champney, University of Arizona, 1971.
535. Chesser, Brigham Young University, 1971.
536. Davis, University of Arizona, 1971.
537. Evans, University of Arizona, 1971.
539. Gottesfeld, University of Arizona, 1971.
541. Kieffer, California Inst. of Technology, 1971.
542. Kokalis, Arizona State University, 1971.
543. Laney, University of Arizona, 1971.
544. Lytle, University of Arizona, 1971.
545. McCabe, Northern Arizona University, 1971.
546. McCurry, Arizona State University, 1971.
547. Marsh, University of Arizona, 1971.
548. Montgomery, University of Arizona, 1971.
550. Schmidt, University of Arizona, 1971.
551. Stewart, University of Arizona, 1971.
552. Stuckless, Stanford University, 1971.
553. Sumner, Stanford University, 1971.
554. Thorson, University of California-Santa Barbara, 1971.
555. Verbeek, Pennsylvania State University, 1971.
556. Vidal, University of Arizona, 1971.
558. Barrett, University of Utah, 1972.
559. Bartos, University of Arizona, 1972.
560. Bladh, University of Arizona, 1972.
561. Boyce, Northern Arizona University, 1972.
562. Burgert, Northern Arizona University, 1972.
564. Cousins, Arizona State University, 1972.
565. Dalton, Northern Arizona University, 1972.
566. Drake, Columbia University, 1972.
567. Durning, University of Arizona, 1972.
568. Graybeal, University of Arizona, 1972.
569. Hampf, University of Arizona, 1972.
570. Harrison, University of Arizona, 1972.
571. Hazenbush, University of Arizona, 1972.
572. Hendricks, Northern Arizona University, 1972.
573. Hillman, University of Cincinnati, 1972.
574. Himes, University of Arizona, 1972.
575. Iberall, University of Arizona, 1972.
577. Leventhal, University of Arizona, 1972.
579. Lynch, University of Arizona, 1972.
581. Malone, Arizona State University, 1972.
582. Marshall, Northern Arizona University, 1972.
583. Moores, University of Arizona, 1972.
584. Reid, University of Arizona, 1972.
586. South, University of Arizona, 1972.
587. Totten, University of Arizona, 1972.
588. Wadell, Arizona State University, 1972.
589. Weber, Indiana State University, 1972.
591. Anderson, Arizona State University, 1973.
592. Aylor, Arizona State University, 1973.
593. Bladh, University of Arizona, 1973.
594. Chakarun, University of Arizona, 1973.
595. Condit, Northern Arizona University, 1973.
597. Earl, University of Arizona, 1973.
598. Gambell, Northern Arizona University, 1973.
599. Jacobs, University of Arizona, 1973.
600. Jansen, University of Arizona, 1973.
601. Lewis, Northern Arizona University, 1973.
602. Lewis, Brigham Young University, 1973.
603. Lingley, Western Washington State University, 1973.
604. Mayer, Dartmouth College, 1973.
605. Murray, Northern Arizona University, 1973.
606. Scofield, Queens College, N. Y., 1973.
607. Sears, University of Wyoming, 1973.
608. Shank, Arizona State University, 1973.
609. Stevenson, Northern Arizona University, 1973.
610. Stoeser, University of Oregon, 1973.
611. Swiderski, Columbia University, 1973.
613. Thayer, University of Arizona, 1973.
615. Van Fleet, University of Arizona, 1973.
616. Walen, Western Washington State University, 1973.
617. Wallick, University of Arizona, 1973.
618. Wanless, Johns Hopkins University, 1973.
619. Alexander, Northern Arizona University, 1974.
620. Bliss, Arizona State University, 1974.
621. Boyer, University of Arizona, 1974.
622. Briscoe, Northern Arizona University, 1974.
623. Brook, University of Arizona, 1974.
624. Cheeseman, Northern Arizona University, 1974.
625. Cordiviola, University of Cincinnati, 1974.
626. Davis, University of Arizona, 1974.
627. Donnelly, Stanford University, 1974.
629. Fredericksen, University of Arizona, 1974.
630. Fuis, California Inst. of Technology, 1974.
631. Jones, University of Arizona, 1974.
632. Kluth, Northern Arizona University, 1974.
633. Krish, Colorado School of Mines, 1974.
634. Laine, University of Arizona, 1974.
635. Lausten, Arizona State University, 1974.
636. Liming, University of Arizona, 1974.
637. Ludwig, California Inst. of Technology, 1974.
638. Merrill, Arizona State University, 1974.
639. Moore, University of New Mexico, 1974.
640. Newell, Stanford University, 1974.
641. Packard, University of Arizona, 1974.
642. Pickens, Arizona State University, 1974.
643. Pope, Arizona State University, 1974.
645. Sanders, Northern Arizona University, 1974.
646. Schloderer, University of Arizona, 1974.
647. Scott, University of Texas-Dallas, 1974.
648. Scott, Northern Arizona University, 1974.
649. Shakel, University of Arizona, 1974.
650. Sherwonit, University of Arizona, 1974.
651. Simmons, Arizona State University, 1974.
653. Spatz, University of Arizona, 1974.
654. Turner, Northern Arizona University, 1974.
655. Van Arsdale, University of Cincinnati, 1974.
656. Vice, Arizona State University, 1974.
658. Wilkins, University of Arizona, 1974.
659. Zelinski, New Mexico Inst. of Mining and Tech., 1974.
660. Applebaum, University of Arizona, 1975.
663. Baskin, University of Arizona, 1975.
664. Bennett, University of Arizona, 1975.
665. Bradshaw, Northern Arizona University, 1975.
666. Budden, University of Arizona, 1975.
667. Clayton, Arizona State University, 1975.
668. Conyers, Arizona State University, 1975.
669. Daneker, Northern Arizona University, 1975.
670. Davis, Southern Methodist University, 1975.
671. Dolloff, University of Arizona, 1975.
672. Dykstra, Dartmouth College, 1975.
673. Fielden, Arizona State University, 1975.
674. Goodoff, University of Arizona, 1975.
675. Grocock, University of Colorado, 1975.
676. Howell, University of Toronto, 1975.
677. Johnston, University of Arizona, 1975.
679. Kent, Northern Arizona University, 1975.
680. Knapp, University of Arizona, 1975.
681. Kostura, Bowling Green State University, 1975.
683. Ladd, University of Arizona, 1975.
684. Light, Northern Arizona University, 1975.
685. Little, Arizona State University, 1975.
686. Lufholm, Northern Arizona University, 1975.
687. McDonald, Northern Arizona University, 1975.
688. Martinsen, Northern Arizona University, 1975.
689. Mohon, University of Arizona, 1975.
690. Reed, Oklahoma State University, 1975.
691. Reid, Northern Arizona University, 1975.
692. Robertson, Arizona State University, 1975.
693. Salvador, Stanford University, 1975.
695. Scott, Northern Arizona University, 1975.
698. Smith, University of Arizona, 1975.
699. Sturdevant, Pennsylvania State University, 1975.
700. Tarman, University of Arizona, 1975.
702. Turek, Arizona State University, 1975.
703. Ullmer, University of Arizona, 1975.
704. Van Kooten, Arizona State University, 1975.
705. Wenrich-Verbeek, Pennsylvania State University, 1975.
708. Auld, Northern Arizona University, 1976.
709. Barry, Princeton University, 1976.
710. Bittson, University of Arizona, 1976.
711. Bladh, University of Arizona, 1976.
713. Chen, Columbia University, 1976.
714. Christenson, Arizona State University, 1976.
715. Clark, University of Leicester, Great Britain, 1976.
716. Conway, California Inst. of Technology, 1976.
719. DeWitt, University of Arizona, 1976.
720. Effler, University of Cincinnati, 1976.
722. Harrison, Northern Arizona University, 1976.
723. Henkle, Northern Arizona University, 1976.
724. Hoelle, University of Arizona, 1976.
725. Jones, University of Arizona, 1976.
726. Kessler, University of Arizona, 1976.
727. Kiven, University of Arizona, 1976.
728. Koval, Northern Arizona University, 1976.
729. *Lange, University of Arizona, 1976.*
730. Larson, University of Arizona, 1976.
732. McCain, Northern Arizona University, 1976.
733. Matthews, Northern Arizona University, 1976.
734. Meader, University of Arizona, 1976.
735. Phillips, University of Arizona, 1976.
737. Powers, Texas Tech, 1976.
739. Reed, Northern Arizona University, 1976.
740. Robinson, University of Arizona, 1976.
741. Roe, University of Arizona, 1976.
743. *Schofield, University of Arizona, 1976.*
744. Sedgeley, Arizona State University, 1976.
745. Shackelford, University of So. Calif.-Los Angeles, 1976.
746. Sherrer, San Diego State University, 1976.
747. Suneson, Arizona State University, 1976.
748. Swan, University of Arizona, 1976.
749. Varga, University of Arizona, 1976.
751. Watkins, Colorado School of Mines, 1976.
752. Weitz, University of Arizona, 1976.
753. Wells, University of Cincinnati, 1976.
754. *Wentworth, Cornell University, 1976.*
755. White, University of Arizona, 1976.
756. Winter, University of Arizona, 1976.
757. Witter, University of Arizona, 1976.
760. Bressler, University of Arizona, 1977.
762. Cloran, Arizona State University, 1977.
763. Collins, University of Nevada-Reno, 1977.
764. Cuffney, Colorado School of Mines, 1977.
765. Deslauriers, Arizona State University, 1977.
766. Edson, University of Arizona, 1977.
767. *Frost, University of Arizona, 1977.*
768. Gass, University of Arizona, 1977.
769. Gassaway, San Diego State University, 1977.
770. Gordon, Arizona State University, 1977.
771. Gray, Arizona State University, 1977.
772. Green, University of Oklahoma, 1977.
773. Hanson, University of Idaho, 1977.
774. Hoffman, University of Wyoming, 1977.
776. Holway, Arizona State University, 1977.
777. Honey, University of Arizona, 1977.
778. Howell, University of Arizona, 1977.
779. Ijirigo, University of Arizona, 1977.
780. Jennings, Arizona State University, 1977.
784. Meader, University of Arizona, 1977.
785. Pugmire, Northern Arizona University, 1977.
786. Reches, Stanford University, 1977.
787. Roden, University of Texas-Austin, 1977.
788. Rogers, University of Arizona, 1977.
789. Schenker, University of Arizona, 1977.
790. Sigleo, University of Arizona, 1977.
791. Sternberg, University of Arizona, 1977.
792. Suemnicht, University of Arizona, 1977.
793. Updike, Arizona State University, 1977.
794. Ward, Arizona State University, 1977.
795. Welsch, Arizona State University, 1977.
796. Wilson, University of Arizona, 1977.
797. Wohletz, Arizona State University, 1977.
798. Bodnar, University of Arizona, 1978.
799. Boyd, University of Arizona, 1978.
800. Broomhall, Northern Arizona University, 1978.
802. *Christie, University of Arizona, 1978.*
803. Christman, University of Arizona, 1978.
804. Cordy, Arizona State University, 1978.
806. Emmons, Northern Arizona University, 1978.
807. Evans, University of Utah, 1978.
808. Gebel, Northern Arizona University, 1978.
809. Grimm, University of Arizona, 1978.
810. Gust, Rice University, 1978.
811. Harding, University of Arizona, 1978.
812. Hargan, University of Arizona, 1978.
813. *Hillier, Arizona State University, 1978.*
814. Hughes, Northern Arizona University, 1978.
815. Hulse, University of Arizona, 1978.
816. Isarangkoon, South Dakota School of Mines and Tech., 1978.
817. Janders, Arizona State University, 1978.
818. Johnson, University of Texas-Austin, 1978.
819. Kayler, Arizona State University, 1978.
820. Koenig, University of Arizona, 1978.
821. Koski, Stanford University, 1978.
822. Kovas, Northern Arizona University, 1978.
823. *Kuck, University of Arizona, 1978.*
824. Lehman, University of Arizona, 1978.
825. Lytle-Webb, University of Arizona, 1978.
826. McFadden, University of Arizona, 1978.
827. Mainzer, University of Utah, 1978.
828. Parker, University of Arizona, 1978.
830. Rushing, University of Arizona, 1978.
831. Soule, University of Arizona, 1978.
832. Staab, Northern Arizona University, 1978.
833. Sullivan, University of New Mexico, 1978.
834. *Surles, University of Arizona, 1978.*

INTERIOR—GEOLOGICAL SURVEY, RESTON, VIRGINIA—1975

J. D. S 1/7/93

Pinal Copper - Greenback Mine

HAROLD FERRIN called (1-6-93)
(Ted Hopkins LLL)

Property optioned To Canadian Co. listed
in U.S. as "Cutlass Mng Corp"
CANADIAN STOCK Promotion

Also promoting Desoto Mine near Hayden, AZ.

FERRIN - unlisted phone no.
985-1763
744 - N. 56th ST.
MESA, AZ. 85205

Att'y: BILL Elsing - Phx.

Tom Mitchum told Ferrin that [illegible]
had looked at the Core on the 3000' hole.
Ferrin asked if he could see the Log -
I informed him that we never got around
To Logging The Hole -
Ferrin stated that "Cutlass Mng" has drilled
About 15 holes - 300-400' in depth & has
About 10 million Tons of Low Grade leaching
Copper blocked out.

-RBC-

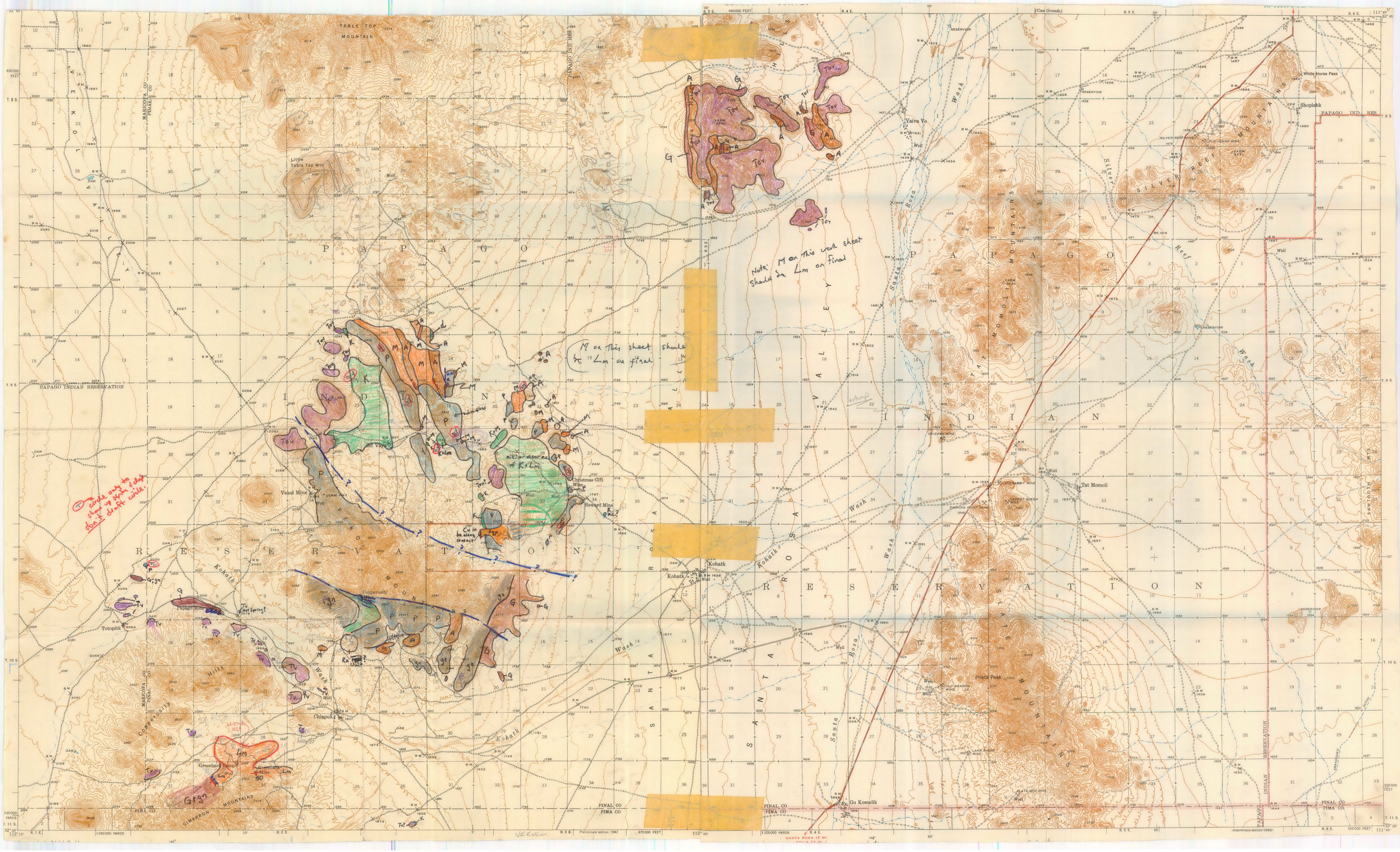


TABLE TOP MOUNTAIN
Little Table Top Mtn
PAPAGO IND RES
MARICOPA CO
PINAL CO
PAPAGO INDIAN RESERVATION
Note: M on this work sheet should be Lm on final
M on this sheet should be Lm on final
circle only to show up this dike don't do it circle.
Vekol Mine
Christmas Gift Mine
Reward Mine
Coppersulfy Mine
Papago Mine
Totopitis
Chiapuki
Greenback Camp
Greenback Mine
Kohatk
Vaiva Vo
Shopiahk
White Horse Pass
Tat Momoli
Prieta Peak
Gu Komelik
SILVER REEF MOUNTAINS
MOMOLI MOUNTAINS
SANTA ROSA MOUNTAINS
SIMARON MOUNTAINS
Santa Rosa Wash
Kohatk Wash
Reef Wash
PINAL CO
PIMA CO
SANTA ROSA 15 MI.
Preliminary edition 1942

THE TOPOGRAPHIC MAPS OF THE UNITED STATES

The United States Geological Survey is making a series of standard topographic maps to cover the United States. This work has been in progress since 1882, and the published maps cover more than 47 percent of the country, exclusive of outlying possessions.

The maps are published on sheets that measure about 16½ by 20 inches. Under the general plan adopted the country is divided into quadrangles bounded by parallels of latitude and meridians of longitude. These quadrangles are mapped on different scales, the scale selected for each map being that which is best adapted to general use in the development of the country, and consequently, though the standard maps are of nearly uniform size, the areas that they represent are of different sizes. On the lower margin of each map are printed graphic scales showing distances in feet, meters, miles, and kilometers. In addition, the scale of the map is shown by a fraction expressing a fixed ratio between linear measurements on the map and corresponding distances on the ground. For example, the scale $\frac{1}{62,500}$ means that 1 unit on the map (such as 1 inch, 1 foot, or 1 meter) represents 62,500 of the same units on the earth's surface.

Although some areas are surveyed and some maps are compiled and published on special scales for special purposes, the standard topographic surveys and the resulting maps have for many years been of three types, differentiated as follows:

1. Surveys of areas in which there are problems of great public importance—relating, for example, to mineral development, irrigation, or reclamation of swamp areas—are made with sufficient detail to be used in the publication of maps on a scale of $\frac{1}{31,680}$ (1 inch = one-half mile) or $\frac{1}{24,000}$ (1 inch = 2,000 feet), with a contour interval of 1 to 100 feet, according to the relief of the particular area mapped.

2. Surveys of areas in which there are problems of average public importance, such as most of the basin of the Mississippi and its tributaries, are made with sufficient detail to be used in the publication of maps on a scale of $\frac{1}{62,500}$ (1 inch = nearly 1 mile), with a contour interval of 10 to 100 feet.

3. Surveys of areas in which the problems are of minor public importance, such as much of the mountain or desert region of Arizona or New Mexico, and the high mountain area of the northwest, are made with sufficient detail to be used in the publication of maps on a scale of $\frac{1}{125,000}$ (1 inch = nearly 2 miles) or $\frac{1}{250,000}$ (1 inch = nearly 4 miles), with a contour interval of 20 to 250 feet.

The aerial camera is now being used in mapping. From the information recorded on the photographs, planimetric maps, which show only drainage and culture, have been made for some areas in the United States. By the use of stereoscopic plotting apparatus, aerial photographs are utilized also in the making of the regular topographic maps, which show relief as well as drainage and culture.

A topographic survey of Alaska has been in progress since 1898, and nearly 44 percent of its area has now been mapped. About 15 percent of the Territory has been covered by maps on a scale of $\frac{1}{500,000}$ (1 inch = nearly 8 miles). For most of the remainder of the area surveyed the maps published are on a scale of $\frac{1}{250,000}$ (1 inch = nearly 4 miles). For some areas of particular economic importance, covering about 4,300 square miles, the maps published are on a scale of $\frac{1}{62,500}$ (1 inch = nearly 1 mile) or larger. In addition to the area covered by topographic maps, about 11,300 square miles of southeastern Alaska has been covered by planimetric maps on scales of $\frac{1}{125,000}$ and $\frac{1}{250,000}$.

The Hawaiian Islands have been surveyed, and the resulting maps are published on a scale of $\frac{1}{62,500}$.

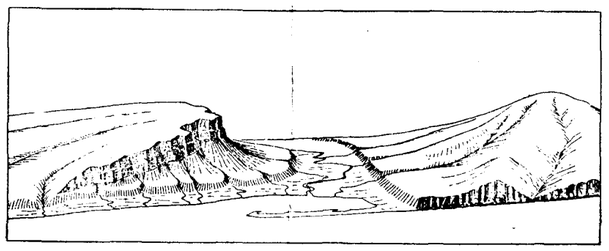
A survey of Puerto Rico is now in progress. The scale of the published maps is $\frac{1}{30,000}$.

The features shown on topographic maps may be arranged in three groups—(1) water, including seas, lakes, rivers, canals, swamps, and other bodies of water; (2) relief, including mountains, hills, valleys, and other features of the land surface; (3) culture (works of man), such as towns, cities, roads, railroads, and boundaries. The symbols used to represent these features are shown and explained below. Variations appear on some earlier maps, and additional features are represented on some special maps.

All the water features are represented in blue, the smaller streams and canals by single blue lines and the larger streams by double lines. The larger streams, lakes, and the sea are accentuated by blue water lining or blue tint. Intermittent streams—those whose beds are dry for a large part of the year—are shown by lines of blue dots and dashes.

Relief is shown by contour lines in brown, which on a few maps are supplemented by shading showing the effect of light thrown from the northwest across the area represented, for the purpose of giving the appearance of relief and thus aiding in the interpretation of the contour lines. A contour line represents an imaginary line on the ground (a contour) every part of which is at the same altitude above sea level. Such a line could be drawn at any altitude, but in practice only the contours at certain regular intervals of altitude are shown. The datum or zero of altitude of the Geological Survey maps is mean sea level. The 20-foot contour would be the shore line if the sea should rise 20 feet above mean sea level. Contour lines show the shape of the hills, mountains, and valleys, as well as their altitude. Successive contour lines that are far apart on the map indicate a gentle slope, lines that are close together indicate a steep slope, and lines that run together indicate a cliff.

The manner in which contour lines express altitude, form, and grade is shown in the figure below.



The sketch represents a river valley that lies between two hills. In the foreground is the sea, with a bay that is partly enclosed by a hooked sand bar. On each side of the valley is a terrace into which small streams have cut narrow gullies. The hill on the right has a rounded summit and gently sloping spurs separated by ravines. The spurs are truncated at their lower ends by a sea cliff. The hill at the left terminates abruptly at the valley in a steep scarp, from which it slopes gradually away and forms an inclined tableland that is traversed by a few shallow gullies. On the map each of these features is represented, directly beneath its position in the sketch, by contour lines.

The contour interval, or the vertical distance in feet between one contour and the next, is stated at the bottom of each map. This interval differs according to the topography of the area mapped: in a flat country it may be as small as 1 foot; in a mountainous region it may be as great as 250 feet. In order that the contours may be read more easily certain contour lines, every fourth or fifth, are made heavier than the others and are accompanied by figures showing altitude. The heights of many points—such as road intersections, summits, surfaces of lakes, and benchmarks—are also given on the map in figures, which show altitudes to the nearest foot only. More precise figures for the altitudes of benchmarks are given in the Geological Survey's bulletins on spirit leveling. The geodetic coordinates of triangulation and transit-traverse stations are also published in bulletins.

Lettering and the works of man are shown in black. Boundaries, such as those of a State, county, city, land grant, township, or reservation, are shown by continuous or broken lines of different kinds and weights. Public roads suitable for motor travel the greater part of the year are shown by solid double lines; poor public roads and private roads by dashed double lines; trails by dashed single lines. Additional public road classification if available is shown by red overprint.

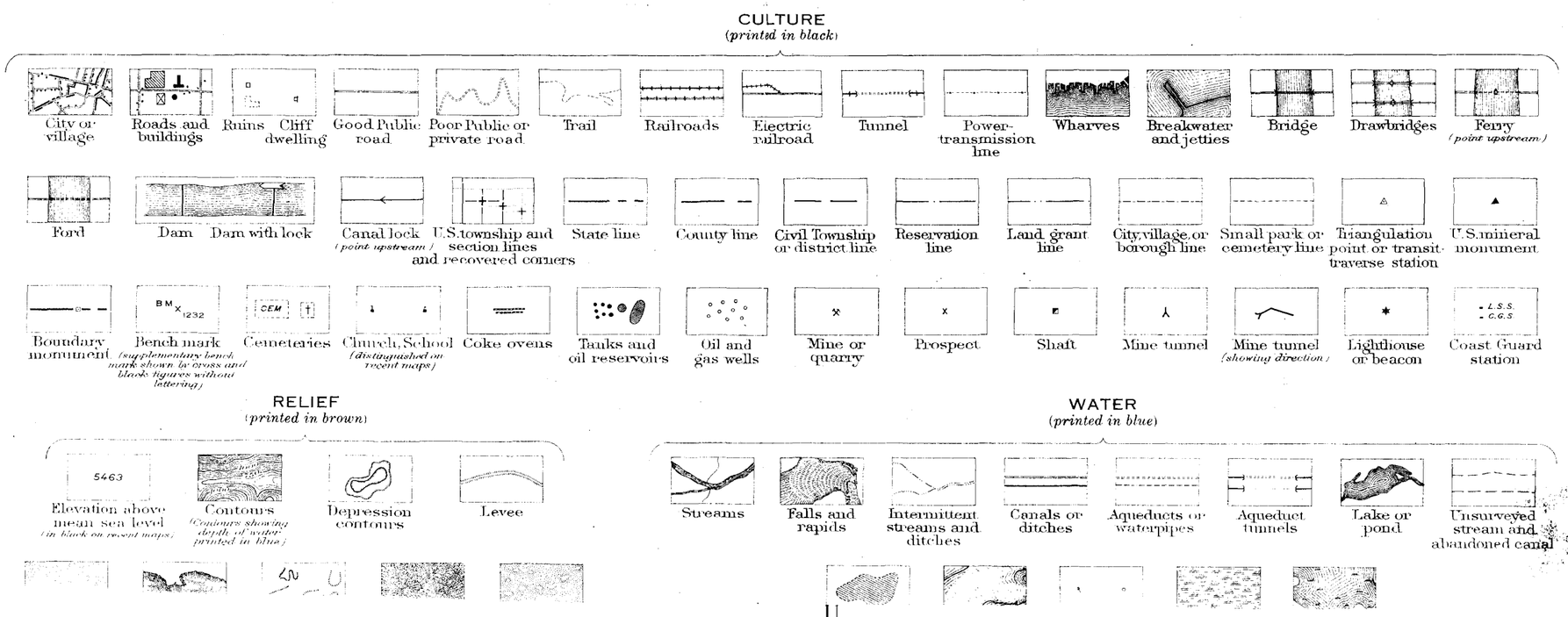
Each quadrangle is designated by the name of a city, town, or prominent natural feature within it, and on the margins of the map are printed the names of adjoining quadrangles of which maps have been published. More than 4,100 quadrangles in the United States have been surveyed, and maps of them similar to the one on the other side of this sheet have been published.

Geologic maps of some of the areas shown on the topographic maps have been published in the form of folios. Each folio includes maps showing the topography, geology, underground structure, and mineral deposits of the area mapped, and several pages of descriptive text. The text explains the maps and describes the topographic and geologic features of the country and its mineral products. Two hundred twenty-five folios have been published.

Index maps of each State and of Alaska and Hawaii showing the areas covered by topographic maps and geologic folios published by the United States Geological Survey may be obtained free. Copies of the standard topographic maps may be obtained for 10 cents each; some special maps are sold at different prices. A discount of 40 percent is allowed on an order amounting to $5 or more at the retail price. The discount is allowed on an order for maps alone, either of one kind or in any assortment, or for maps together with geologic folios. The geologic folios are sold for 25 cents or more each, the price depending on the size of the folio. A circular describing the folios will be sent on request.

Applications for maps or folios should be accompanied by cash, draft, or money order (not postage stamps) and should be addressed to

THE DIRECTOR,
United States Geological Survey,
Washington, D. C.

November 1937.

STANDARD SYMBOLS